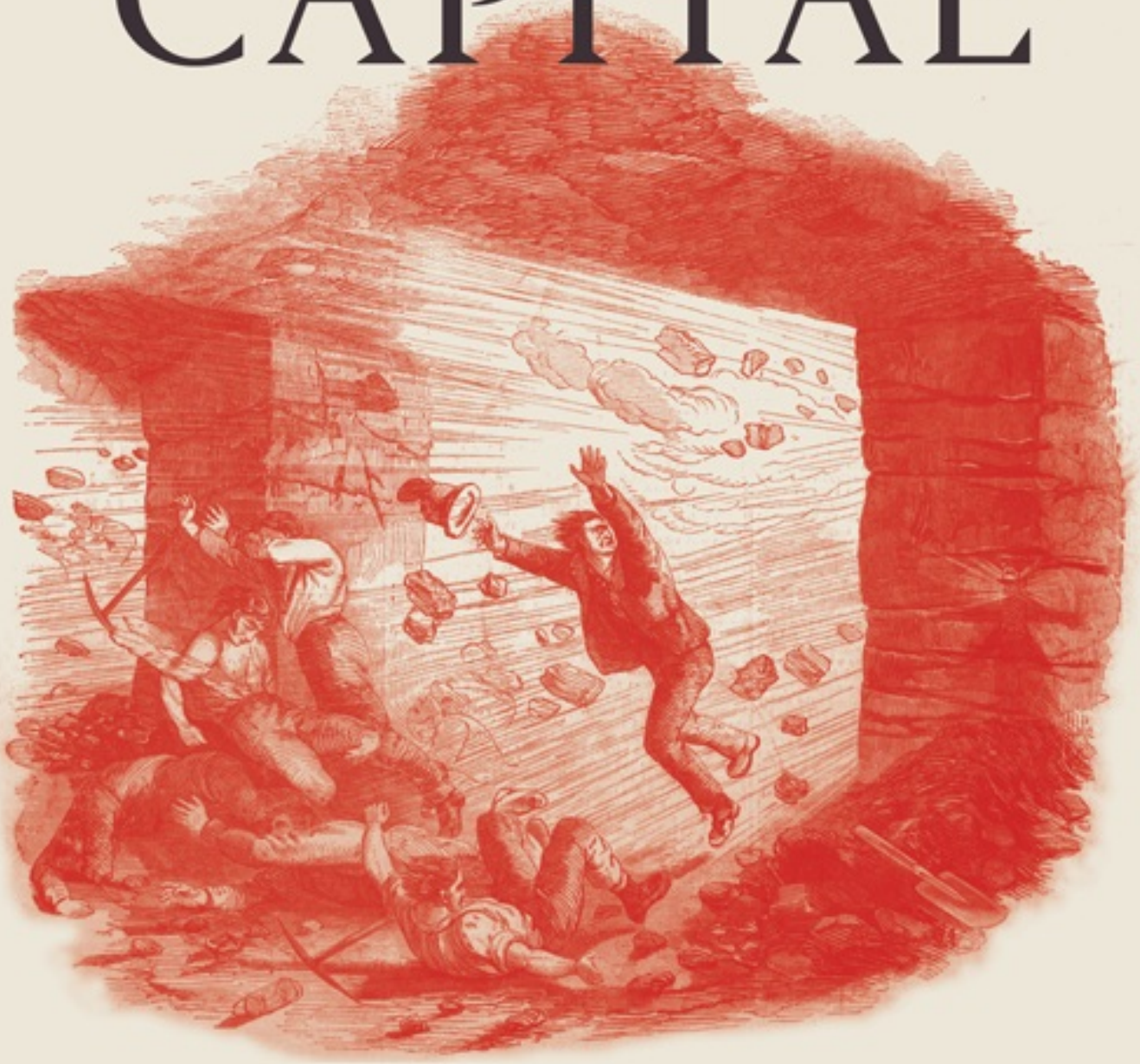
FOSSIL CAPITAL



The Rise of Steam Power and the Roots of Global Warming

ANDREAS MALM

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CHAPTER 1

In the Heat of the Past: Towards a History of the Fossil Economy

> In those spacious halls the benignant power of steam summons around him his myriads of willing menials, and assigns to each the regulated task, substituting for painful muscular effort on their part, the energies of his own gigantic arm, and demanding in turn only attention and dexterity to correct such little aberrations as casually occur in workmanship.
>
> Andrew Ure, *The Philosophy of Manufactures* (1835)

> The chemical changes which thus take place are constantly increasing the atmosphere by large quantities of carbonic acid [i.e. carbon dioxide] and other gases noxious to animal life. The means by which nature decomposes these elements, or reconverts them into a solid form, are not sufficiently known.
>
> Charles Babbage, *On the Economy of Machinery and Manufactures* (1835)

> Besides, what has your steam engine and your cast iron done for us? Not to mention the gas, whose frequent explosions threaten one day to blow up Babylon itself.
>
> Anonymous worker in *The Metropolitan,* 'Imprisonment for debt' (May 1834)

Global warming is the unintended by-product par excellence. A cotton manufacturer of early nineteenth-century Lancashire who decided to forgo his old waterwheel and invest in a steam engine, erect a chimney and order coal from a nearby pit did not, in all likelihood, entertain the possibility that this act could have any kind of relationship to the extent of Arctic sea ice, the salinity of Nile Delta soil, the altitude of the Maldives, the frequency of droughts on the Horn of Africa, the diversity of amphibian species in Central American rain forests, the availability of water in Asian rivers or, for that matter, the risk of flooding along the Thames and the English coastline. Nonetheless, sporadic forebodings appear in the literature of the time. One notable flash of apprehension about the atmospheric consequences of employing steam power in factories can be found in the first chapter of Charles Babbage's classic treatise *On the Economy of Machinery and Manufactures*. Babbage is credited with being the father of the modern computer; his book is considered the first to introduce 'the factory into the realm of economic analysis'.[1] He made his fleeting remark some three decades before John Tyndall explained the greenhouse effect and some six decades before Svante Arrhenius first calculated the rise in surface temperature on the earth following an increase in emissions of carbon dioxide (called

'carbonic acid' by Arrhenius as well).[2]

But the environmentally concerned enquiry of the pioneer economist was instantly truncated, due to sheer lack of knowledge. Babbage was verging on uncharted territory. Instead, his book continued as one long encomium to the wonders of machinery – first and foremost 'the check which it affords against the inattention, the idleness, or the dishonesty of human agents'.[3] In that turn of phrase, Babbage articulated a leitmotif of bourgeois thinking corresponding to the operating procedures of manufacturers, who fought the annoying idiosyncrasies of human workers precisely by installing ever more machinery impelled by ever more powerful steam engines, unsuspecting of any particular noxious effects. Those on the receiving end of that machinery had more reason to be afraid.

Now They Know What They Do

By now the science of the by-product is perfectly clear. It has been so, in its basic outlines, for roughly as long as capitalism has been free of really existing adversaries: in 1990, the Intergovernmental Panel on Climate Change (IPCC) submitted its first report on the likely fate of a warming world. The facts and projections served as the basis for the United Nations Framework Convention on Climate Change (UNFCCC), signed at the Earth Summit in Rio de Janeiro in 1992 and ratified by all UN members, who pledged to 'prevent dangerous anthropogenic interference with the climate system' by *cutting* their emissions of greenhouse gases, chief among them carbon dioxide. Yet in 2012, global CO_2 emissions were 58 percent higher than in 1990.[4] By that time, the IPCC was preparing its fifth report – each edition more certain of the disastrous implications of 'business-as-usual' than the previous one – as a permanent hailstorm of scientific warnings rained down on humanity. A random pick from some leading journals in the years 2012–14: hurricanes in all ocean basins are becoming markedly stronger due to higher temperatures; North American butterfly populations have embarked on a perilous journey north to escape the rising heat; Arctic ecosystems are fast approaching a whole range of tipping points; the threshold beyond which the Greenland ice sheet will plunge into irreversible melting – raising sea levels by six meters – is a warming of 1.6°C rather than 3.1°C as previously thought; the retreat of glaciers in Tien Shan is accelerating, primarily in areas where they are most essential for irrigation in summertime, some rivers having already shrunk to tiny rivulets; since the mid-1980s, the vegetation of Congolese rain forests has browned, dried out and declined; climate change could wipe out the equivalent of the entire present yield of maize, soybeans, wheat and rice in key producing regions by the end of the century; the old target of keeping global warming below 2 degrees – widely regarded as obsolete, due to the already painful impacts of a mere 0.85 degrees – is rapidly slipping out of reach: and on it goes.[5] Everybody knows it. Whether one chooses to ignore, suppress, deny or agonise over the knowledge of what is happening, it is there, in the air, heavier by the year. And yet the descendants of the Lancashire manufacturers, whose dominion now span the globe, are taking decisions on a daily basis to invest in new oil wells, new coal-fired power plants, new airports, new highways, new liquefied natural gas facilities, new machines to replace human workers, so that emissions are not only continuing to grow but doing so at a higher speed. In the 1990s, the annual increase in global CO_2 emissions stood at an average 1 percent; since 2000, the figure has been 3.1 percent – a tripled growth rate, exceeding the worst-case scenarios developed by the

IPCC and expressing a trend that still does not show any sign of reversal: the more knowledge there is of the consequences, the more fossil fuels are burnt.[6]

How did we get caught up in this mess?

History under a Heavy Sky

In the first pages of his acclaimed textbook *Political Ecology,* Paul Robbins travels to Yellowstone National Park to observe what lies behind its veneer of pristine wilderness. To an untrained eye, the iconic features of the landscape might appear perfectly natural. In fact they are intensely produced. The native hunters that once roamed the land have been removed by fiat; wolves were first extinguished and then reintroduced. Managing authorities have alternated between culling elk populations and allowing them to explode, suppressing fires and permitting them to rip through the valleys and leave their mark on the biota. At every step, walking through forests and along rivers, sighting some animals and not others, Robbins discerns the effects of power struggles that have raged over the park: between the state and the native population, between hunters and environmentalists, hoteliers and scientists. Out of the raw material at hand, political actors have created the ecology of Yellowstone, often with chains of unintended consequences.[7]

A traveller along the frontiers of climate change today – not to speak of tomorrow – might encounter a landscape even more thoroughly shaped by humans with power. Weather conditions, types of vegetation, entire biomes, even the sea itself might have fallen into place as a fallout of the combustion of fossil fuels. But where Robbins is able to trace a certain property of the Yellowstone landscape to a specific decision made in the past – the absence of natives to their historical removal – the climate change traveller can, by the nature of things, see no such straight lines. A submerged islet has born the full weight of a history lacking differentiation. No single decision, no emission of one tonne of greenhouse gases can be connected to this particular scene: the burning of this barrel of Texas oil cannot be pinned down as the cause of this Levantine drought. Every impact of anthropogenic climate change carries the imprint of every human act with a radiative forcing, such that they are infinitesimal representatives of two moving aggregates – the aftermath and the source – intimately coupled yet strangely disconnected from each other. Eyes gazing on abruptly transformed ecosystems are forced to turn back towards human society to understand what has happened – but where should they look? Only a totality can be the object of interest. We shall call it, provisionally, ‘the fossil economy’.

Seen from another angle, global warming is a sun mercilessly projecting a new light onto history. Only now is it becoming apparent what it really meant to burn coal and send forth smoke from a stack in Manchester in 1842. When natural scientists discovered global warming, they passed on a discovery to historians yet to be made on anything like a comprehensive scale: these things were there for two centuries, invisible up to the present. Now is the time to turn over a thousand stones, to unearth the climatic implications of innumerable actions – not merely because the smallest puff of smoke in Manchester in 1842 released a quantity of CO_2 which then lingered in the atmosphere, playing a microscopic part in the creation of the current climate, but also, and more importantly, because the fossil economy was established, entrenched and expanded in the process. It is as though a novel dimension has been suddenly revealed in modern history. Just think, in this light, of the building of the railway networks, the construction of the Suez Canal, the introduction of electricity, the discovery of oil in the Middle East, the rise of

suburbia, the CIA coup against Mohammad Mossadeq, the opening of the Chinese economy by Deng Xiaoping, the American invasion of Iraq … As a series of moments in the historical totality of the fossil economy – deepening its channels, adding ever-greater volumes of fossil fuels to the fire – these events are retroactively suffused with a new significance, calling for a return to history, eyes wide open.

Would such a history be environmental? Most traditional concerns in the field – say, deforestation, air pollution, species extinction through hunting or overfishing, pathogen movement through trade or invasion – exhibit some kind of historical immediacy: the cutting down of a forest *is* deforestation. In his *The Chimney of the World: A History of Smoke Pollution in Victorian and Edwardian Manchester,* Stephen Mosley points out that 'smoke could be easily perceived by four of the five senses: one could see it, smell it, touch it, and it could be tasted.'[8] He is obviously engaging in an environmental history, writing of how the natural world in and around Manchester was transformed through the explosive spread of dense black clouds in the nineteenth century. But the burning of coal in that town also had another ramification, which did not, as it were, touch down in the environment until much later, after a whole series of biogeochemical and social mediations. The writing of that history should be a central task, and yet it is bound to have an odd quality of detachment from environmental repercussions. Insofar as we are interested in the fossil economy as the instigator of climate change, its ecological dimensions must be placed within the brackets of posterity in a way that hardly applies to any other problem of environmental history: even nuclear waste, whose fallout is comparable to global warming in duration, is immediately constituted and handled as such. Anthropogenic climate change – this is part of its very definition – has its roots *outside* the realm of temperature and precipitation, turtles and polar bears, inside a sphere of human praxis that could be summed up in one word as *labour*.

At the intersection of climate and history, most scholarly traffic has so far moved in the other direction. The search for meteorological causes of past events is currently undergoing a spectacular renaissance: climatic fluctuations are said to have had a finger or two in everything from the collapse of the Mayan civilisation and the conquests of the Vikings to the witch hunts and the French Revolution. Promising analogues for the future, this endeavour uses data on temperature and precipitation to explain crisis, war, persecution, upheaval and other social affairs – explanations well worth pursuing for their own sake (albeit with certain well-known pitfalls) but not particularly appropriate in constructing the historiography of global warming. Here it is a matter of searching not for climate in history, but for *history in climate*. Data on factory legislation or free-trade policy should be brought to bear on rainfall and ice, rather than the other way around; in a warming world, causation runs, at least initially, from company to cloud. It is that leap across ontological divides that calls for reconstruction.

The Revenge of Time

Over the past decades, critical theory has moved towards space, away from time as the long-favoured dimension, the classical vessel of structure, causation, rupture, possibility. Within historical materialism, this 'spatial turn' has generated the meteoric rise of critical geography, now equalling or surpassing the time-honoured discipline of history in innovativeness and influence: the star of David Harvey shines brighter than that of any Marxist historian. Another adept in the field, Neil Smith, hymns the victory of space over time in *Uneven Development:*

Nature, Capital, and the Production of Space, quoting approvingly such one-liners as 'we are in the epoch of simultaneity'; 'the present epoch will perhaps be above all the epoch of space'; 'prophecy now involves a geographical rather than historical projection' (whatever that could possibly mean) – even endorsing Francis Fukuyama's infamous thesis of the 'end of history' by asserting that 'indeed historical time would seem to be over'.[9] Global warming should put such fantasies to rest.

Floors below the desk where these words are written, people travel to work in cars, go on visits and vacations in cars, drive their shopping lists and shopping bags back and forth in cars: nowhere is simultaneity to be seen. Cars, to begin with, run on fossil energy, a legacy of photosynthesis originating hundreds of millions of years ago. The vehicles were not invented just now; they spread in the twentieth century. The choice to travel in them rather than in trams or buses or on bicycles is conditioned by a vast infrastructure of oil terminals, petroleum refineries, asphalt plants, road networks, gasoline stations – not to speak of the film industry, the lobbying groups, the billboards – which did not fall from the sky in this moment but was built up *over time,* eventually amassing such weight and inertia that other modes of transportation are now excluded, or at least prevented from rising to predominance. This is what some refer to as 'carbon lock-in': a cementation of fossil fuel–based technologies, deflecting alternatives and obstructing policies of climate change mitigation: a poisoned fruit of history.[10] Furthermore, there is reason to suspect that the heat wave and drought plaguing this part of the country, sending residents to seek relief by leaving the town in cars, has some connection to climate change – signs of a future to come, a state-of-weather-in-the-making – and if that suspicion is at least partly correct, not even the weather belongs fully to the moment. It is a product of past emissions. The emissions produced by the cars running to and fro, meanwhile, will have their greatest impact on generations not yet born: they are so many invisible missiles aimed at the future.

Wherever we look at our changing climate, we find ourselves in the grip of the flow of *time*. The transfer of carbon from geological reserves to fireplaces and thence to the atmosphere, into the running carbon cycle from which it was locked away for ages and eras, sets the process in motion. But the effects are always delayed. It takes time before a certain quantity of CO_2 emissions is realised as a corresponding amount of warming, and before that warming takes its full toll on the ecosystems. For every emission added to past output, the atmospheric concentration of the gas increases, its effect further augmented in accordance with 'the fundamental tenet of climate science: emissions are cumulative'.[11] The release of one tonne of CO_2 would not be so dangerous were it not for the billions of tonnes already out there; it is the total accumulation that pushes temperatures upwards, and the more that has been emitted, the smaller the prospect of limiting the ongoing rise. If humanity wishes to avoid a certain temperature threshold – say, 2 degrees Celsius – only a certain amount can be emitted – roughly one trillion tons – and for every year emissions continue (not to speak of *increase)* that budget is progressively squandered.[12] If one tonne is emitted in this second, a fourth of it will stay in the atmosphere for hundreds of thousands of years.[13] If we wait some time longer and then demolish the fossil economy in one giant blow, it would still cast a shadow far into the future: emissions slashed to zero, the sea might continue to rise for many hundreds of years, the waters slowly expanding as the heat makes its way deeper and deeper into the oceans. A rising and warming sea could then unhinge ice sheets, thaw permafrost, destabilise methane hydrates or trigger other feedback mechanisms centuries after a complete cessation of emissions – once a certain

historical level has been reached – in keeping with 'the long memory of the climate system'.[14] At its core, then, climate change is a messy mix-up of time scales. The fundamental variables of the process – the nature of fossil fuels, the economies based on them, the societies addicted to them, the consequences of their combustion – operate over seemingly unrelated temporal spans, all refracted in the moving, elusive present of a warming world; in an elevated sense of the term, every *conjuncture* now combines relics and arrows, loops and postponements that stretch from the deepest past to the most distant future, via a now that is non-contemporaneous with itself.[15] Ours is, if anything, an epoch of diachronicity.

'The temporal aspect is particularly striking,' writes philosopher Stephen Gardiner, who has done perhaps more than anyone to foreground it, in *A Perfect Moral Storm: The Ethical Tragedy of Climate Change:* it catches us in a bind. Given that global warming is 'seriously backloaded' (every moment experiencing a higher temperature posted from the past) and 'substantially deferred' (the cumulative effects of current emissions arriving in the future), a warped ethical structure arises. The person who harms others by burning fossil fuels cannot even potentially encounter his victims, because they do not yet exist. Living in the here and now, he reaps all the benefits from the combustion but few of the injuries, which will be suffered by people who are not around and cannot voice their opposition. Each generation, reasons Gardiner, thus faces a perverse incentive to 'pass the buck' to the next, which also profits from its own fossil fuel combustion while dodging the pain from it, and so on, in a vicious cycle of infliction of harm.[16]

Rob Nixon would call it 'slow violence'. In *Slow Violence and the Environmentalism of the Poor,* he grapples with a problem closely related to Gardiner's, though coming from the angle of literary theory. 'Violence is customarily conceived as an event or action that is immediate in time, explosive and spectacular in space, and as erupting into instant sensational visibility,' he writes, but there is also a different kind of violence: not rapid but slow motion, not instantaneous but incremental, not body-to-body but playing out over vast stretches of time *through the medium of ecosystems* and therefore far more difficult to capture between book covers or on-screen than the bullets of a sniper. When a company dumps a toxic chemical substance in a poor country, the violence is only being felt gradually, 'decoupled from its original causes by the workings of time,' never contemporaneous with the act itself; Nixon places fossil fuel combustion in the same category.[17] He then asks: how can slow violence be represented in narratives that catch our attention? What are its equivalents in the crime novel, the war epic, the action movie? Symptomatically, he finds and reads stories and essays on the slow violence of the Bhopal disaster, oil exploitation in the Arabian Gulf and the Niger Delta, mega-dams in India, natural parks in South Africa, depleted uranium in Iraq *but none on climate change as such*. Here the capacity to imagine violence seems to have reached its limit.

There is more to these temporalities than dilemmas of ethics and representation, however. The longer business-as-usual persists, the harder it becomes to break out of it. Every round of new pipelines and tankers and deep-water drilling rigs encumbers the next decades with an even more ponderous mass of infrastructure into which carbon has been locked: the ruts of path dependency deepen. Every generation presiding over growing emissions adds more than the former to the accumulation of CO_2 in the atmosphere.[18] For every year global warming continues and temperatures soar higher, living conditions on earth will be determined more intensely by the emissions of yore, so that the grip of yesteryear on today intensifies – or, put differently, *the causal power of the past inexorably rises,* all the way up to the point when it is indeed 'too late'. The significance of that terrible destiny, so often warned of in climate change discourse, is the

final *falling in of history on the present*.

History does not usually work in this way. The echo of Caesar's march across Rubicon, the fall of the Ming dynasty, the formation of the Sokoto caliphate or the storming of the Bastille can be expected to fade away as time goes by – or at least there is no inbuilt mechanism to amplify it. But in times of global warming, iron laws of economics and geophysics boost the past from behind, so to speak. 'The tradition of the dead generations weighs like a nightmare on the minds of the living,' Karl Marx famously wrote in *The Eighteenth Brumaire of Louis Bonaparte:* in a warming world, it weighs down heavier and heavier, on the bodies of the living and their surroundings, in a relentless consolidation of the tyranny of the past.[19] This will certainly be more than a gradual progression. Extreme weather events convert the attrition of slow violence into photogenic spectacle: think of a flooding in Pakistan or a wildfire in Colorado. The snap disasters of abrupt climate change – the fatal crossings of tipping points in the earth system – would mark the sudden irruption of the mounting history of the fossil economy onto the stage of the present. Indeed, as unseasonable weather is becoming the new norm, this is already happening: when Julius, the protagonist in Teju Cole's novel *Open City,* roams the streets of New York in the middle of November without yet having had the occasion to wear his coat, he cannot help but suspect, with a sense of 'sudden discomfort,' an effect of global warming.[20] Contrary to popular misconceptions in the media (and to Julius's own scepticism), it is now perfectly possible to attribute a particular heat wave or other anomaly to the underlying rise in average temperatures, in whose absence such events would have been utterly improbable.[21] The thermometer can be legitimately suspected as a barometer of the rolling invasion of the past into the present.

There follows, from all of this, a very peculiar temporality of climate change politics. Few if any other issues have such heightening urgency built into them by dint of sheer physical laws: the point of *too late* is coming closer by the day, and the closer it comes, the more swift and comprehensive the emissions cuts must be. The tradition of the dead is breathing down the necks of the living, leaving them with two choices: smash their way out of business-as-usual – and the heavier the breath, the more extreme the measures must be – or succumb to an accumulated, unbearable destiny. As of this writing, both scenarios remain possible. The famed 'window of opportunity' for abolishing the fossil economy and stabilising climate within tolerable bounds – even returning it to safer conditions – is still there; if emissions were reduced to zero, the rise in temperatures would soon taper off.[22] Such an enterprise would have to stage a full-scale onslaught on the structural nightmares bequeathed by the past. It would be a revolution against history, an exodus, an escape from it in the last moment, and it would have to know what it has to struggle against.

None of this is meant to deny that space is a crucial dimension or that geographers have enriched critical theory with an abundance of insights; we shall deal with the former and draw on the latter quite extensively in what follows. But now is a singularly bad time for declaring the demise of time.[23] The spaces of climate change are relevant only insofar as they are folded within the process: the *change,* the warm*ing*. As the word indicates, this tempest is eminently temporal.

Searching for the Origins of the Fossil Economy

What do we mean by 'the fossil economy'? A simple definition would be: an economy of self-sustaining growth predicated on the growing consumption of fossil fuels, and therefore generating a sustained growth in emissions of carbon dioxide. Roughly synonymous with 'business-as-usual' in the lexicon of climate politics, this, we submit, is the main driver of global warming. It first appeared during the Industrial Revolution, whose great historical feat was to inaugurate an era of 'self-sustaining growth,' meaning a process of growth that was not episodic, evanescent, broken off after a brief efflorescence, but persistent and unremitting, a secular progression propelled by its own inner forces.[24] In biophysical or thermodynamic terms, no growth can, of course, feed upon itself: one of the key lessons of ecological economics is that it always relies on the withdrawal and dissipation of natural resources. But through mechanisms to be specified later, the fire of modern growth reproduces an economic gas that necessarily ignites as more growth, the result of the process spurring it to advance further, the loop reinforced anew on a grander scale – and in this and only this sense is it self-sustaining. The fossil economy was born when that fire began to be fed by the material fuel of fossil energy.

Now we immediately see that the fossil economy, under this definition, cannot account for all human influence on the climate. Fossil fuel combustion is only one cause of global warming, just as the sun is only one of the bodies in the solar system and the American president only one in a larger team: the others, puny by comparison, revolve around it. 'Land-use change' – read: deforestation – accounts for a fourth of all CO_2 released since 1870, but its share is secularly diminishing, now standing at around 8 percent of current emissions, fossil fuels taking up virtually all the rest.[25] Then there are the other greenhouse gases – methane, nitrous dioxide, ozone, sulphur hexafluoride… – whose social histories would have to be recounted for a full picture to emerge. But it is safe to say that the burning of fossil fuels is the hard core of the problem, quantitatively dominant and qualitatively determinant. It deserves special focus.

If emissions of carbon dioxide ceased to increase and stayed constant, atmospheric concentrations would still continue to climb: absolute volumes of CO_2 are, in the end, what matters for climate. Then why include their *growth* in the definition of the fossil economy? Because it is the union of economic expansion and fossil energy consumption that has pushed emissions up to the present, utterly unsustainable – and still rising – levels: this is the really existing process, the alloy that has brought us to this warmer place. Three major deviations from the norm are possible. An economy that grows while its emissions flatten out, even if on a high level, can be classified as a *decoupled* fossil economy; it might still be overwhelmingly based on fossil fuels, but only one of the two components remains in motion. One with no trend in either respect may be termed a *steady-state* fossil economy, while one with continuously diminishing emissions – due to spontaneous breakdown, deliberately orchestrated policies or some other factor – is a fossil economy *in decline*. To the extent that these variants have existed at all, they have been exceptions proving the rule, or aberrations from business-as-usual (pretensions to decoupling gainsaid by rising emissions embodied in imports; steady-state situations a transient feature of crisis, such as in 2009; decline – notably in Eastern Europe in the 1990s – followed by rebound).[26] None undermines our definition of the object of historical inquiry.

The fossil economy has the character of a totality, a distinguishable entity: a socio-ecological structure, in which a certain economic process and a certain form of energy are welded together. It has some identity over time; contrary to the axioms of methodological individualism, the embryonic individual is suspended in its fluid. A person born today in Britain or China enters a preexisting fossil economy, which has long since assumed an existence of its own and confronts

the newborn as an objective fact. It possesses real causal powers – most notably the power to alter the climatic conditions on planet Earth, but this only as a function of its power to direct human conduct. A factory manager will be pressured to obtain energy by plugging into the current from the nearest coal-fired power plant rather than building her own waterwheel. The company owner will send her commodities to the world market on cargo vessels, rather than sailing ships. A cashier may have little choice but to commute to the supermarket in a car – she certainly won't ride a horse – and if she wants to go on vacation, she will encounter intense advertising for flying as a transportation option. Moreover, none of these emitting actions would be possible without integration into the fossil economy: alone on an island, or living in a country untouched by this economy, an individual could complete none of them. As such, then, the fossil economy is an altogether *historical* substance. It must have undergone its own birth once upon a time. The causal powers it now exerts are emergent properties: they were not always there. Agents must have created it through events amounting to a moment of construction, much as, once erected, a building's structure is now an enduring feature of the world; entrenched in the environment, it conditions the movements of the people inside. Eventually it appears indistinguishable from life itself: business-as-usual. But the fossil economy was once constructed and has since been reproduced and enlarged, and anything built over time can potentially be torn down (or escaped).[27]

So how did it all begin? Where would the search for a moment of construction lead us? While several countries could lay claim to being the cradle of modernity, capitalism, enlightenment or liberal democracy, the fossil economy has one incontestable birthplace: Britain accounted for 80 percent of global emissions of CO_2 from fossil fuel combustion in 1825 and 62 percent in 1850.[28] There is a margin of error in these figures, but they give us an idea of the proportions and trends, suggesting that Britain lost some of its paramountcy as the consumption of fossil fuels spread to other countries but continued to generate *more than half* of the world's emissions far into the nineteenth century. The origins of our predicament must be located on British soil.

Consequently, there has been a minor flurry of interest in revisiting the British Industrial Revolution for clues as to how all of this happened and, not the least, what to do now. An energy transition – most simply defined as 'a switch from an economic system dependent on one or a series of energy sources and technologies to another' – occurred at that time; we are heading towards another transition; thus, the argument goes, we need to learn from the past to proceed as best we can now.[29] If we think of the fossil economy not as a static building but rather as a train put at a point in the past on the current perilous track, we require knowledge of the switching mechanism to enter a safer course. The British Industrial Revolution here assumes the status of a unique archive of lessons. What do they say? 'First, the transition was slow. Second, it was driven by prices. Third, it required new technology.' Add human capital, scientific discovery, cooperation and narrow self-interest in equal measures and, concludes economic historian Robert Allen, a future transition to sustainable energy will also share these characteristics. Most importantly, 'people respond to price incentives'.[30]

One lesson often taken away from the switch to fossil fuels is precisely that it was protracted, passing through several phases of stumbling experimentation, the agents slowly learning to master the novel form of energy – and hence the shift *away* from them should follow the same pace and refrain from 'pre-mature scaling up of technologies and industries'.[31] A transition must be given time. Even more critical, as we shall see, is the presumed lesson of prices: fossil fuels won the original race because they were cheapest, and the same advantage will now have to be

secured for renewable alternatives if they shall have a chance. Moreover, if the British Industrial Revolution stands as a model for 'the second industrial revolution,' or the green or the low-carbon or the sustainable one, yet another lesson seems unavoidable: 'The profit-motive of small and medium-sized enterprises rather than community action might drive innovation. The fact that' the instigators of the switches back then 'were competitive capitalists and became wealthy as a result' counsels us from assuming that 'only communal initiatives can drive radical change.'[32] Capitalists slowly unrolling technologies with lower prices: this is the manual to follow.

But any straight parallelism between the entry into and the exit from the fossil economy is spurious. It comes close to the fallacy of presupposing that the present is essentially the same as the past, allowing for an immediate transfer of precepts, such as when generals have drawn up their strategies from the lessons of ancient battles and suffered grievous defeat, forgetting the Heracleitan rule that you cannot step into the same river twice. As several scholars have pointed out, the transition now impending – if indeed it is – would be motivated by the urgent need to stave off or at least minimise catastrophic climate change, a danger humanity has never before confronted, and one which certainly did not figure in the calculations of early British industrialists. The most highly prized quality of renewable energy would be low or zero emissions of carbon dioxide: a public good, not a private benefit. Time is already characterised by being short. For these and other reasons, the next transition cannot share the canonical features of the British Industrial Revolution; above all, this time it would have to be *collectively planned*.[33] But it would face impediments. Measures necessary for an enforced, rapid, politically driven phaseout of fossil fuels may, as IPCC tersely notes in a 'Summary for Policymakers' from 2007, be 'difficult to implement' due to what the panel labels a 'key constraint': namely *'resistance by vested interests'*.[34] In these few words, a planet of antagonism briefly comes into view. So fossil fuels have to be discarded for human civilisation to endure and thrive – but there are 'vested interests' standing in the way. What are they?

Here might lie a better reason to revisit the Industrial Revolution. If the fossil economy is a train that never stops but always accelerates, even when approaching the precipice, the task is to pull the brakes (or maybe jump off) in time, and if there is a driver who seeks to keep this from happening, she has probably been seated in the locomotive for some time: we need to know who she is and how she works (or perhaps it is an automatic engine, a driverless construction – but the need would be the same). The interests that once put the train in motion may still be driving it. The previous transition, then, would be not so much a template for the next as *a key to understanding and removing the impediments*. We cannot know this for sure: it is a mere suspicion. It is, of course, conceivable that the initial reasons for taking up fossil fuels are entirely unrelated to the interest in clinging to them now, which might have taken over at some point along the journey. But if we want to know more about the propulsive forces of the fossil economy, its laws of motion and the interests invested in it, the beginning seems a good place to start.

Whether we frame this as a search for parables or for enemies, the underlying assumption is that meaningful action can be undertaken: it is not yet too late. But what if it is? 'If there's no action before 2012, that's too late,' declared Rajendra Pachauri, chair of the IPCC, in 2007: 'What we do in the next two or three years will determine our future. This is the defining moment.'[35] What if that were no mere rhetoric, but an accurate forecast soon to be fully vindicated – then would there be any point in delving into the annals of the fossil economy? If

any historical matters exist that would be of interest under sea levels two metres higher, this might be one of the few. Or, with Gardiner: there is a 'task of *bearing witness* to serious wrongs even when there is little hope of change'.[36] The militant reason for studying the history of the fossil economy has a meditative backup. Both boil down to, in the simplest possible terms, that one burning question: how did we end up in this predicament?

The Moment of Steam

So we return to the Industrial Revolution in the hope that it will divulge its reasons for welding growth to fossil fuels, the first of which was coal. But coal had been burnt in Britain for millennia. From the Bronze Age and the Roman occupation to the Middle Ages, fires of coal were appreciated for their intense heat, used, as we shall see, in the kindling of religious ceremonies, the heating of homes, the cooking of food and the processing of some materials, notably iron in smitheries. Yet few would argue that the fossil economy emerged around the year 2000 BCE or 50 CE or in the thirteenth century. The union between self-sustaining growth and coal combustion existed at none of these times, because the former had yet to develop and the latter remained limited to heat generation. Britain had to wait for the Industrial Revolution to write out the growth formula *and* initiate a qualitative leap in the manner of coal consumption: the transformation of heat into motion, or the conversion of thermal into mechanical energy, by means of *the steam engine*.

In the first steam engines, coal was burnt in order to force a piston up and down in a vertical motion well suited for the pumping of water, but not much else. Another form of motion was called for: in the words of a mid-nineteenth-century treatise, 'of all sorts of motion, that which is most frequently required in the arts, is one of continued rotation. Mills in factories of every kind are impelled by machinery which receives its motion from a wheel.' It was the earth-shattering exploit of James Watt to connect the coal fire to the wheel. With the device he patented in 1784, Watt finally 'adapted the motion of the piston to produce *continuous circular motion,* and thereby made his engine applicable to all purposes of manufacture,' as stated by another tract.[37] With this, the foundations of the fossil economy were laid down.

What could the rotative steam engine accomplish that the hearth and pump of old could not? Most obviously, it could impel a *machine:* the prime fulcrum of self-sustaining growth, increasing output per capita, raising the productivity of labour in a universal speedup that has yet to see its end. As a source of thermal energy, coal was useful for a range of processes requiring that input, but only as a source of mechanical – rotative – energy could it fuel the production of all sorts of commodities. 'Machinery is,' explained the *Rees' Cyclopædia,* the most important compilation of technical knowledge in the early decades of the nineteenth century, 'the organs by which motion is altered in its velocity, its period, and direction, and thus adapted to any purpose'; once coal had been made to power it, the fuel could flow into the veins of an economy throbbing with expansion.[38] In this book, we shall study how the fossil fuel of coal was coupled to the machine through the rise of stationary steam power in the mills of Britain.

A rotative engine could also impel a *vehicle,* the second fulcrum of self-sustaining growth, likewise receiving motion from wheels, travelling across sea and land and transporting commodities – raw, finished – to and from the mills. A sequel to this study entitled *Fossil Empire* will deal with mobile steam power on a global scale. Heat could work on materials with certain chemical properties; pumps could force up liquids. Machines and vehicles alone could

fabricate and distribute the widest imaginable range of commodities; driving them with coal, the steam engine first made fossil fuels integral to growth across boundless expanses. Moreover, the combustion of coal in British cottages and smitheries never spurred *other* countries to adopt the fuel. Only the machine and the vehicle had the power to project the fossil economy out from the British Isles, through the pressures of economic competition and military invasion. A country flooded by commodities from steam-powered mills or attacked by the overwhelming force of steamboats would feel the whip of external necessity and perhaps seek to emulate the technology in order to save its industry or survive as a nation; as long as coal was primarily consumed within British households, distant communities had little reason to take notice.

The existence of coal seams in Britain – or indeed on any continent in the world – was evidently not a sufficient condition for the transition. The same goes for the rotative steam engine. Like strata in the rock, that artefact could not, as a mute physical thing, spark off something like a fossil economy by itself. The mere presence of the engine as certified in the legal rights of the inventor tells us nothing about the extent to which it was actually installed, its function in the economy or the propensity to emit carbon dioxide: the atmosphere does not feel the breath from a patent. History is stocked with inventions petrified into objects of exhibitions or fantasies in the style of da Vinci, and so the question of the steam engine is the question of *why it was adopted and diffused* – in Britain and, above all, in the cotton industry. There it supplanted the waterwheel. Before steam, the British cotton industry – the fast lane of the Industrial Revolution, in which self-sustaining growth first appeared – impelled its machines with water. So why did cotton capitalists turn from water to steam? By examining the causes of that original transition, we may come closer to an understanding of the mechanisms that launched, and perhaps still drive, the process now known as business-as-usual.

Seeing Power as Power

The word ‘power’ in the English language has a dual meaning: ‘power’ as in a force of nature, a current of energy, a measure of work; ‘power’ as in a relation between humans, an authority, a structure of domination. The conjunction is not as close in other major European languages. ‘Motive power’ and ‘absolute power’ are ‘fuerza motriz’ and ‘poder absoluto’ in Spanish – no apparent connection there – while French distinguishes between ‘énergie’ and ‘courant’ on the natural side of things and ‘puissance’ and ‘pouvoir’ on the social, roughly equivalent to Kraft/Strom and Macht/Gewalt in German (hence Atomkraft but Weltmacht). Why have the two poles collapsed into one in English? An inquiry into such comparative European etymology is outside the scope of this study: we can only note the intriguing fact.

Do the two meet in reality? In spite of the semantic confluence in the Anglophone world, thermodynamic and social power are nearly always treated as ‘distinct phenomena, a habit encouraged by the disciplinary structure of academic research,’ as observed in one recent attempt to bridge the gap.[39] Two authoritative works in the respective hemispheres exemplify the separation. In *Energy in Nature and Society: General Energetics of Complex Systems,* Vaclav Smil offers an exact definition of power as ‘the rate of flow of energy,’ or ‘W = J/s,’ where *J* is joule, *s* is second and *W* the unit of power: Watt from James.[40] Put differently, power is here understood as the rate at which work is done or energy transformed – and that is all there is to it, apparently, for in spite of the nominally transdisciplinary character of his work, Smil does not so much as notice that there is another meaning to the term, much less any actual movement

between the two.

Turn to Steven Lukes's sociological classic *Power: A Radical View* and the other eye is shut. Here the overlap between 'horse power' and 'power struggles' is mentioned merely to indicate the terminological chaos surrounding 'power' in society: the nature of social power can only be distilled if cleansed of all associations with the mechanical phenomenon, in a first, essential act of analytical distinction.[41] In the dozens of dissections of the concept filling Lukes's pages, there is no hint at power being *at once* energetic and interpersonal, nor does he see any potential for plumbing the depths of social power by taking its mechanical base into account. The colloquial drift between the poles – reflexive, unnoticed and perfectly realistic – has its counterpart in a stern intellectual segregation. The English language might contain a basic truth from which scientific research has become estranged; in any case, it permits us to formulate a general hypothesis guiding the rest of this work: *the power derived from fossil fuels was dual in meaning and nature from the very start*. Steam as a form of superior power was just that. The two moments cannot be isolated from each other, since they *constituted each other* in a unity, the opposites interpenetrating throughout.

It is proven beyond all reasonable doubt that global warming does not have natural causes. Solar radiation, volcanic outgassing, endogenous variations in the carbon cycle, and other similar suspects have been decisively cleared of responsibility for the rise in temperatures, the root causes firmly passed to the social side of the equation. Once we cross that line, we immediately encounter *power* – indeed, this happens as soon as we use the term 'fossil fuels'. They are, by definition, a materialisation of social relations.[42] No piece of coal or drop of oil has yet turned itself into fuel, and no humans have yet engaged in systematic large-scale extraction of either to satisfy subsistence needs: fossil fuels necessitate waged or forced labour – the power of some to direct the labour of others – as conditions of their very existence. If we take the message of climate science seriously, we should direct our attention to power in the dual sense, first of all in the process of labour. That is the point of contact between humans and the rest of nature, where biophysical resources pass into the circuits of social metabolism, where coal and oil and gas are extracted, transported, coupled to machines: burnt. The process is peopled. 'As a primary agent of energy and matter transformation through the labor process,' writes environmental historian Stefania Barca, 'workers are the primary interface between society and nature,' wielding and subject to power.[43] *That* is the sphere where the fossil economy must have originated.

Neither environmental nor labour history has, for their own particular reasons, been very keen on connecting the dots of workers and the wider environment, class and climate. The same silence reigns in research on energy in the Industrial Revolution. Indeed, climate change as such remains primarily an object of natural science, recent spurts of interest in the social sciences notwithstanding. We are awash in data on the disastrous effects but comparatively poor on insights into the drivers.[44] Or, to paraphrase Marx: most climate science still dwells in the noiseless atmosphere, where everything takes place on the surface, rather than entering the hidden abode of production, where fossil fuels are actually produced and consumed. Natural scientists have so far interpreted global warming as a phenomenon in nature; the point, however, is to trace its human origins. Only thus can we retain at least a hypothetical possibility of changing course.

CHAPTER 2

Scarcity, Progress, the Nature of the Human Species? Theories of the Rise of Steam

Steam as Response to Scarcity

Long before global warming crept up on modernity, a quick look sufficed to spot energy at the heart of the Industrial Revolution: in the rear-view mirror of historians, among the most conspicuous facets were novel ways of harnessing the powers of nature for the purposes of production. The doyen of modern research on the role of energy in the Industrial Revolution is E. A. Wrigley. In a pathbreaking article in 1962, he first broached ideas later developed into a grand narrative of the dynamics of change in eighteenth- and nineteenth-century Britain and, more generally, of economic growth.[1] In what he would come to call 'the organic economy,' all forms of material production are based on the land: raw materials, thermal energy and motive force – human and animal bodies used to put things in motion – are drawn from the yield of present photosynthesis. That yield is restricted. There is no way to enlarge it beyond the constant supply of land. A growing organic economy will inevitably find itself trapped in fierce competition for scarce resources, making 'a permanent, radical increase of industrial raw material supply' – a necessary condition for self-sustaining growth – 'very difficult to obtain'.[2] Dependency on the land imposes a tight bottleneck on industrial production. Fossil fuels shatter that bottleneck.

Preindustrial Britain was an archetypal organic economy, where the farmers fetched whatever they needed from the land: food, fodder for the animals – some sheared, some slaughtered, some employed as beasts of burden – furniture, building materials, originally even fuel for the fires: everything came from the fields and the forests. The spinners and weavers, tanners and dyers, sawyers and carpenters, smiths and cabinetmakers worked with fruits of one and the same earth, such as wool, flax, leather, hair, fur, straw, charcoal and, not the least important, wood itself. A growing sector could continue to grow only if it seized a larger slice of the pie from another. Within the tight energy budget of the organic economy, where all activities jostled for access to the same finite area of photosynthetic productivity, the process of growth could not possibly become universal or self-sustaining: sooner rather than later, it would peter out.

This idea Wrigley has borrowed, of course, from David Ricardo, to whom he gives ample

credit. According to Ricardo, growth has to lay claim to more fertile land. As long as the economy is young and the country sparsely populated, this will present no problem, but at some point 'land of an inferior quality' will have to be called into cultivation: wetlands, steep slopes, fields in the mountains hitherto left untouched are scoured for more soil on which to expand. More products now have to be wrested from increasingly meagre land with greater inputs of labour. Nature turns from a giver to a taker: 'In proportion as she becomes niggardly in her gifts, she exacts a greater price for her work'; the prices of the foodstuffs extracted from her soil rise. Profits fall, accumulation sags; general descent into economic paralysis sets in, emanating from natural constraints: the stagnation will, Ricardo writes in a formulation repeatedly quoted by Wrigley, 'necessarily be rendered permanent *by the laws of nature, which have limited the productive powers of the land*'.[3] It is this chain of causation that Wrigley applies to the Industrial Revolution. It explains the turn to fossil fuels.

The new system – designated the 'inorganic' or 'mineral-based' economy by Wrigley – finally broke the spell of stagnation. When iron, pottery, bricks, glass, salt and other industries turned to coal, they bypassed the restricted surface area by digging into the stores of *past* photosynthesis, wholly new vistas of expansion opening up beneath the forest and the field. Further down the same subterranean road, cars, ships, trains, planes, all sorts of consumer and capital goods would be made out of fossil fuels, thanks to which a perpetually growing economy could fly past Ricardian constraints. In Wrigley's scheme of things, such constraints explain not merely the preference for fossil fuels, but also, and perhaps more importantly, the very conditions of self-sustaining growth. Only when British capitalists removed the stones from the tombs of coal could expansion be called out to live eternally.

One method used by Wrigley and his followers to illustrate the logic is to convert coal into acres of land required to generate the same amount of energy. In 1750, all coal produced in England would have equalled 4.3 million acres of woodland, or 13 percent of the national territory. In 1800, substituting wood for all coal would have demanded 11.2 million acres, or 35 percent of the British land surface; by 1850, the figures had risen to 48.1 million acres and 150 percent, respectively. As early as in 1750, then, a hypothetical total conversion from coal to wood in the British economy would have 'represented a significant proportion of the land surface for which there were many other competing uses'; in 1800, it would have been 'quite impractical'; in 1850 – the threshold of 100 percent crossed – 'self-evidently an impossibility'. In other words, 'in the absence of coal as an energy source, Ricardian pressures would have become acute': forests denuded, soils exhausted, growth grinding to a halt.[4] In a similar computation inspired by Wrigley, Rolf Pieter Sieferle concludes that, already by the 1820s, coal had freed an area equivalent to the total surface of Britain, while Paolo Malanima, likewise standing on the shoulders of Wrigley, estimates that in the absence of fossil fuels, Europe would have needed a land area more than 2.7 times its entire continental surface in 1900, rising to more than *20 times* in 2000.[5]

But the pressures undone by coal were not only Ricardian in character. They arose from reproduction as much as from production. According to Wrigley, Malthus's theorem of geometrically growing population and arithmetically growing food supplies, generating a tendency for output per head to fall, was indeed valid in an organic economy. The arguments of the old parson – plants struggle for room within the constricted bounds of the planet; all animals have a 'constant tendency to increase beyond the means of subsistence'; surplus populations unable to find food will be sired – are incontrovertible *as long as fossil fuels have not been*

hauled into the economy.[6] Before that point, population growth will necessarily cause a decline in living standards, since more people have to divide the same fixed supply of land into smaller pieces. After that point, pressure on the land will be dramatically alleviated: coal will allow for the population to increase by leaps and bounds. Here was another cause of its usage.

The Malthusian component of the argument has, however, received its most articulate expression in a study by Richard G. Wilkinson, nowadays better known for his work on the unhealthy impacts of social inequality in books such as *The Spirit Level*. In *Poverty and Progress: An Ecological Model of Economic Development,* Wilkinson seeks to construct, as the title suggests, a most general model of development derived from the case of the British Industrial Revolution. People do not invent new technologies because they are affluent, but because – and only when – they are poor. Poverty is a symptom of resource scarcity. Such a condition comes about when a human population succumbs to its innate tendency, common to 'every animal population,' to reproduce beyond the bounds of its resource base – the early deductions in Malthus's *Essay* transcribed virtually verbatim (plus a dose of Darwin).[7] Normally, humans try to uphold a precarious ecological equilibrium and cut their coat according to their cloth by means of cultural norms, including everything from infanticide to taboos on profligate sexual intercourse. For some reason, however, that equilibrium might break down – and it is then that things begin to move.

A society that fails to curb its appetite for procreation because of a 'disturbance to some part of the cultural system' plunges into want. It has no choice but to innovate. Swelling numbers being impossible to sustain within the given niche, scarcity *'forces* the society to make some alteration in the way it gains its living from the environment': exactly what happened on the eve of the Industrial Revolution, in the late seventeenth century. English couples lost their self-restraint and fertility spiked; the growing population resorted at first to the available slack in the resource base, but by the eighteenth century, the breakdown had reached abysmal levels, obliging England to embark on 'the substitution of mineral resources for landbased ones.' Coal resolved a crisis of overpopulation. Like all innovations that composed the Industrial Revolution, the exploitation of fossil fuels was the outcome of 'a valiant struggle of a society with its back to the ecological wall,' a 'response to a particular resource shortage,' a decision 'made under duress.'[8]

Ricardo and Malthus, then, are the fathers of this way of thinking about energy in the Industrial Revolution. The great irony, according to Wrigley, is that both made their pronouncements on the impossibility of self-sustaining growth at the very moment when the obstacles to such growth were removed. Yet they bequeathed the proper tools for understanding the transition. In that precious box may also be found the insights of Adam Smith, as argued by Kenneth Pomeranz in *The Great Divergence: China, Europe, and the Making of the Modern World Economy,* a work that set much of the agenda for economic history in the twenty-first century. Pomeranz contends that England and China, or rather the Yangzi Delta, essentially followed the same trajectories all the way up to the nineteenth century. Both exhibited high population densities, specialisation, Smithian division of labour, a gradually heightened propensity to truck, barter and exchange: economic growth, in short. Both likewise achieved rising agricultural productivity, relatively free markets for land and labour, improved standards of living – and both were running headlong towards ecological crash. The land constraint was just about to pull them down when England realised the full potentials of its coal reserves.

Pomeranz's explanation for the great nineteenth-century divergence between England and the Yangzi Delta has two prongs: colonies and coal, to which England alone had access. No specific

constellation of social relations and technologies set the West on its exceptional path; rather, institutions and basic mechanical proficiencies were, to all intents and purposes, *identical* in the Far East. But coal from the Chinese inland had to be transported over prohibitive distances to the coast, while English manufacturers had coal mines if not under their feet then within the easy reach of their ships. China failed to ferry fossil fuels to its littoral hothouses of Smithian growth, stayed within the limits of finite land and began to regress; England became a world leader. Anchored in nearby mineral endowments (and distant dominions, with scant purchase on the strictly energetic side of the process), Western Europe – England its core – 'became a fortunate freak,' breaking 'through the fundamental constraints of energy use and resource availability that had previously limited *everyone's* horizons'.[9] With this interpretation of the divergence, Pomeranz in effect elevates the triple drivers of division of labour, trade and population growth – Smith, Ricardo, Malthus – into global vectors, equally present in eighteenth-century China and England, equally threatened by the universal land constraint. The lucky islanders alone could then excavate a track to exponential growth.

The endorsement of the school of thought pioneered by Wrigley has taken the form of a near-consensus. Culminating in his magnum opus *Energy and the English Industrial Revolution* from 2010, it now deserves the epithet of a paradigm, most normal research on the topic following its lodestar. Since the land constraint of Ricardo is dominant within it, the procreating populations of Malthus secondary and Smith a relatively peripheral figure, we shall call it 'the Ricardian-Malthusian paradigm'. Astrid Kander and her colleagues sum up its cardinal thesis in their *Power to the People: Energy in Europe over the Last Five Centuries,* a study dressing up Wrigley's account with more numbers: 'The start of the energy transition was brought about by the need to replace natural resources *that were becoming scarce* in the face of rising demand.'[10] A liberation, a break-out, an escape, the switch to fossil energy is here caused by scarcities while pointing to the future as the opening act of self-sustaining growth in what might seem, at first glance, a coherent and compelling analysis.

How, then, does the Ricardian-Malthusian paradigm account for the rise of steam power? Wrigley, for one, singles it out as the decisive departure from the organic economy. As long as it was burnt for heat, coal remained of limited value, relief from the curses of Ricardo and Malthus a doubtful prospect – but once the fuel had become a source of mechanical power, 'the way was clear for individual productivity to make a quantum leap. The tortoise could now sprint rather than crawl. Production could outpace population.' Mechanical – not thermal – power shattered the bottleneck, and it did so only in *the second quarter of the nineteenth century,* when, as Wrigley notices, the steam engine became the dominant prime mover in (some) manufacturing. First to be let out of confinement was the cotton industry. It housed more engines than any other sector of the British economy up to perhaps 1870, through a period when the very same engines were 'the most important single consumer of coal'.[11]

A thermodynamic Ricardian, Wrigley builds his model on the limitations of present photosynthesis: plants capture a fraction of the incoming solar radiation and convert it into organic matter on the land, which is restricted, leaving only a narrow energy base on which humans can draw. The organic economy of preindustrial Britain was characterised by its complete dependence on *plants,* directly (wood as fuel) or indirectly (fodder for beasts of burden, and so on). This is where Ricardo's theorems come into effect: 'A rising demand for energy could only be met from the products of plant photosynthesis. It therefore necessarily meant increased pressure on the land. And this spelt trouble in the long run.'[12] Now, if the adoption of

steam power in manufacturing constituted the critical step out of the bounds of the organic economy and into continuous growth, and if the virtue of coal was to detach energy needs from present photosynthesis, then the prime movers replaced by steam must, for Wrigley's model to hold, have been fuelled by plants: woodburning stoves or food-burning muscles. But that was precisely not the case. *Water* was the element on which Britain's industries – cotton foremost among them – surfed before they turned to steam. Watt's engine vanquished the waterwheel, but obviously not because of the inherent limitations of present photosynthesis. Water is no plant, nor does it have to eat one to flow.

To identify a Ricardian exigency in the transition from water to steam, Wrigley has to uproot the notion of scarcity from the soil and broaden it to encompass any kind of shortage, such as that of, in this case, waterfalls. In his original 1962 piece, he notes the delay between Watt's invention (in the 1780s) and the adoption of steam in the cotton industry (in the second quarter of the nineteenth century), contending that 'only after a generation of expansion had caused the need for power to outstrip the capabilities of the human arm and the water wheel was the steam engine brought into use'. In this version of events, the wheels were discarded *because they could not deliver the requisite quantities of energy, their fuel being in too short supply*. 'Unused waterfalls with a sufficient head' had become 'few and remote,' roughly corresponding to the Ricardian law of diminishing returns, presumably realised through a rise in the price of water relative to steam.[13]

Wilkinson settles for the same story. 'The use of water power was limited by the number of streams with suitable sites for mills: new sites became scarce in many parts of the country during the *seventeenth* century,' whereas 'coal to fuel the steam engine was plentiful – especially at the pit head. *The spread of steam power was ecologically favoured.*' But, he goes on to assert, jumping between the centuries, 'it was not until the late eighteenth century, when the new cotton mills began to add to the demand for rotary power and *good mill sites were no longer available,* that Boulton and Watt' invented steam and delivered manufacturers from the acute shortage.[14] Equally aware of the implications of the steam breakthrough, Pomeranz alleges that 'water power, no matter how much the wheels were improved, simply did not have the same potential to provide energy inputs that would significantly outpace a rapidly growing population'; Kander and her fellow pupils of Wrigley, who copy his view of the steam engine as the true quantum leap, affirm that water 'could not keep up with population growth' and so had to be abandoned.[15] An ecological niche bursting at the seams, a dearth of water blocking further growth: here is the Ricardian-Malthusian account of the rise of steam power. We shall see how it fits with the historical record.

Steam as Human Fire

On 9 May 2013, the daily average concentration of carbon dioxide in the air as measured high on the slopes of a Hawaiian volcano, at the Mauna Loa Observatory, the oldest station for monitoring CO_2 in the world and the global benchmark site for tracking the rise and rise of the gas, first crept above 400 parts per million (ppm).[16] The milestone elicited few banner headlines. To the scientific community and those members of the public who were concerned, it was yet another reminder of the disturbing fact that the composition of the atmosphere is flying out of bounds at record speed. The last time the concentration of CO_2 hovered around 400 ppm was at

least 2.5 million years ago, during the epoch of the Pliocene; it is believed to have stayed below 500 ppm since the onset of the Miocene, around 24 million years back in deep history. During the Holocene – the epoch beginning when the last ice age ended nearly 12,000 years ago – it has fluctuated between 260 and 285 ppm like a ball gently rolling between narrow rails, the boundaries within which sedentary civilisation developed. In the past millennium, the variations were no larger than 5 ppm, until the Industrial Revolution threw the gas into another orbit.[17] Presently the concentration rises by 2 ppm *every year*.

Given that carbon dioxide acts as a thermostat in regulating the temperature on earth, and given that the temperature sets the climatic conditions in which all life on earth exists, the magnitude of the rise – from 285 ppm as late as the mid-nineteenth century to the current 400 plus – upgrades *Homo sapiens* into a geological agent. She now tinkers with some of the most fundamental variables of the earth system. The markers of epochs are altered – in the vast geological (Pliocene, Miocene, Holocene), not the mundane historical (Sassani, Fatimid, Victorian) sense – historical time catching up with and penetrating geological time. The Holocene has come to an end. Or so argue a growing chorus of geologists, chemists, environmental historians, sustainability scientists and others, who champion the idea that a new epoch has dawned on the planet: the 'Anthropocene'. The term

> suggests that the Earth has now left its natural geological epoch, the present interglacial state called the Holocene. Human activities have become so pervasive and profound that they rival the great forces of Nature and are pushing the Earth into planetary *terra incognita*.[18]

The claim is not, of course, that humans never left any imprint on their environments in earlier times, but rather that a qualitative scale-up has occurred. Even such events as the extinction of the Pleistocene megafauna or the deforestation of Mediterranean hills failed to touch *all* ecosystems, reach into all niches of terrestrial and aquatic life or modulate the state of the planet as a whole at once: precisely what the overaccumulation of heat within the biosphere through the rise in CO_2 is now accomplishing. Global warming, however, is only one of the truly epochal changes wrought by humans, as theorists of the Anthropocene are keen to stress. Besides carbon, several cycles of elements essential to life – notably nitrogen, phosphorous and sulphur – are now out of joint due to human over-extraction and over-emission; the water cycle has been upset by the damming of rivers and the clearing of land; the sixth major event of species extinction is underway; oceans are acidifying; ozone is depleted; and the list goes on. Signs of planetwide human ascendancy seem to crisscross all spheres of life. Yet the proponents of the Anthropocene concept tend to give global warming and the rise of its main chemical agent pride of place as crucial evidence of a new age: 'We propose that atmospheric CO_2 concentration can be used as a single, simple indicator to track the progression of the Anthropocene,' write Will Steffen and colleagues, and the proposition is sound.[19] No other perturbation of the biosphere can rival the destructive potential of this one.

A question than imposes itself: when did it all begin? The breakthrough of the neologism dates to atmospheric chemist and Nobel laureate Paul Crutzen's short piece 'The Geology of Mankind' in *Nature* in 2002, beginning with the observation that global climate may depart from natural behaviour 'for many millennia to come,' followed by a striking announcement:

> The Anthropocene could be said to have started in the latter part of the eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and

> methane. This date also happens to coincide with James Watt's design of the steam engine in 1784.[20]

The chronology went viral. In the burgeoning literature on the Anthropocene, the birth of the epoch is frequently if not habitually associated with Watt's invention of the rotative steam engine, as the one artefact that catapulted the human species to full-spectrum dominance of the planet. Among the cited precursors to the concept is Henri Bergson, who peered far into the future in his *L'Evolution Créatrice* from 1907:

> A century has elapsed since the invention of the steam engine, and we are only just beginning to feel the depths of the shock it gave us … In thousands of years, when, seen from a distance, only the broad lines of the present age will still be visible, our wars and our revolutions will count for little, even supposing they are remembered at all; but the steam engine, and the procession of inventions of every kind that accompanied it, will perhaps be spoken of as we speak of the bronze or of the chipped stone of pre-historic times: *it will serve to define an age*.[21]

Or perhaps the end of all ages? In *Hyperobjects: Philosophy and Ecology after the End of the World,* celebrated ecocritic Timothy Morton outlines a bold new worldview appropriate to the Anthropocene in general and global warming in particular, and he knows more than most. 'The end of the world has already occurred. We can be uncannily precise about the date on which the world ended,' Morton writes, giving the event a rather odd interpretation and a very exact date: 'It was April 1784, when James Watt patented the steam engine, an act that commenced the depositing of carbon in Earth's crust – namely, the inception of humanity as a geophysical force on a planetary scale.'[22] So the world no longer exists, thanks to Watt's patent.

Such hyperbole aside, the adduced reasons for appointing the steam engine as the executioner of epochs are not always very convincing. The small rise in the concentration of CO_2 that can be detected in polar ice from the late eighteenth century remained well within the natural variability of the Holocene; it cannot possibly have been caused by a simultaneously issued patent; by that time, the emissions from deforestation were still larger than those from fossil fuels. The rationale for placing the coming of steam on par with an asteroid impact or the end of a glacial period must be *qualitative,* along the lines sketched above: steam heralded a new union between growth and fossil fuels, or, 'the energy-society feedback loop went into overdrive,' in the words of climate best seller *The Burning Question*.[23] None of this can be a matter of invention. A patent is but a piece of paper, however symbolic; not Watt, but manufacturers who chose to *adopt* his engine issued in business-as-usual.

What, then, do theorists of the Anthropocene have to say about the actual causes of the rise of steam? Not much. But they do propound a general framework for understanding the historical causality behind the transition to fossil fuels, which, for reasons of logical necessity, they deduce from human nature. If the dynamics were of a more contingent character, the narrative of an entire species – the *anthropos* as such – ascending to biospheric supremacy would be difficult to uphold: 'the geology of mankind' must have its roots in the properties of that being. Anything less would make it a geology of some smaller entity, perhaps some subset of *Homo sapiens*. The answer to the historical questions is therefore a story told around a classical element: fire. The human species alone can manipulate fire.

In 'Carbon and the Anthropocene,' prominent climate scientists Michael R. Raupach and Josep G. Canadell observe that life on earth has 'created vast stores of detrital carbon – the remnants of carbon-based organisms after they have died'. Fossil fuels fall into this basic

category, as do dead vegetation and the bodies of killed animals. Now, around half a million years ago, the ancestors of humankind began systematically to *burn* such detrital carbon, as they learned to master the element of fire, igniting, spreading and putting it out at will. This unique capability accorded advantages to the human lineage, allowing it to tap into exosomatic energy like no other creature on earth. Here was 'the essential evolutionary trigger for the Anthropocene'. It drove humanity straight to

> the discovery that energy could be derived not only from detrital biotic carbon but also from detrital fossil carbon, at first from coal. This much more concentrated energy source catalysed developments in technology, *which led eventually to the technological explosion of [the] industrial era* and thence to the Anthropocene as usually defined. In the Anthropocene, the human species has come to dominate the planet … Exosomatic energy was, and still is, an *essential catalyst* for this development, and *the primary reason* for its availability is that, long before the industrial era, a particular primate species learned how to tap the energy reserves stored in detrital carbon.[24]

It is worth pausing to consider what is being said here. It is not that the Anthropocene began long before the Industrial Revolution; Raupach and Canadell stick to the Crutzen chronology. Rather, they claim that the 'essential catalyst' and 'primary reason' for the large-scale combustion of fossil fuels as it spread in the industrial era are in fact the mastering of fire by a particular primate species some half a million years ago. My learning to walk at the age of one is the reason for me dancing salsa today: the same with humanity burning first a tree and then, 500,000 years later, a barrel of oil. Indeed, in the eyes of Raupach and Canadell, the line runs straight from the original mastery of fire to the surge in CO_2 emissions from China in the early twenty-first century. The very existence of 'detrital fossil carbon,' combined with humanity's primordial knowledge of how to burn the biotic variant, *led* to the technological explosion of the industrial era, from which the rest followed as a matter of course. Whatever we may think of the substance of these claims, it is important to note, again, that their logical structure is indispensible for the maintenance of the Anthropocene narrative: some universal trait of the species must have blazed the trail to the geological epoch that is its own.

For literary theorist Karen Pinkus, the present is indistinguishable from the very distant past. Not much new has happened for nearly a million years. 'The present' – the one now called the Anthropocene – 'begins around 992,000 years ago as *Homo erectus* rises' and sets a fire alight, a first step leading straight to the second, in the sixteenth century, when British wood becomes scarce and coal is adopted as a fuel, followed by the conclusive invention of 1784.[25] Geographer Nigel Clark goes even further. He avers that climate change 'is primarily the result of an escalating human capacity for combustion,' traced back to *Homo erectus*'s handling of fire on the African savannah 1.6 million years ago – standard Anthropocene talk, but then he proceeds to ask: '*What kind of planet is this that births a creature capable of doing such things?*'

The pyromaniac inclination inheres in the earth itself. A store of fireworks circulating around the sun, the planet possesses an atmosphere rich in oxygen, flammable fuels and plenty of materials for ignition; as long as the earth has existed, its surface has been burning. Wherever there is vegetation, a wildfire sooner or later breaks out. Humans have done nothing more than articulate this geological DNA, augmenting 'the planet's own pyrophytic tendencies,' accelerating 'a combustive imperative that defines the earth itself' of which 'the recent propensity to tap into sedimented and fossilised biomass is the latest'. Here the concept of the Anthropocene is pressed towards its outer limits. Human agency is now the medium through which the planet realises its latent destructivity, the combustion of coal and oil a sort of telluric

ventriloquism or delegated pyromania. In Clark, the earth qua celestial body is the active incendiary: it has invested in fire, 'wagered on fire' – it has been 'perverse enough to produce a fire creature' known as man.[26] On this view, the ultimate cause of climate change in the Anthropocene, implemented through the steam engine and all the other technologies, is not a distant event in the evolution of the human species, but *the genesis of planet Earth itself some 4 billion years ago,* from whose combustible rocks an arsonist son has arisen.

But Clark is on the fringe of Anthropocene theory. It is more common to draw the line of causation back to early human evolution but no further; to ruminate over the late fossil feats of 'the fire-ape, *Homo pyrophilis*,' as in former environmental activist Mark Lynas's popularisation of Anthropocene thinking, aptly titled *The God Species: How the Planet Can Survive the Age of Humans*.[27] At other times, familiar Malthusian themes are mobilised to explain the turn to fossil fuels. The original contribution and telltale trope of Anthropocene theory – or perhaps we shall lend it the more humble status of a narrative – is neither fire nor scarcity, however, but precisely the belief in the *human species* as the source of steam power, fossil fuel combustion, climate change and related biospheric afflictions: there is constant talk of something called 'the human enterprise' as the force now colliding with the rest of nature. What exactly this enterprise consists of is never specified, but we are led to understand that it represents a species on the move, acting out predispositions present since the early days of the hominids.[28]

Debate continues to rage over the details of the Anthropocene: some advocate a far earlier date of birth for the epoch, but the Industrial Revolution still enjoys near consensus. Since 2008, and with another few years of negotiations expected before a verdict, the Stratigraphy Commission of the Geological Society of London is considering the formal announcement of Anthropocene as the current epoch. A few dissidents allege that the concept belongs to 'pop culture' rather than rigorous stratigraphic practice, and indeed, it has undergone a most spectacular career since Crutzen's 2002 paper, spreading far beyond the ivory tower, embraced by everyone from *The Economist* to Marxist scholars.[29] Whether or not the Anthropocene is officially declared successor to the Holocene, it has already suffused discourses around global warming and other facets of environmental change; if only by virtue of this influence, it has become a reality to reckon with. At a closer look, it may also be a part of the problem.

Steam as Superior Machine

'The hand-mill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist.' Thus runs what is undoubtedly the most famous statement by Karl Marx featuring steam. It appears in *The Poverty of Philosophy,* Marx's assault on the ideas of Pierre-Joseph Proudhon, in the context of an attempt to explain not the rise of steam power, but social change in general and the development of capitalist relations of production in particular. In his maxim, Marx spells out an unequivocal and, within the wider Marxist tradition, highly influential hypothesis on the arrow of causation in an industrialising economy such as Britain's: steam begets capital – not the other way around.

More precisely, steam engenders the division and organisation of labour we recognise as typically capitalist: 'Labour is organized, is divided differently according to the instruments it disposes over. The hand-mill presupposes a different division of labour from the steam-mill.' Some script enclosed within the technology of steam power dictates a certain cast of capitalists and workers, foremen and assistants and other roles to be occupied inside the factory and spilling

out into society at large. Reversing the terms – putting relations before machinery in the causal sequence – would be tantamount to 'slapping history in the face'; in *The Poverty,* no doubt is left on the determining instance or direction of progress. 'In acquiring new productive forces men change their mode of production; and in changing their mode of production, in changing the way of earning their living, they change all their social relations.'[30] It is this historical law that is illustrated by the hand-mill/steam-mill aphorism, steam chosen as the emblematic productive force moulding society in its own image.

This version of the Marxist theory of history – there are others, certainly, to be inspected later – is sometimes referred to as 'productive force determinism'; it received its classical exposition in G. A. Cohen's *Karl Marx's Theory of History: A Defence,* where the analytical philosopher grapples with two questions left suspended by Marx and Engels. First, what is it that makes technology develop on its own? Second, how is it that this development comes to determine that of society? Or, in Marxist terminology: what is the motor driving the productive forces forward in history, and via what transmission system do they govern the relations of production? Cohen answers by drawing a picture of 'man' as placed in a hostile environment, a crude, unforgiving nature that never caters to his needs: the 'situation of humanity is one of material scarcity'.[31] To better his lot, man must engage in labour and, more precisely, activate his two unique faculties of intelligence and rationality. He will be intelligent enough to invent a spade that allows him to dig into the crust in shorter time and with less effort than before, and if his brother has the choice to pick up that newly invented spade, he will be rational enough to do it. Scarcity provides the abiding incentive to invention; intelligence fashions smart solutions; rationality ensures their adoption; ever looking for novel ways to prevail against nature, men perpetually boost their productive forces, and this 'growth of human power is the central process of history. The need for that growth explains why there *is* history.'[32]

Along the way, knowledge arises. 'The development of the productive forces is very largely the growth in knowledge of how to control and transform nature,' Cohen writes, going on to quote Marx: "'The handmill gives you society with the feudal lord, the steam mill society with the industrial capitalist"' – a steam-powered generation of the capitalist which, at bottom, results from advancing knowledge. The raison d'être of the engine is its technological superiority: it gives men new abilities to combat shortage, be more efficient, extract resources from nature at a higher rate. Steam is there because it represents progress. Indeed, knowledge of the engine is a sufficient condition for its deployment; to suggest otherwise would be to 'offend human rationality'. Given how humans are constituted – intelligent and rational – they will avail themselves of any known technology that facilitates their struggle against parsimonious nature; the productive forces are knowledge made concrete, and as such they will prevail.

But how would something like a steam engine come to arrange the internal affairs of men? Befitting a philosopher, Cohen answers with a thought experiment, centred on a device for producing mechanical energy: a treadmill. Although he choses neither a hand mill nor a steam mill, he likely has the aphorism in mind when constructing his story; indeed, it can be read as an explication of what Marx meant to say. 'Imagine,' Cohen begins, 'a productively weak society whose members live in equality at subsistence level, and who wish they were better off.' This is the original situation of scarcity. Now, 'one of them suspects that the introduction of treadmills on the bank of the river on which they rely for irrigation would increase the flow of water onto the land, raise its yield, and thus enhance their welfare.' This is the moment of human intelligence. 'He puts his idea *to the community, who are impressed,* and a group is forthwith

commissioned to design and construct the devices.' This is the hour of rationality – and, apparently, of community-wide decision making, a sort of democratic deliberation over whether or not to introduce the invention.

Then the treadmills are 'installed at suitable points on the river bank, and tested, all members of the community participating in the test'. Wise as they are, they correctly appreciate the benefits of the machines, and a call goes out for volunteers to man them. But now the troubles begin. No one steps forward. Treading is odious work; everyone detests the mere thought of it; instead, it is agreed to select unfortunate drudges by lot. But soon it becomes apparent that the rebarbative job will not be executed without supervision. From this moment – laid down by the technological requirements of the treadmill – 'gradually a class structure (supervisors, farmers, treaders) rises in what was an egalitarian community'.[33] The history of class relations has dawned.

So, by dint of their physical constitution inserted into the lives of men, the productive forces bring forth new relations of production, intervening in society and selecting the organisation they need to develop fully. How would this theory apply to the steam engine? Cohen does not investigate it – he investigates *no* actual cases – but it is fairly obvious how a basic story line in compliance with his laws would read: before the engine, men were afflicted by a scarcity of energy. One man was intelligent enough to invent it. Being rational, his fellow members of the community immediately saw the value of the knowledge, losing no time in the struggle against scarcity; the steam engine was promptly installed. Because of the technical requirements of the apparatus, the roles were opened for the industrial capitalist, the overlooker and the factory operative to own, supervise and serve the engine, output steadily on the rise.[34]

And such is indeed the storyline that has dominated much of the historiography of the Industrial Revolution and the rise of steam power in particular; outside of Marxism, in the bourgeois mainstream, it is better known as technological determinism or simply 'technicism'. In *Capital and Steam-Power 1750–1800,* written in the mid-1960s, John Lord depicts the ascent of steam as the climbing of a scientific ladder leading from primitive prototypes in the mines to consummated designs in the mills. By inventing the rotative engine, Watt

> completed the breach between employer and employed – they were separated completely. A capitalist class had been evolved, and admission to its ranks could only be obtained by accident. The progress of apprentice to master was the exception instead of the rule, and the line of cleavage that has troubled the world ever since had been drawn.[35]

The Marxist version belongs to a wider crop of technological determinism, with two distinctive beliefs.[36] First, some superiority intrinsic to the very makeup of novel technologies ensures their diffusion. Second, that same makeup brings forth a corresponding set of social roles. Applied to the rise of steam, the rotative engine would have outmatched alternative prime movers due to better performance, higher efficiency or some similar technical property – much as Cohen's treadmill raised the yield – and then summoned capitalists and workers to enter their special relationship. The theory is fully compatible and indeed overlaps with the Ricardian-Malthusian paradigm and the Anthropocene narrative; all advance some doctrine of a 'human enterprise'. The question of steam may serve as a litmus test for all three. How might it be conducted?

The Ricardian-Malthusian paradigm and productive force determinism both result in fairly straightforward hypotheses on the causes of the rise of steam. If it turned out that the transition

occurred despite the energy of the alternative prime mover remaining *abundant* and *cheaper* – if it exhibited neither scarcity nor a rise in the relative price – then the Ricardian-Malthusian hypothesis would hang by a thread. If the productive force contending with the steam engine retained considerable potential for technological prowess unrealised at the time of the transition, or if steam triumphed even without a distinct edge in neutral, instrumental terms of performance or efficiency, the hypothesis of productive force (and technological) determinism would be in trouble. It would suffer an even harder blow if the relations of production – particularly those between capital and labour – enforced the selection of steam power and not vice versa. The causal claims of the Anthropocene narrative, on the other hand, are of a more conceptual, philosophical, perhaps even metaphysical nature; we shall reflect upon them as such later. But if some humans introduced steam power *against the explicit resistance of other humans,* then it would be hard to maintain a notion of it as the expression of a species-wide project. The data will have to decide the matter. If they contradict the three theoretical frameworks, we would need to construct another explanation for the rise of steam and, more broadly, another theory of the fossil economy. A point of departure might then be the hypothesis – if supported by the data – that steam arose as a form of power exercised by some people against others.

CHAPTER 3

The Long Life of the Flow: Industrial Energy Before Coal

Flow, Animate Power, Stock

The term 'prime mover' has a strangely dual import. In any dictionary or encyclopaedia, two definitions rub elbows: there is, first, the metaphysical prime mover, the original and unmoved impulse, the 'self-caused agent that is the cause of all things' – God being the common referent – or, otherwise put, 'the self-moved being that is the source of all motion'. This phenomenon is distinguished precisely by not requiring any external input. God runs on no fuel. But then, secondly, there is the mechanical prime mover, which, according to Webster's 1989 edition, is also an 'initial agent' but of a very different kind: it is 'a machine, as a water wheel or steam engine, which receives and modifies energy as supplied by some natural source'.[1] In this more earthly sense, the prime mover is anything but self-moved. Rather, it is utterly dependent on 'some natural source' – a fuel – without which it will set neither itself nor any other entity in motion.

In early nineteenth-century Britain, the term had descended from the skies and conclusively taken on its second meaning in mills and workshops across the kingdom. In his *Treatise on the Steam-Engine* from 1827, John Farey noticed the inversion of the metaphysical definition: 'Here it should be remarked, that the first mover does not actually produce the force with which it operates, but is adapted to collect and concentrate the force which arises from some natural cause, so as to derive the motion from that cause.'[2] The first act of the manufacturer, the mechanic or the millwright was to locate and appropriate a suitable force *already existing* in nature, the task of the prime mover being merely to harvest that force and pass it on to other bodies.

A range of prime movers existed from which to choose. The main options were windmills, waterwheels, horse gins, human beings and steam engines, all falling under the prosaic definition: a prime mover is a mechanism for generating mechanical power out of an energy source and putting other mechanisms in motion. We may thus group the prime movers into categories according to their *sources of energy*. Under what rubrics? The terms 'carbon-neutral' and 'carbon-intensive' point to properties of energy sources that are of great interest to us and probably even more to future generations, but not to the manufacturers of the time. Writers of the early nineteenth century were indeed aware of the high carbon content of coal, but this was not a factor in decisions on what source to use; the same goes for the dichotomy 'renewable' versus

'nonrenewable'.

Other couplets fail on different counts. As we have seen, E. A. Wrigley has proposed a distinction between an 'organic' economy based on the products of photosynthesis and an 'inorganic' one dependent on fossil fuels. But the terms are unfortunate. No matter how long it has been underground, coal is a substance of organic nature (which is why its combustion releases carbon); wind and water are not. A manufacturer turning from a waterwheel to a steam engine would thus have shifted from an inorganic to an organic energy source, moving in a historical direction opposite to the one Wrigley has in mind. It does not seem any better to label the inorganic economy 'mineral,' as this would apply to Iron Age and Bronze Age economies alike; equally invalid is the distinction between 'animate' and 'inanimate' sources, since water, wind and coal are all inanimate. We need better concepts to unlock the dynamics of the historical transition and pinpoint the properties that *actually mattered* to its agents. The sun might be a suitable starting point. All prime movers available to British manufacturers around the turn of the century derived their power from energy sources that were, ultimately, of solar provenance. But if all sources originated in the sun's thermonuclear reactions, they stood at varying distances from that stellar home, located at different points in space and time on earth. Each had a set of distinctive qualities, a logic of its own, or what we shall refer to as a *spatiotemporal profile*. There were three basic categories.

The flow of energy. Some sources of energy originating in the sun flowed through the biosphere, uncaptured by photosynthesis, accessible for direct collection and concentration by prime movers designed for the purpose. We shall call this category 'the flow'. Wind and water both belonged to it. Manufacturers encountered them as practically immediate transformations of solar radiation, to be caught for an instant as they passed by: a windmill tapped into the power of the blowing winds, a waterwheel into the force of running water. As soon as these fuels had been harvested, they slipped away from the prime movers and continued on their course. No special human labour was required to bring them forth: they were already present in motion.

The flow, however, was determined by particular conditions in space and time. Supplies were, to begin with, functions of the attributes of the landscape: they could be found in certain locations but not in others, and they had to be used on the spot, electrical transmission still lying far in the future. The wind would not blow in a crevice or at the bottom of a deep valley, but more probably on flat coastal land or at the top of a hill; to be captured by a wheel, the water had to run through a stream, by definition a specific, non-ubiquitous feature of any terrain. The flow was subject to the temporal fluctuations in the weather. One day the wind might be still, the next day a thunderous storm could blow in; water could freeze, dry out, overflow or run at the average height of the stream, all depending on the season of the year and the weather of the day or even hour. In short, the flow was conditioned *in space* by its circulation through the landscape and *in time* by its integration in weather cycles. Yet another of its characteristics was well rendered by Babbage:

> Of those machines by which we produce power, it may be observed, that although they are to us immense acquisitions, yet in regard to two of the sources of this power – the force of wind and of water – we merely make use of bodies in a state of motion by nature; we change the directions of their movement in order to render them subservient to our purposes, but we neither add to nor diminish the quantity of motion in existence.[3]

The flow was in no way exhausted or sapped through use in manufacturing. A windmill or a

waterwheel caused no reduction in the supplies of either fuel: barring some fundamental change in climate or restructuring of the landscape, wind and water were bound to return in full force no matter how many factories they impelled.

Here was the profile of the flow, founded on its appearance in space and time: a practically immediate result of solar radiation, existing prior to or apart from photosynthesis, independent of human labour, incorporated in the landscape, captive of the cycles of weather and seasons, undiminished at its source by consumption. Other energy sources than wind and water obviously would have fulfilled the same criteria; solar energy proper, wave power and tidal power spring to mind. In nineteenth-century Britain, there was some knowledge of the power that could be harnessed directly from the sun's rays, but it never materialised as a prime mover of potential application in the mills. Tidal power had a long pedigree, but was not a serious option for the industry.[4] Wave power required the technological breakthroughs of a different era. Thus we shall reserve, in our historical inquiry, the concept of 'the flow' for wind and water, while keeping a window open for its extension at a later date.

Animate power. Some sources of energy were embodied in living creatures, as the power of muscles to put things in motion. We shall call this category 'animate power'. It comprised animals and human beings. As heterotrophs, both were at least one step removed from solar radiation, relying on autotrophs to produce complex organic compounds through photosynthesis. Still, the time span separating the incoming radiation from the appearance of animals and human beings was relatively short: the food of which their bodies were built might have taken months or, as in the case of beef cattle, years to mature into edible nourishment, but scarcely much longer; the rays were, so to speak, still fresh in their tissues.[5]

Animate power was conditioned by the imperatives of *metabolism*. Both animal and human bodies required a regular intake of nutrients to energise their activity, sleep to recover strength and preferably some amount of rest or leisure for the same purpose. While the temporality of the flow was contingent upon that of the weather, that of animate power was subordinated to metabolic exigencies: bodies could be made to drive machines in wet weather as well as in dry, but not for several consecutive days and nights, without any intake of food, as more than a rare exception to the rules of management. Animals and humans did not have to be used on the spot of their first appearance. Mobile within the landscape, they could be moved from their habitations and concentrated in selected spots, but a diminution of their potential energy might ensue: circumscribed by their metabolism, they would be taxed by any labour and exhausted, overworked or even worse by heavy slog. Lastly, both animals and human beings were, to varying degrees, endowed with their own *will,* a faculty absent in wind and water, which might make external labour necessary to mobilise the potential energies of their muscles. Both could be engaged as sources imparting motion to other devices – a horse gin, a treadmill – or, at least in the case of humans, deployed *directly* as prime movers – feet treadling wheels, arms sending shuttles through warp.[6]

The stock of energy. One source of energy, finally, consisted of relics of solar energy of the very distant past. We shall call this category 'the stock'.[7] In early nineteenth-century Britain, oil was known to be used as a fuel in some faraway places, but coal was the sole part of the stock de facto available to manufacturers. Reserves of the fuel had been generated in some ancient era, and this characteristic property was fully realised when the British cotton industry emerged: coal was long-since labelled a *fossil* fuel. In 1835, John Holland gave it a fairly knowledgeable treatment in his *History and Description of Fossil Fuel, the Collieries, and Coal Trade of Great*

Britain, a combined geological treatise, business history and social report. Coal originated, Holland made clear, through a process 'in which the *remains of living bodies are successively accumulated, in an order not less fixed than that of the rocks which contain them*'.[8] Today, we know that plant matter once sank into bogs, turned into peat and then, submitting to the workings of heat and pressure, gradually lost its water content and solidified into coal. Ninety percent of the world's reserves stem from the namesake Carboniferous, some 360 to 286 million years ago, when the rate of coal burial reached a level 600 times higher than the average for the other 98 percent of the history of the Earth, thanks to some exceptionally favourable conditions: wet climate, vast flood plains, large woody plants colonising upland areas as well as swamps and seashores, leaving an abundance of material for coalification.[9]

It was this legacy that entrepreneurs in late eighteenth- and early nineteenth-century Britain encountered, as a source of energy resting *outside of the landscape*. Coal deposits were exterior to the terrestrial surface seen, visited and occupied by human beings, concealed in a subterranean world into which few people would venture unless to dig up the fuel.[10] The entry point would appear on the horizon as bell pits for shallow mines, adits in the hillsides or pit mouths with pumps, wagons, shovels and other equipment, but the *energy source itself* remained disjointed from the landscape. Brought into it as passive and detached bits and pieces, it could be freely transported and stored in a way that applied neither to water or wind, nor to animals or human beings: the separation of coal from the landscape entailed a unique mobility and storability within it. But considerable amounts of human labour were a prerequisite. Wind and water showed up of their own accord; coal had to be cut, hauled and wound to the surface.

As for the dimension of time, the stock occupied a similar position. It appeared to be standing *outside of time*. Neither weather fluctuations nor metabolic imperatives influenced the temporality of the stock; cut off from diurnal, seasonal, historical, even civilisational time, deposits of coal were independent of anything that occurred on timescales perceptible to the denizens of Britain. Instead, coal was the heritage of *past* climate, *past* metabolism, *past* topographies, all gone forever. It followed, moreover, that coal was never 'in a state of motion by nature,' to borrow from Babbage again: no one ever got touched, crushed, blown down or carried away by a piece of coal moving on its own. Frozen in space and time, the highly concentrated energy potential of the stock had to undergo a chemically and technologically intricate process of transformation into mechanical energy: the raison d'être of the steam engine. Any prime mover of the flow or animate power merely had to relay motion to machines; the steam engine had to conjure it up from the start. This implied, furthermore, that coal was utterly destroyed through consumption – an inherent aspect of its usage, absent in all of the alternatives. By setting coal on fire, humans simultaneously released its capacity for putting objects in motion *and* wasted it, discharging the transient powers of the black stone *and* turning it into smoke and ash. The sole way to convert coal into motion was to consume it, literally.

The Rise of the Water Mill

The early spinning machines were exclusively based on animate power and flow. Hargreaves's jenny, Arkwright's water frame, Crompton's mule were all originally designed to be impelled by humans or horses; with the exception of the jenny, they were soon connected to waterwheels on a much grander scale. None was developed for a prime mover of the stock.[11] The great burst of innovation in the field of cotton spinning, which marked out the second half of the eighteenth

century and provided an essential foundation for the Industrial Revolution, surged forward on the backs of energy sources close to incoming solar radiation, with a sparkling presence in time and space, unfossilised and in motion. Meanwhile, in the weaving sector, labour still continued as it had done since time immemorial, on handlooms inside homes, with human bodies as the sole prime movers.

In spinning, horses were vital for getting the inventions and mills running. Requiring no riverbed, windy field or any other unchanging feature of the landscape, the horses could be stationed anywhere and their numbers varied according to the needs of the manufacturer, from a single beast to a dozen working side by side; horse gins were cheap to install. These merits – mobility, flexibility, inexpensiveness – made them useful acquisitions for beginners in the cotton industry.[12] But there were narrow limits to their achievements. Quickly exhausted, their speed slackened as the burden of machines grew; as a rule, horses could not work with decent efficiency for more than eight hours, and while that sounds like the length of a modern working day, the nascent cotton industry craved far more. A second relay would have to replace the first: metabolic imperatives limited the force in time. In space, horses were collectible but bulky; as with all draught animals (and human beings) only a certain number could be crammed into a gin or meaningfully grouped around any other object to be pulled or turned. With heads of their own, the beasts were not always reliable as faithful servants, and the harder they were driven, the more often they had to be replaced – and the higher the cost of fodder. As Britain plunged into the Napoleonic Wars in the 1790s, feed prices began to climb, provisioning weighing down heavily on horse-powered businesses.[13] Literal horsepower was a passing moment. Over the 1790s, the temporality and spatiality of the animals came to act as a fetter on the long working days and novel machinery of the booming cotton industry: a different prime mover would have to come to the fore.

Wind power was, at least theoretically, a conceivable option. Around the year 1800, some 5,000 windmills operated on days when the wind blew in England, most of them located in southern and eastern counties where they were used for grinding corn, draining ground and sawing timber, 'numerous windmills spreading their sails to catch the breeze'.[14] The installation was cheap. It was not quite as strictly tied to a singular spot in the landscape as a waterwheel: wind blew *over* the landscape, not in a bed or furrow. But there was one salient drawback, which all but excluded wind power from serious consideration in the cotton industry. 'The use of this species of mechanical force,' wrote Charles F. Partington in his 1826 steam engine manual, 'is however principally limited to the grinding of corn, the pressing of seed and other simple manipulations; the great irregularity of this element precluding its application to those processes which require a continued motion.'[15] Wind never played a noticeable role in the cotton mills.[16] Instead, it was another ancient energy source on whose wings the industry learned to fly: water.

Known since before Christ, the principle of the waterwheel was simplicity itself: a circular structure with floats or buckets arranged so as to intercept the water running from higher to lower ground, thereby capturing some of the energy produced naturally in the process.[17] Britain was lavishly endowed with the fuel. Rolling in from the North Atlantic, rainfall regularly soaked two regions – Scotland and northern England – which also happened to share a Pleistocene legacy of abundant rivers, cut out by meltwater from glacial lakes. The rivers mostly ran throughout the year, rarely silted up and maintained modest sizes on their way through hilly country. Such conditions contrasted starkly with other parts of the world, notably India and China, where the giant rivers fluctuated violently with the seasons, suddenly migrating across flat plains and

carrying heavy cargos of silt.[18] Lancashire was especially favoured among the English counties: the Pennine Mountains forced the incoming clouds to release intense precipitation, collected it in catchment basins in the upper hills and distributed the water across the region through numerous brooks, rivulets and major rivers. Scotland was even more profusely blessed.

It was on this pillar that Richard Arkwright built his empire of factories, starting at Cromford, a tiny village in the rural backwaters of Derbyshire with one outstanding attraction: 'a remarkable fine Stream of Water,' in Arkwright's own words.[19] The stream – a tributary to the river Derwent – was reputed not to freeze in winter. Opened in 1772, the prototype Cromford mill employed some 300 people; five years later, a neighbouring mill was erected and output doubled; by the end of the 1780s, the total workforce at the complex amounted to around 1,150, and expansion continued. By the early nineteenth century, Cromford was considered the inauguration of a new era, and the perception still holds. The creation of the factory system detonated a novel form of capital accumulation, spreading in no small part thanks to Arkwright's own galloping investments: the first spinning mill in Manchester in 1780, two more in Derbyshire, one in Staffordshire, two in Scotland, yet another plant in Cromford, all powered by water. 'Wealth flowed in upon him with a full stream from his skilfully managed concerns,' in the words of Edward Baines, author of the 1835 *History of the Cotton Manufacture in Great Britain*. The founder of the modern factory achieved rates of profit above the 50 percent mark, and at the time of his death in 1792, an obituary asserted that 'he has died immensely rich,' leaving behind factories 'the income of which is greater than that of most German principalities … Sir Richard, we are informed, with the qualities necessary for the accumulation of wealth, possessed, in an eminent degree, the art of keeping it.'[20]

Cotton spinning as a venue for the accumulation and keeping of such colossal wealth naturally aroused the interest of other men with access to capital. In *The Water-Spinners,* an enormous catalogue of Arkwright's followers, historian Chris Aspin details how they chased, and often attained, the wealth Sir Richard had dangled before them, quoting by way of illustration two lines from a poem by a Yorkshire manufacturer composed in 1789: 'O! Money! Money! I too plainly see / That in good earnest I'm in love with thee.' 'Capital,' Baines wrote, 'rushed to this manufacture in a torrent, attracted by the unequalled profits which it yielded.'[21] The boom spread across Britain, as avid entrepreneurs invaded the damp valleys of Derbyshire, Nottinghamshire, Wales and above all Lancashire, where the local newspapers filled up with advertisements of ideal sites. A visitor passing through the southeastern parts of the county in 1792 noted in his diary that 'every vale swarms with cotton-mills, some not bigger than cottages – for any little stream, by means of a reservoir, will supply them.'[22] In 1788, there were an estimated 200 water mills built on the Arkwright principles – a tenfold increase over eight years – of which nearly a quarter were found in Lancashire; by the turn of the century, at least a thousand were scattered over several English counties. But it was Scotland that emerged as the second heartland of cotton, only one step behind Lancashire. In 1793, the *Statistical Account of Scotland* reported from Glasgow that 'cotton-mills, bleachfields, and printfields, have been erected on almost all the streams in the neighbourhood, affording water sufficient to move machinery, besides many erected at a very considerable distance.'[23] Particularly favourable sites were found at the boundaries of the Highlands, where the steep gradients of the rivers entered lowland terrain, the streams often meandering around peninsulas where uncommonly large mills could be built to send biting competition southwards.

The rise of the water mill affected, in the eyes of contemporaries, a stunning break with past

routine. In the bombastic style of Andrew Ure, Cromford and its spawn marked the end of an era when 'manufactures were everywhere feeble and fluctuating in their development, shooting forth luxuriantly for a season, and again withering almost to the roots, like annual plants. Their perennial growth now began in England, and attracted capital in copious streams to irrigate the rich domains of industry.'[24] That heroic narrative has taken a severe battering from the gradualist tendency of recent revisionist research – or so it seems. Work by economic historian Nicholas Crafts has undermined the traditional view of the 1780s as the revolutionary decade when the factory system hit Britain like a bolt from the blue and ignited modern growth, with its hallmark of high levels sustained for year upon year. Total growth in real output of commodities did not reach above 2 percent until the early 1820s, its emergence being a much more 'gradual' – a keyword of Crafts's – affair then previously thought. But that figure is an *aggregate*. If the British economy remained a slow-growing, almost flat lawn until the second quarter of the nineteenth century, a flagpole had shot up from its ground much earlier. 'There is a large dispersion in sectoral growth rates, especially in 1770–1811,' Crafts observes: 'Cotton is seen to be an exceptionally fast growing sector.' Zooming in on this industry, Crafts could not fail to discern a spectacular spurt in the 1780s, when real output leapt forwards by an average of 12.76 percent per year – doubling the rate of the 1770s – compared to 0.95 for leather, 0.54 for wool, 3.79 for iron, 2.36 for coal, all dropping from slightly higher levels in the previous decade. 'There is a more gradual "average" advance to set beside the explosive acceleration in the cotton textiles industry,' particularly in the line of spinning, for which all the talk of revolution remains justified.[25] Seen from this perspective, the effect of Crafts's revisionism is rather a defoliation of the Industrial Revolution, tearing away the leaves of other sectors and laying bare the trunk of cotton.[26]

The sharp upturn in cotton around the year 1780 stemmed from the takeover of an existing market – for clothing, one of the most basic human needs – by the type of mill first developed by Richard Arkwright. With waterpowered machines, cotton was spun in a fraction of the time demanded by the spinning wheel, the jenny, the frame, the mule raising productivity by several orders of magnitude. Avant-garde entrepreneurs who installed state-of-the-art technology could overrun whole segments of the market by fixing their prices safely below old-fashioned competitors *and* above their own costs of production – while the falling prices ensured widening demand for the products – thereby realising superprofits of the archetypal kind. This was the trail that Arkwright blazed. It had no equivalent in any other line of industry; beyond the walls of the cotton mills, traditional technologies remained preponderant, leaving half of all productivity gains in manufacturing before 1830 to this single branch alone. 'The rapid increase of the cotton trade appears to have been owing, in a great measure, to the more liberal introduction of machinery into every part of it, than into any other of our staple manufactures,' stated *Rees' Cyclopædia* – more generally, 'it is to this source we must look for *the increase of property* of every description'.[28]

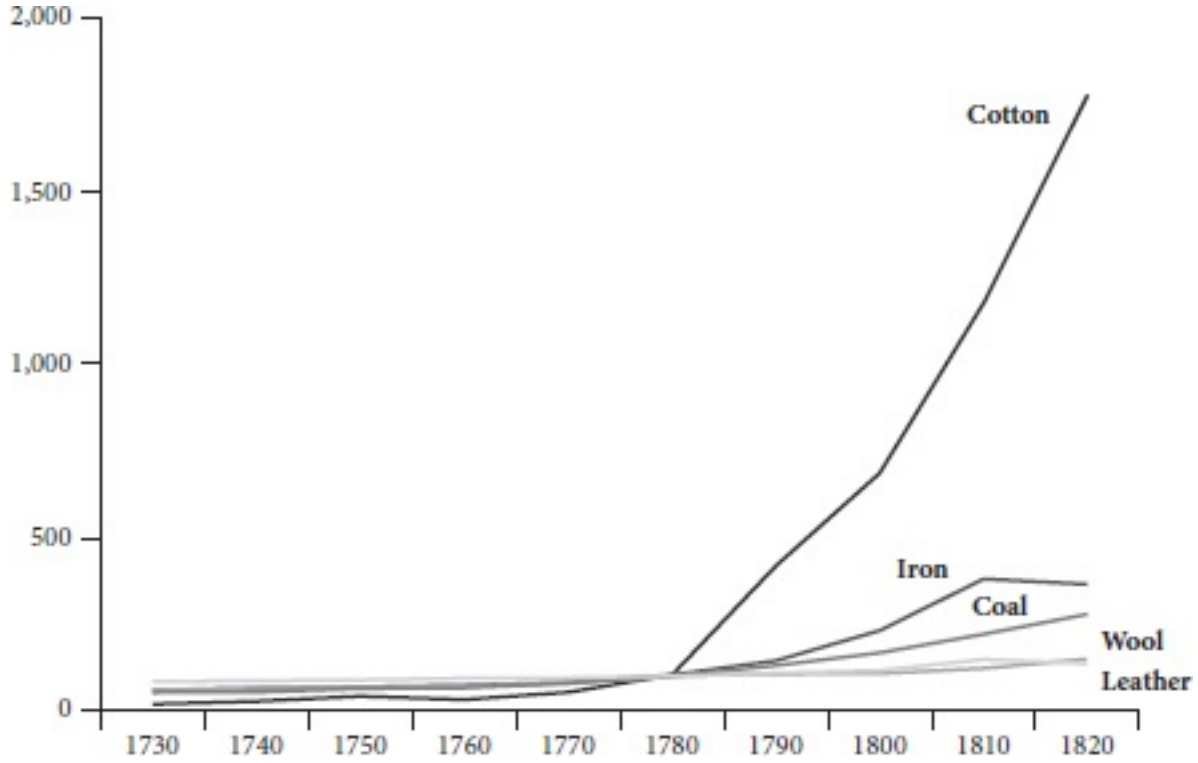

Figure 3.1. The cotton explosion. Growth in index numbers of real production for five British manufacturing sectors, 1730–1820. 1780 = 100.[27]

And property surely increased. Rates of profit in the vicinity of 30 to 50 percent were nothing unusual in the first two or three decades after Cromford. Luring newcomers to the business, they also provided the crucial medium for further extensions: profits were *ploughed back* into the mills, reinvested in greater productive capacity, new and improved machines, more powerful waterwheels. A novel logic of self-fuelling expansion was implanted into the British economy, or, in the words of Crafts's colleague Nick Harley: 'Cotton with its new technology and organisation originated a process of "development" with *qualitative changes* not present' in the surroundings, namely: ceaseless improvements in productivity, high rates of profit, reinvestment of profits and thereby – output multiplying – *continuous accumulation of industrial capital*.[29] Self-sustaining growth had arrived. It took another half a century or so before it seized hold of the British economy in its entirety – this is the gist of the revisionist findings – but in one industry, a previously unknown momentum spiralled forth from the 1780s onwards. It derived its pulsating energy from the flow. The factory system, from which commodities were churned out in unprecedented quantities, arose on the basis of water.[30] Coal stood outside the whirlpool. The two partners of the fossil economy – self-sustaining growth, energy from the stock – had yet to be united.

The Proto-fossil Economy

Before it was burnt to heat up lodgings or food, coal was used in cremation rites, or so the archaeological record seems to indicate. In the earliest proven use of the fuel on the British Isles, coal served to generate crematory heat in Bronze Age South Wales; mystical qualities were

probably attributed to it. But only with the arrival of the Romans did coal consumption acquire some regularity. The flammable, heat-generating properties of the black stone were known in Graeco-Roman civilisations, as related by Holland in his *History and Description of Fossil Fuel* in which he quotes Theophrastus, student and successor of Aristotle: 'Those fossil substances, that are called coals, and are broken for use, are earthy; they kindle, however, and burn like wood coals'; in some places, Theophrastus continued, they 'are used by the smiths'.[31] Upon their occupation of the British Isles, the Romans began to systematically dig, cart and burn coal for a range of purposes: heating military garrisons and homes, working iron in smitheries, processing salt and malt, keeping the perpetual fire alive at the temple of Minerva.[32] Already in the first centuries of the Common Era, the consumption of coal had attained all of its basic pre-steam forms.

Following the departure of the Romans, the deposits were left dormant for seven long centuries. Coal made a first comeback among smiths and cottagers in the thirteenth century, though it was still 'of no greater consequence in the national life than in that of ancient China' – rather less so, as we shall see in a moment – in the assessment of John Nef, the peerless scholar of the early British coal industry.[33] A more definitive takeoff occurred in the late sixteenth century. The years around 1560 marked the onset of a virtual coal fever, all major fields soon undergoing extensive development; over the coming century and a half, national output probably soared more than tenfold. We shall refer to this as 'the Elizabethan leap'. It coincided with the diffusion of coal as a fuel for domestic heating: in his 1577 *Description of England,* William Harrison noticed that the 'greatest trade' of coal 'beginneth to growe from the forge into the kitchen and halle, as may appear already in most cities and townes that lye about the coast'.[34] One single city, however, absorbed the generality of coal for kitchens and halls: London. There was no market comparable to it, no contemporary city in the world even remotely as suffused by a fossil fuel.

In the Elizabethan leap, British coal combustion thus moved to hearths, the fuel injected into a primordial economic activity: the generation of heat for its own sake and for the preparation of food. But industrial consumption advanced concomitantly. Artisan professions accustomed to the black stone since medieval times underwent expansion *and* turned decisively to coal; as smitheries fabricating and repairing everything from horseshoes, scythes and shovels to locks, arms and nails extended their activities, they gradually abandoned charcoal. As early as in 1552, a merchant commented that smiths who bought coal from the northeastern fields 'can lyve no more without [it] than the fysh without water'.[35] Craving vast amounts of fuel to heat their cauldrons, brewers of ale became voracious consumers; manufacturers of saltpetre, soap, starch, tiles and tobacco pipes depended upon a steady delivery of coal; potteries and bakeries, glassworks and lime kilns, salt pans and sugar refineries thrived on the fire. All added their demands to a *longue durée* of growing coal consumption by dint of their need for heat, mostly for boiling liquids. All substituted coal for wood. They used the fuel in the same elemental way as a woman at the time would do to cook dinner, heat her home or wash her children: for the immediate consumption of thermal energy. None did it for power.

How shall we assess these great strides of coal? According to John Hatcher, the only scholar to venture a study approaching Nef's *Rise of the British Coal Industry* in sweep and scope, 'by the opening decades of the seventeenth century substantial parts of Britain were far advanced along the road to dependency on coal'; by the early eighteenth, the entire country 'was on the way to becoming a coal-based economy'. Underlying this assessment is Hatcher's estimate that 'fossil

fuel had eclipsed plant fuels as the leading provider of the nation's heat' – certainly by 1700, and possibly before 1650. Nef hinges a similar analysis upon the watershed of the late sixteenth century; citing numerous contemporary testimonies on the indispensability of coal in the seventeenth, he argues that the fuel had by then become a natural part of British life: 'On more than one occasion Shakespeare gathers his characters about a "seacoal" fire.'[36] So had the fossil economy already appeared?

Before we answer that question, some further considerations are in order. First and most obviously, since coal provided energy exclusively in the form of heat, it had yet to enter into any competition with water, wind, horses or humans as motive forces in manufacturing. In the industries where coal did make headway, the mode of consumption was qualitatively identical to that of Minerva's worshippers, Theophrastus's smiths and indeed the Bronze Age cremators. But it was in the kitchens and halls that coal was used most extensively: before 1700, more than half of all coal produced in Britain was burnt in homes. As Hatcher makes clear, the Elizabethan leap was primarily realised through the substitution of coal for wood in the heating of homes and the cooking of meals; the market for the black stone expanded inasmuch as it became 'a basic subsistence commodity'. This century-long process of replacement – incomplete, of course, but of massive proportions nonetheless – pulled coal consumption to unprecedented heights, at which, however, they then plateaued. The growth potentials of kitchens and halls were naturally restricted, and by the late sixteenth century the constraints were making themselves felt: 'In the absence of new uses for very substantial quantities of coal further rapid growth could only come *from rising population.*'[37] That rise was slow.

But there was another process inflating the domestic demand for coal: urbanisation. The more people lived in towns, the greater the need for a fuel that could be concentrated on the spot. Wood prescribed relatively dispersed patterns of settlement, as villages and towns subsisted on adjacent forests; at a certain point, their further growth would denude the surroundings and extinguish the fuel supply within reach. With coal, conurbations – London foremost among them – could dispense heat to row after row of homes, since the fuel could be hauled up, shipped to the centre and heaped up within it. As urbanisation proceeded apace in the sixteenth and seventeenth centuries and the capital swelled precipitously, demand for coal rose; conversely, the shift to coal made the process possible.[38] This dialectic of urbanisation and coal consumption would produce serious consequences at a much later juncture.

Seventeenth-century Britain, however, did not fully meet the criteria for a fossil economy, as we have defined it. There were no dynamics of self-sustaining growth to which fossil fuels could be wedded; the prime fulcrum of such dynamics – the machine – had yet to appear on any scale; the extensive manufacturing operations that did take place continued to rest on animate power and the flow as sources of mechanical energy. The heating of homes and the cooking of meals have never powered limitless growth, nor have they compelled others to turn to fossil fuels; they were pursued in the quietude of the home, delimited by the number of people living there. A crude arithmetic line might be drawn: as long as more than half of all coal consumption occurs in the domestic sphere, a fossil economy has not yet been born.

But that does not diminish the astounding achievement of the Elizabethan leap, as insisted upon by Hatcher: 'Well before the eighteenth century [coal] had become the leading industrial fuel.' With the important exception of iron making, 'coal was being burnt in all the major industries in which the provision of heat was a significant part of the production process' – and the significance of heat in industry should not be underestimated.[39] The most adequate label for

the kind of economy brought forth by the Elizabethan leap thus seems to be *proto-fossil*. A proto-fossil economy is one that, to borrow from Hatcher, is *on the way* to becoming fossil, has perhaps even advanced far along the road, but is *not yet there*. The transition to a fossil economy proper still lies in the future, and the crossing to the other side is by no means preordained. If we think of a road (the proto-fossil economy) leading among other destinations to a bridge (the transition) which passes over to another realm (the fossil economy), there are several possible outcomes for the travellers: they may turn around before reaching the bridge, stop, crash into the abyss, fall through the bridge or simply switch to a different route.

Something of this kind appears to have happened in the empire of the Northern Song. Coal had been used as a fuel in China since at least the fourth century, but consumption took off for real in the middle of the eleventh, under the auspices of the Song dynasty based in the northeastern part of the Middle Kingdom. The iron industry led the way: ploughs, spades, sickles and other agricultural implements; swords, bows, arrows and other weapons; coins, nails, salt pans and a multitude of other products flowed from the workshops to flourishing markets and a fortified state. Nothing short of an early economic miracle, the industry rested on coal. Over the course of the eleventh century, it shifted from charcoal to coke in furnaces, forges and smitheries, coal replacing wood as a source of heat across the line, from the moment of smelting the ore to final design. Song put latter-day Britain in the shade. By the 1070s, the ironworks of two of the most vibrant industrial regions together burnt an annual quantity of coal equivalent to 70 percent of the total amount used *in all of the British metal industries at the beginning of the eighteenth century*.[40]

Several other Song industries – brick, tile, salt – picked up coal, as did, crucially, the households of Kaifeng, capital of the empire. With a million inhabitants by the end of the eleventh century, the metropolis was twice as large as London *at the end of the seventeenth;* struggling with cold winters, blessed with newly dug pits easily reached by boat – the distance being less than one-third of that from Newcastle to London – the government organised coal markets and goaded the households of Kaifeng to forego traditional wood fuels. By the early twelfth century, 'not a single dwelling burned firewood'. 'The last seventy-five years of the Northern Sung dynasty,' from circa 1050 to 1127, was, in the view of Robert Harwell, the main authority on the subject, 'a period when North China became the center of significant, perhaps revolutionary, changes in the sources of fuel; a time when coal became *the most important source of heat for both industrial and domestic use,'* unparalleled anywhere in the world before the Elizabethan leap at the earliest.[41] And then everything collapsed. The Northern Song gave way to the Southern; the ironworks fell silent; the coal mines closed in a complete reversal of the short-lived efflorescence. In subsequent centuries, coal consumption slowly spread to other parts of China and might even, in the Ming and Qing, have surpassed that of the Northern Song in extent, but it did not move into new fields or break out of the proto-fossil fold.[42]

Juxtaposed to the Northern Song, the Elizabethan leap seems slightly less precocious. In fact, it merely repeated an old exploit from a very distant land: there was nothing qualitatively novel about it from a world-historical viewpoint, and it did not ignite global warming any more than the Song did. The two differed in that the proto-fossil economy of Britain was followed by a critical transition, while that of China was not (until well after commercial and geopolitical interactions with thoroughly fossilised Britain had commenced). Though the prefix *proto* has a teleological connotation difficult to erase, we may therefore employ the term *proto-fossil* with allowance for inconclusive development as part of its very definition. More precisely, a proto-

fossil economy is one in which 1) a coal industry has developed, with underground mines and regular trade; 2) coal has become the major source of heat in the domestic sphere; 3) coal has penetrated industry as a heat provider; 4) domestic consumption is predominant; and 5) impressive rates of growth in coal consumption are achieved during the phases of substitution, without any self-sustaining economic growth being predicated on fossil fuels. All of these five criteria were fulfilled in early modern Britain; in Northern Song, only the fourth is in doubt, due to paucity of data. That should be enough to designate both as proto-fossil economies, but few other examples come to mind – indeed, as the eighteenth century dawned, 'coal output in Britain was many times greater than that in the whole of the rest of the world'.[43] Other advanced industrial economies such as the United States and Germany would only turn from wood to coal as their main sources of domestic heat *after* Britain had completed the transition to a fossil economy and steam engines had been imported to run their mills. Few economies became proto-fossil before they – and the British – went fossil, but the phenomenon was there.

It follows that no serious account of the history of the fossil economy can evade proto-fossil Britain, as the road leading up to the bridge. The shift to coal as the main source of heat in the sixteenth and seventeenth centuries figures prominently in narratives of energy and the Industrial Revolution – particularly in the Ricardian-Malthusian paradigm – and constitutes a touchstone for any analysis of the roots of our current predicament. We shall therefore return to it in a later chapter. We shall revisit some overlooked aspects of Nef's work and, above all, ask what really caused the Elizabethan leap and why it followed such a unique trajectory.

Steam Repelled

Like waterwheels and regular coal use, the principles of steam power appear to have had their origins in Graeco-Roman antiquity. The fundamental insight is not hard to come by: boiling water emits an invisible vapour – steam – possessed with a force that pushes against objects in its way, expands with the heat and creates a vacuum when condensed. From these properties arise the possibility of constructing a prime mover. The many experiments with steam, from the playthings of Hero of Alexandria, Galileo and the Marquis of Worcester via the pumps of Savery and Newcomen to the various patents of Watt – the separate condenser, the double-acting engine, the sun and planet gear – form an endlessly retold bildungsroman, one of the most closely studied and adulated sequences in the annals of Western science; there is no need to retrace it here. In the annus mirabilis 1784, with all the components of a rotative steam engine in place, Watt obtained his fourth and decisive patent. Only adoption and diffusion now remained. To make commercial propositions of his inventions, Watt relied, of course, on his business partner Matthew Boulton, a boundlessly energetic entrepreneur in the Birmingham metal industry who began to court the inventor in the late 1760s, smelling vast profit potentials.

The only technically viable fuel option for the steam engine was coal, a concentrated and dense source of energy against which wood did not stand a chance. Extremely wasteful in its fuel consumption, the Newcomen engine had been tethered to pit mouths where coal was plentiful and could be squandered without loss, but the separate condenser, patented by Watt in 1769, cut consumption to a third and allowed the engine – still only a reciprocating pump – to be used where coal was dear, notably in the tin mines of Cornwall. Early in the 1780s, however, the mining market for Boulton & Watt was drying up. Urging his partner to complete his work, Boulton pointed to another emerging outlet: 'There is no other Cornwall to be found and the

most likely line for consumption of our engines is the application of them to mills which is certainly an extensive field.' Cotton and rotation were the future. Embodying the 'revolutionary capitalist manufacturer,' Boulton had the foresight to identify the factory system cropping up in Cromford as the primary target: in the mills hitherto driven by water lay the real promise. 'The Manchester folks will now erect Cotton-mills enough but want engines to work them,' or, in a more famous formulation, dispatched in June 1781: 'The people in London, Manchester and Birmingham are Steam Mill Mad, and therefore let us be wise and take the advantage' – and again in 1782: 'I think that these mills represent *a field that is endless,* and that will be more permanent than these transient mines.'[44] Once the rotative engine had been finalised, its superiority merely had to be proven to the mill-owners for their purses to open. A model ought to be constructed for them and everyone else to see.

While Watt put the finishing touches on the fourth patent, Boulton conceived the idea of a mill for grinding corn in London as a real-life advertisement and window into the process. Having overcome some scepticism among grinders accustomed to water, he, Watt and their partners in the venture constructed the first plant to be designed for a steam engine on the bank of the Thames near the Blackfriars Bridge. The Albion Mill was inaugurated in 1786 as the most advanced industrial establishment on display in the capital, demonstrating the technical ability of the engine to turn no fewer than ten grinding stones; corn prices on the London market dropped, and curious manufacturers streamed to the mill.[45] Around the same time, the first cotton thread was spun by the new prime mover.

In the year of the fourth patent – supposed birth of the Anthropocene – the brothers Robinson, owners of the giant Papplewick mill and four other cotton factories strung across the river Leen in Nottinghamshire, ordered an engine of the rotative kind from Boulton & Watt. It was delivered and erected in 1786. With a capacity of ten horsepower to supplement the force of the stream, it was the first rotative steam engine ever to power a cotton mill; while they were at it, the Robinsons ordered a second engine for yet another mill under construction. Among the first followers of Arkwright, their cluster of factories on the Leen had by the mid-1780s attained an extraordinary size and level of technical sophistication, and their taste for fresh innovations emboldened them enough to try Boulton & Watt. But the Robinsons accumulated disappointments. Finding their engines intolerably expensive to run, they only used them occasionally when the river was low, and at some point in the early 1790s, they sold their second exemplar. In a complaint that would haunt steam power through – and, in fact, well beyond – the transition, the Robinsons faulted the engines for the excessively high cost of fuel. Coal commanded a price of 11 to 12 shillings a ton in their district, to be measured against the free running water of the Leen. As their experiment with steam unravelled, the Robinsons continued to refine their powerful armoury of water: extensive reservoirs, huge wheels, centrifugal governors, iron rather than wooden gears. Instead of steam, this was the basis – ancient but modernised – they fell back upon. The first trial of the steam engine in the cotton industry ended badly.[46]

By 1790, Boulton & Watt had managed to sell a dozen engines to English cotton manufacturers, five of whom switched from waterpower and three from horses. Yet diffusion would elude them far longer than they had expected. Richard Arkwright, for one, toyed with the idea of installing steam at Cromford, but eventually resolved against it due to the high costs of fuel. He dumped the engine in his factory at Nottingham after a single year of trial; Watt labelled him 'obstinate'.[47] In 1791, a manufacturer at Wellington replied to an offer from Boulton &

Watt: 'The Expense of a small engine as well as the consumption of coal and water being much greater than I apprehended would be required for our work, it seems more advisable to place our machines on a stream of water about a mile from our house.' The 'Steam Mill Mad' manufacturers turned out not to be so mad after all. The two partners admitted that 'Manchester has been backward in adopting our engines,' Watt offering an even more sober assessment: 'I hear that there are so many mills resting on powerful streams in the North of England that the trade must soon be over-done.'[48]

Some inroads were made, however. The two partners McConnel & Kennedy purchased a plot of land in Manchester for a major new factory in 1797, let go of the horses that had hitherto run their mules and invested in a Boulton & Watt engine; within a couple of years, they had secured a position as a leading spinning firm of the Cottonopolis. In some Lancashire cotton towns – notably Oldham and Preston – the manufacturers were relatively eager to embrace the new prime mover, a handful of them vying for leadership in the market on the basis of steam-powered mule spinning.[49] As the century drew to a close, Matthew Boulton's intuition became at least partly vindicated: the cotton industry displaced mining as his largest market by far. Out of a total of 289 engines erected by Boulton & Watt in England between 1775 and 1800, 84 were in cotton mills, representing 29 percent of the total number; collieries were a distant second with 30 sold items. Yet water defended its supremacy in the industry. Eighty-four engines should be compared to around 1,000 waterpowered cotton mills in 1800; in Scotland, roughly 100 mills housed a total of seven engines.[50]

The rapid seizure of the industry Boulton had foreseen never even approached completion within his or his partner's lifetime. Everything but linear or automatic, the transition from water to steam instead took the form of a protracted contest, in which water sometimes seemed to *gain* ground. Arkwright and the Robinsons were far from the only cotton manufacturers to revert to water once they had tried steam in the last decades of the eighteenth century; another high-profile case was that of Robert Owen, who abandoned one of the largest steam-powered mills in Manchester for the waters of New Lanark in 1797. Ironically, Boulton & Watt themselves found it profitable to use waterwheels in their Soho works well into the nineteenth century, as did most of their colleagues in the metal, iron and steel trades of the Midlands.[51]

A widely diffused, long familiar, reliable and cheap prime mover, the waterwheel put up robust resistance. In 1807, John Robison, a professor of national philosophy and longtime friend of Watt, who had once inspired the young inventor's interest in steam, offered a bleak picture for the future of the engine:

> In all mills it is necessary that a considerable power be employed in order to accomplish the intended purpose. Water is the most common power, and indeed the best, as being the most constant and equable; while wind comes sometimes with greater violence, and at others is totally gone. Mills may also be moved by the force of steam, as were the Albion-mills at London; but *the expense of fuel must undoubtedly prevent this mode of constructing mills from ever becoming general*.[52]

By this time, the stage for the fateful marriage between self-sustaining growth and fossil fuel combustion – each with its own independent lineage – appears to have been set. From the early 1790s, the steam engine was widely recognised as a functional prime mover for cotton spinning, answering, in purely technical terms, to the needs of the mill; by the turn of the century, twenty-five Boulton & Watt exemplars had also been exported to other countries – the Netherlands, France, Spain, even Russia – mostly for the purposes of grinding grain and minting coins.[53] Lack

of technical knowledge obviously did not hamper a rapid shift to steam in the British cotton industry. To the contrary, soon after the patent of 1784 it became well known as a serious challenge to the waterwheel, the two prime movers running as if on parallel tracks between which manufacturers could switch. The situation at the dawn of the nineteenth century thus established one of the most persistent conundrums in economic history: 'Explaining the slow adoption of steam power in the cotton industry is an important problem for the historians of its technology,' in the matter-of-fact words of Robert Allen.[54] But the problem could just as well be formulated in the reverse terms. The process cries out for an explanation not only of why it happened so late, but of *why steam power was adopted at all*.

CHAPTER 4

‘There Are Mighty Energies in those Masses’: Mobilising Power in a Time of Crisis

The First Structural Crisis of Industrial Capitalism

In the early 1820s, the long wave of the booming cotton industry entered a crest of extraordinary effervescence. From Scotland to Derbyshire, plants were built and enlarged like never before, equipped with fresh engines or giant wheels, mill-owners pursuing every possible avenue of expansion. Their investments were facilitated by easy credit. With interest rates at exceptionally low levels and cash flowing freely through country banks, all monied persons with a semblance of solidity were invited to the lending binge. The bounds of sound business were wantonly transgressed. By the summer of 1825, sales of British cotton products on foreign markets tapered off; come autumn, country banks began to crumble under the weight of loans extended to more or less insolvent customers. Panic spread. On 8 December, the first major London bank collapsed, unleashing a chain reaction, first along its own corresponding country banks and then farther afield: bank after bank suspended payments. A week later, the *Manchester Guardian* surveyed the ruins of Britain’s financial system: ‘There has never, within the experience of the oldest tradesman living, been a week so pregnant in calamity to the commercial world as that which is now closing.’[1] The greatest financial meltdown of the nineteenth century had begun – indeed, the ‘crash of December 1825 was (still is perhaps) unprecedented in its ferocity,’ wrote historian Boyd Hilton two years before 2008. With a shudder, contemporaries would simply refer to it as ‘the panic’.[2]

There was more to the event than a bubble, however. Beneath the froth of financial excesses and breakdowns, deep imbalances came out in the open: by December 1825, the first structural crisis of industrial capitalism in its country of birth had begun. It was centred on cotton. The bonanza of the previous years came to a screeching halt as exports fell to their lowest levels in a decade. Masters and merchants who had amassed raw cotton, yarn and cloth during the overheated final months suddenly failed to find customers; even in Manchester – home to some of the most solid houses – dozens of firms went bankrupt; unemployment in the manufacturing districts skyrocketed.[3] In its now regular feature ‘State of Trade,’ *The Times* reported in late February 1826 that rows of Manchester mills were reducing production to half-time or less, since markets remained burdened by glut: ‘There is neither a lessening of stocks, nor an increase in

demand.' Three years later, the very same stagnation was still in full effect, causing the newly launched *Circular to Bankers* – possibly the first business paper, predating *The Economist* – to observe that the situation 'differs from all preceding cases of depressions, essentially, in this respect, – that the evil is spreading itself gradually and permanently,' and the 'destruction of capital is proceeding in a more regular and a more hopeless manner, than at any former period.' When five years had passed without improvement, the *Circular* concluded that the glorious era of manufacture and commerce was approaching a complete end.[4]

Profits in the cotton industry were all but obliterated. 'I consider that there was a considerable profit in cotton-spinning prior to 1826; but since that period it has not paid,' explained one Manchester manufacturer to a parliamentary committee investigating the crisis in 1833; similar statements abound in reports and inquiries of the time, for individual companies as well as the cotton industry and, indeed, industrial capital as a whole.[5] Everything was 'in vain for the accumulation of any capital,' lamented Henry Houldsworth, a leading cotton manufacturer in Manchester and Glasgow, his diagnosis corroborated by linen drapers and calico printers, woollen manufacturers and iron-makers, bill-brokers, bankers, builders, brass-founders, the *Circular to Bankers* advising 'all persons trading with large capital' to count on 'a certain loss'.[6] A curve of declining profits after 1825 encompassed most if not all of British capitalism; as for cotton, the superprofits of 50 percent from the Arkwright era were down to an average of 5 percent or lower in the decade after the panic. The road from the former to the latter was not hard to map out. 'To what circumstances do you attribute the low state of profit in the cotton trade?,' the committee of 1833 asked Kirkman Finlay, owner of some of the largest water mills in Britain, to which we shall return. He responded: 'To an extremely extensive production with reference to the demand,' induced by 'the high rate of profit in former times, which, by attracting a large amount of capital to the business, has necessarily led to the low state of profit we now see.'[7]

The bubble of the early 1820s exacerbated the malaise. As one Manchester banker testified, in those days of insane speculation, a superfluity of factories were built, 'not because there was an increased demand for their produce, but because the parties were doing well, and having an opportunity of borrowing money'.[8] The result, according to a chorus of manufacturers and economists, factory inspectors and pundits, was *overproduction*. Most simply defined as a persistent excess of productive capacity over demand, overproduction was the form of a *structural* crisis – not a brief, easily transcended recession, but a prolonged predicament anchored in the very successes of the cotton industry. Precisely because it underwent such a productivity explosion – the fount of superprofits – investors threw themselves into what might also be called an overaccumulation of capital, building up in the late eighteenth century and surfacing in 1825. Put differently, there were too many companies active in the branch; the gold rush had induced too many fortune seekers to build too many mills, which saturated the markets and caused prices and profits to fall. Once the crisis had kicked in, competition became savage. 'We are extremely alarm'd by these heavy losses,' McConnel & Kennedy confided to one of their agents in 1831, continuing on an even more bodeful note: 'Should the present hard times continue, all the large houses at least will sink one after another which had not, before the present crisis began, ample funds to spare.'[9] Only the very fittest would survive this test.

In late 1833, a recovery finally got underway. Prices on most of the principal commodities, including cotton products, began to rise from their dismal lows, buoyed by increasing demand from foreign markets. For the first time since 1825, there was an outburst of construction of new

mills; between 1834 and 1836, the number of factories in the major cotton towns of Lancashire and Cheshire increased by 32.5 percent. In these two years of brief exuberance, the pressures of the structural crisis were compressed into some momentous decisions on energy sources, as mill-owners turned towards certain machines and prime movers and away from others. Then again in late 1836, another speculative bubble – this time inflated by the railway boom – burst, cotton exports took a nosedive, and in 1837 the crisis was back with a vengeance, the cycle from 1825 repeated with near perfection. More years of famine followed, until in 1841–42 the most disastrous hyper-depression of the century descended on Britain. 'It was said that the whole of the manufacturing districts were on the eve of a general bankruptcy.'[10] General strike and revolution stalked the kingdom.

From the very first day, the structural crisis was as much social as it was economic. In the summer of 1824, Parliament repealed the Combination Laws, which, after a quarter of a century in operation, had proven ineffectual and, in the eyes of many, outright counterproductive. Rather than extinguishing the menace, bourgeois critics argued, the ban on all trade union activity radicalised the 'hands' and drove them into underground conspiracies by preventing them from making even the most humble demands. In the late 1810s and early 1820s, workers themselves began to move in concert against the detested Laws; when cotton spinners went on strike – in 1818, 1821, 1823 – they immediately proceeded to agitate for the right to form unions, while weavers, shoemakers, mechanics and other more or less well-organised collectives weighed in with petitions for repeal. Faith in the strategy of blank repression deserted the ruling class. In early June 1824, an act legalising trade unions went through the House of Commons without a vote, and without as much as a debate.[11]

The instant result was a barrage of strikes. Rushing forward as if released from a dungeon, workers in the cotton industry turned out in Glasgow, Manchester and other Lancashire towns, marching through the streets, setting up local unions, dispatching delegations to neighbouring districts without any need to hide their actions; in late 1824, the wages of spinners jumped by one-fifth to one-third.[12] Hardly had the Combination Laws been abolished before manufacturing interests instigated a campaign to reinstate them. 'There is a great uproar making, by a large portion of the country press, against the combinations of workmen,' the *Manchester Guardian* noted in October 1825, as the financial system showed the first signs of cracking.[13] But the genie was out of the bottle. The unions had seen the light of legality and swiftly mobilised to guard their right to exist, sending a storm of protests, petitions and committees to the capital. Parliament took heed; 1825 ended with a compromise. A new act specified that any attempt to extort a person to cease work or register for a combination would be considered a criminal felony, but the right to go on strike and form a union as such remained enshrined, the essence of repeal untouched. On the ground, this half-victory sustained the wave of strikes: colliers, carpenters, carvers, potters, rope-makers, ladies' shoemakers and wool combers were among the workers downing their tools in 1825. When the parliamentary wrangling had settled, a new generation of combinations cropped up, some of them emerging from the underground and others organised for the first time.[14] So it happened that the forces of labour launched a militant offensive *just as industrial capital crashed*.

Outbreaks of popular insurrection then punctuated the structural crisis. One after the other, they seemed to push Britain towards the brink of all-out revolution: first the Lancashire rising of 1826, then the Swing Riots of 1830, the South Wales rebellion of 1831, the Reform crisis of 1831–2, the general unionism of 1832–4, all succeeded in 1838 by the supreme challenge of

Chartism, culminating in the general strike of 1842 – the most critical near-revolutionary moment in the nineteenth century, if not in the entire modern history of Britain.[15] Class war raged through the manufacturing districts. The labour press springing up in the early 1830s adopted a belligerent tone: 'A revolution is not necessarily a bad thing,' argued *The 'Destructive' and Poor Man's Conservative*. 'If tyrants will not allow society to be reformed by moral and peaceful means, they must expect *physical* and *violent* means': hence the paper declared 'War! War!! War!!!' – a war already ongoing, 'a war of *labour* against *capital,*' in which 'the *Trades' Unions* are the preliminary measures – they are the fortresses whereon the guns of popular power shall play upon the rotten fabric of aristocratic corruption.'[16] Such rhetoric did not go unnoticed by the higher orders.

A Mad, Bad and Dangerous People?, asks the title of Boyd Hilton's magisterial study of England in the years 1783–1846: the one emotion possessing the ruling class and colouring the period was 'fear – fear of revolution, of the masses, of crime, famine, and poverty, of disorder and instability'. The terror commenced already in 1789, but the ogre of the mad, bad and dangerous people became even more frightful after 1825, for two reasons: it now marched on a ground also trembling from the quakes of economic depression, and it mustered the special 'guns' of combative workers formed in unions. 'The psychological shock of December 1825,' writes Hilton, 'was even worse than the actuality'; henceforth, whisperings about the next panic and its likely victims would buzz incessantly, merging with angst over the feral people who bore the brunt of the crisis. In the second quarter of the century, life expectancy in industrial parishes fell to a level unheard of since the Black Death; mortality rates spiked while average height dropped sharply.[17] Stunted and deformed, the bodies of the poor were a source of fear in themselves, the crisis reflected in bourgeois horror over the filthy, sick, infected masses, whose revolutionary inclinations appeared as contagious as their smallpox and cholera. In 1842, journalist and historian William Cooke Taylor went on a private fact-finding mission in the manufacturing districts. He was petrified:

> As a stranger passes through the masses of human beings which have been accumulated round the mills and print-works in Manchester and the neighbouring towns, he cannot contemplate these 'crowded hives' without feelings of anxiety and apprehension almost amounting to dismay. The population, like the system to which it belongs, is NEW; but it is hourly increasing in breadth and strength … [forming a] slow rising and gradual swelling of an ocean which must, at some future and no distant time, bear all the elements of society aloft upon its bosom, and float them – Heaven knows whither. There are mighty energies slumbering in those masses.[18]

Nothing less than the survival of the capitalist order seemed to be at stake. There was an element of hysteria to the fears – after all, no British Revolution actually took place – but the insurrections were all too real, as were the fundamental contradictions plaguing the economy. Towards the end of 1842, another recovery set in; prosperity returned to the cotton industry just as in the middle of the previous decade – until all the curves turned downwards once more, the depression again approaching the intensity of 1842.[19] Only in 1848 did British capitalism manage to break out of the impasse and enter an era of sustained renaissance. In the same year, Chartism collapsed. We shall refer to the period in between, from 1825 to 1848, as 'the structural crisis' or simply 'the crisis'. It was then that the decisive shift to steam occurred.

The Rise of the Iron Man

While making the first attempts to mechanise spinning, inventors in the 1730s dreamed of a 'circular machine' capable of producing yarn 'without the intervention of the human fingers'.[20] Nearly a century later, the dream had yet to come true. At the time of the panic of 1825, large varieties of Crompton's mule predominated in the British cotton mills, carrying perhaps as much as 90 percent of all spindles: human fingers had to constantly intervene to keep them rolling. The spindles were fixed on a carriage, a sort of long box running upon a railway communicating with the rollers fixed on a beam. Coming towards the spinner by the force of the prime mover, the carriage would then be driven back from the beam with the power of his muscles, while his fingers simultaneously regulated the speed of the revolving spindles, making sure the thread did not break, slack or snarl. In the absence of strong arms and dexterous hands, no yarn could be made. Put differently, there were significant *residuals of animate power* in the workings of the mule: while an external prime mover impelled the first movements, the human body had to exert its energies to complete the motion: a sure sign of unfulfilled mechanisation. Such labour could not be performed by any man or woman off the street. A spinner should be well-built and wiry, sensitive in touch, able to coordinate different kinds of actions only to re-coordinate them in the next moment. He – the occupation was reserved for males – remained indispensible, an air of craftsmanship surrounding him as he pulled the strings of production. If he so wished, he could bring the mills to a full stop.[21]

In her *Forces of Labor: Worker's Movements and Globalization since 1870,* Beverly Silver describes how some workers might attain a particularly mighty form of 'workplace bargaining power' – namely, 'workers who are enmeshed in tightly integrated production processes, where a localized work stoppage in a key node can cause disruptions on a much wider scale than the stoppage itself'.[22] Precisely this form of power bolstered the militancy of the mule-spinners in the early nineteenth century. Edward Tufnell, a commissioner for the great Factories Inquiry of 1833, bemoaned how they formed only one-tenth of the workforce in a typical mill – the carders, packers, piecers and other assistants being far more numerous – yet 'their labour is absolutely necessary to the working of the establishment,' and so a cessation of their work would 'force all their fellow-labourers to be thrown out of employment at the same time'. Following the repeal of the Combination Laws, the movement of spinners' unions had 'brought the most extensive manufacture in the world under its authority,' shut down mills for months on end, taken an entire economy hostage – 'and it *has* kept up the rate of wages'. Indeed, the wages of spinners were pushed above the levels of 1825 in the following years *despite the crisis,* reaching a peak in 1831 with 30 shillings a week in the Manchester area and 26 shillings in Bolton, Oldham, Preston, Blackburn. Even engineers earned less. For the masters, the situation was insufferable: as long as unions blocked wage cuts – even imposing *hikes* – the prospects for resurrecting profits were dim indeed.[23]

The contest was not limited to wage rates, however. At its core, it was a struggle for power, at a time when the masters needed to be unchallenged in the driver's seat to steer their firms towards safety. Combinations of every kind 'embarrass the productive powers, spread distrust among the capitalists' and degrade them 'into a state of servitude,' wrote Andrew Ure, professor and private consultant, frequently quoted as an authority on all matters pertaining to industry while specialising in practical assistance to the leading mill-owners of Lancashire and the Midlands, many of whom had once been his students.[24] Against this dystopia come true, Ure posed the ideal of automation. 'Automatic,' he spelled out in his *Dictionary of Arts, Manufactures and Mines,* is 'a term employed to designate such economic arts as are carried on

by self-acting machinery. The word is employed by the physiologist to express involuntary motions' – an association thus established between automatic movement and lack of free will. In the physiology of the factory, all motion ought to spring from outside the human body: 'The term *automatic* is now applied to self-acting machinery, or such as has *within itself the power of regulating entirely its own movements,* although *the moving force is derived from without.*'[25] In this formula lay the solution to the trouble with the spinners.

The masters had discovered it before Ure put the vision on paper. An old idea became a burning desire: if the mule could be made 'self-acting' – return the carriage, control the speed of the spindles, form a neat roll of yarn and, not the least, coordinate all the movements *by its own mechanisms* – hands would no longer be needed. On 22 January 1825, the *Manchester Guardian* informed its readers of yet another fresh strike, this time by the mule-spinners at Hyde. 'The hands who have already quitted their employment paraded through the place, and it is thought their numbers will shortly be greatly augmented,' estimated to reach 10,000.[26] With the Combination Laws gone, the state could no longer be counted upon to apprehend strikers or union leaders. After three months of stalemate, the cotton lords of Hyde, usually locked in competition but now racking their brains together, instead decided to approach a man who might be able to redeem them: Richard Roberts, the genius of a workshop for machine manufacturing in Manchester, run together with his partner Thomas Sharp. A delegation from Hyde begged Roberts to invent a self-acting mule. So he did.

The offspring of these entreaties was sealed as Patent No. 5138 in 1825, wherein Roberts claimed to have made spinning fully automatic, the novelty of his machine consisting 'in the situations of the movements, and not in the movements themselves,' which had merely been copied on the spinners' hands.[27] Five years later, the first operational self-acting mule left the workshop of Sharp, Roberts & Co. – 'in effect, the first truly automatic machine in the world,' in the view of Kristine Bruland, historian of the technology of the Industrial Revolution. When knowledge of the device was brought to the general public through the pages of *The London Journal of Arts and Sciences,* a regular compilation of recent inventions, no ambiguity was left as to the identity of the motive force. '*The machinery being driven by the power of steam,* must possess in itself that regulating property which shall effect the different adjustments usually performed by the hands of a skilful spinner.' Andrew Ure elaborated on the superiority of the 'self-actor': henceforth there would only be a need for attendants with 'nothing to do but to watch its movements,' piece together broken ends, take away finished rolls and clean the machine, the spinning itself entirely driven 'by steam or other power'.[28] The self-acting mule was not only the first truly automatic machine, but also the first invention of the cotton industry to be geared, from its birth, to the steam engine as prime mover. It was nursed with the stock. More importantly, its diffusion in the cotton industry would coincide with a general revolution in energy use: the triumphal procession of the self-acting mule – or the 'Iron Man,' as it would be known among the operatives – was also that of steam. But the linkages between the two were more complex than intimated by *The London Journal of Arts and Sciences*. In fact, a self-acting mule could perfectly well be driven by a waterwheel: no technological string tied it to steam. The connection was of a rather different nature.

Unlike Boulton & Watt, Sharp, Roberts & Co. did not have to persuade customers to buy their machine: Iron Man mad, the manufacturers could hardly wait for it any longer. From 1830, the self-acting model dominated the construction of mules for the spinning of coarse and medium yarns. During the boom of the mid-1830s, massive investments in capacity were undertaken for

the first time since the panic, the upturn in trade justifying the scrapping of functioning machines and heavy outlays on brand new Iron Men, who had the additional advantage of throwing off between one-fourth and one-fifth more yarn per unit of time than living spinners on the common mule. More and more manufacturers took the opportunity to safeguard themselves against future outbursts of union militancy, and in some places, the decision was made in the heat of the confrontation.[29]

Towards the end of the boom, the workers of Preston demanded a wage hike by 18 percent as their legitimate share of the recent prosperity. The masters responded with an offer of a 10 percent rise, on the condition that all spinners sign an agreement not to belong to any union whatsoever: negotiations over wages turned into an open dispute over power in the mills. The 650 spinners of Preston refused the masters' offer and launched a strike in early November 1836, automatically throwing into the battle more than ten times as many workers with other tasks, all thirty factories coming to a standstill. At this point, the cotton capitalists seized the initiative: Iron Men were brought into Preston for the first time, the organised spinners replaced by a combination of self-actors and newly recruited hands. By early spring, not only the strike but the entire spinners' union at Preston had disintegrated. The defeat resounded across Lancashire.[30]

In Scotland, the mule-spinners had long been infamous for their capacity to subvert capitalist authority on the shop floor, dictating who could be employed and what machines would be used, but in early 1837, the mill-owners of Glasgow resolved to reinstate their control once and for all: a wage reduction wiping out two decades of union gains was advertised. The resulting turnout involved some 36,000 workers and put the town 'almost in a state of insurrection,' in the words of the sheriff of Lanarkshire; after three months, however, the funds had been exhausted and the lines were crumbling. The masters sealed their victory by discharging hundreds of male operatives and employing young women in their stead, tasked with attending upon the Iron Man: with force and speed, the self-acting mule was diffused across the Glasgow district.[31] The Scottish spinners' unions would never again rise to more than a shadow of their former selves.

In April 1838, the esteemed Whig journal *Edinburgh Review* revelled in the retreat of the unions along all sectors of the front. 'Several of the new spinning mills in Manchester and Glasgow are so constructed as entirely to dispense with spinners; and numbers have got them so arranged as to reduce the hands to half their former amount'; due to the recent strikes, Sharp, Roberts & Co. were said to be 'overwhelmed with orders'. A decade later, the mill-owners and their allies could congratulate themselves on a crushing victory: 'The consequence of this has been,' Roberts boasted of his invention in 1851, 'that the turn-outs have almost entirely ceased in the spinning department. If the hand-spinners ever turn out now, they are seldom allowed to resume work.'[32] Their workplace bargaining power had been sapped at its foundation. A sort of spinner was still needed to adjust the self-acting mule every now and then, feed it with raw cotton, oil and clean it, but his labour had been seriously degraded; indeed, the spinners were renamed 'minders,' since their task was no longer to spin cotton but to mind *machines* spinning cotton. In the 1840s, wages were down to half what they had been prior to the Iron Man, a fall unequalled on the British labour market at the time. Further aggravated by the general hyper-depression, the *déclassement* was nothing short of cataclysmic: 'We know spinners, once earning 25*s*. to 30*s*. a week, that have offered their services to riddle gravel for 1*s*. per day, and begged to be allowed to have the job,' read a report from Manchester in late 1841.[33] Rarely had the fortunes of a key group in the Industrial Revolution shifted so quickly.

As everyone knew, however, the Iron Man was not *literally* self-acting. When Edward Baines

marvelled at its powers, he did not leave the true source of its movements in doubt, though it appears he mistook the inventor for the fuel: 'Watt, with the subtler and more potent agency of steam, moved an iron arm that never slackens or tires, which whirls around two thousand spindles in a single machine.' If the self-actor was a gun targeting the fortresses of the unions, steam, it might be said, was the ammunition. Investigating the rise of the machine in Stockport, factory inspector Leonard Horner asked a manufacturer in 1842: 'Has the proportion of hands to each horse-power altered during the last few years?' Answer: 'In the spinning department *it clearly has decreased, from improved machinery*' – fewer hands, more mechanical energy.[34] Indeed, since all the motions of the carriage now lay on its shoulders, the Iron Man required some *60 percent more horsepower* (hp) than its predecessor for the spinning of the same amount of cotton.[35]

Put differently, capital prevailed over labour in the key industry of the British economy – smashed the unions, reestablished proper hierarchy, extracted more output out of fewer workers at lower cost – by means of *power,* in the dual sense of the word. Automation drew its force from an extraneous energy source. Only the mobilisation of that source made it possible for the cotton capitalists to begin the process of salvaging profits at the expense of labour. It comes almost as an afterthought – and such has indeed been the traditional status of considerations of this kind – but the power ensured by capital through the technological restructuring of the cotton industry was summoned straight from *power in extra-human nature*. To this process, however, developments in the weaving department were as crucial as those in spinning.

The Rise of the Power Loom

Spun cotton was only half-made. It had to be woven to cover and warm. Even when spinning had long been overtaken by machinery, virtually no changes had been made to the ancient technology and energy use in weaving: upon receiving the rolls from the mills, the weaver would insert them into his wooden loom and send the shuttle with the warp through the weft, back and forth, over and over again, until the cloth became tight and even. For the force of motion, he relied 'chiefly on the muscles of his back, which are kept in constant and vigorous action, while one order of muscles is employed with little power of variation, in moving the shuttle and beam,' as observed by surgeon Peter Gaskell: 'and the exertion required becomes, after a while, laborious.'[36] Strained bodies complemented the top modern spinning factories, half a century after Cromford. The weavers continued to work in their homes, with no immediate oversight but stuck in a web of dependence on the master who 'put out' the yarn, examined the finished cloth, paid for the work and brought the commodity to the marketplace at a profit. Ironically, the rise of the water mill – the leap into permanent technological revolution inside the factory – touched off the greatest boom for a traditional handicraft in the history of Britain.[37] A symbiosis of muscles alongside rivers, the cotton industry first developed *through exploitation of flow and animate power*.

Not that weaving by steam was unknown. The 'power loom' had been invented in 1784, refined over the following decades and demonstrated to be equal or superior to the handloom but consistently snubbed by manufacturers. The general principle of the device was summed up by the leading economist of the time, J. R. McCulloch, in 1833: 'In this sort of loom, the shuttle is thrown, and every part of the work performed, by means of machinery; the joining of the threads

when they break being the only thing left to be performed by manual labour.'[38] But it was the handloom that absorbed the growth, proliferating ever further in cottages and cellars in the decades around the turn of the century. 'During the late 1820s, handlooms in cotton weaving alone may still have outnumbered powerlooms by as many as four to one,' according to Geoffrey Timmins, author of *The Last Shift: The Decline of Handloom Weaving in Nineteenth-Century Lancashire* – indeed, in 1829 there were roughly 240,000 handloom weavers (each presumably equipped with at least one loom) as opposed to 55,000 power looms, making the proportion of four to one a slight underestimation.[39] With a quarter of a million – plus perhaps twice as many family members more or less engaged in the labour – the hand-loom weavers were the largest group of workers connected to *any* British industry, their lifestyle and experience far more typical than those of the mule-spinners.

Here is another classical puzzle in the economic history of the Industrial Revolution: why did a primitive technology not only survive but *flourish* for so long? Part of the answer is the extraordinary cheapness of the labour. When the mills began to churn out unheard-of quantities of yarn in the late eighteenth century, the demand for weavers who could turn them into cloth surged, as did their earnings; in response, tens of thousands of labourers – former hand-spinners made redundant by the factories, weavers who had worked on fabrics outdone by cotton, peasants no longer able to live off the land, workers from closed lead mines, Irish immigrants, soldiers and sailors demobilised after the Napoleonic Wars – poured into the occupation. The handloom and ancillary tools were cheap and easy to master; in contrast to mule-spinning, weaving required no special skills. By the early nineteenth century, an *excess supply of weavers* had become a permanent condition of the trade. The absence of barriers to entry made it a default option for paupers and others without property, who, once they had entered, would have difficulty finding other employment. To that must be added one singular privilege: freedom from constant supervision, imposed rhythms of labour, noise and all the other pests of the mechanised mills. A hideout from the factory, handloom-weaving continued to beguile the empty-handed for a longer time than a strict economic calculus would have justified.[40]

The myriads of handloom weavers could not help but to undercut their own position. Facing a deteriorating balance of forces, they saw their piece rates commence a long and painful fall around 1805; from 23 shillings in that year, the average weekly wage plummeted to 8 shillings in 1820 and 6 shillings in 1830. They naturally attempted to defend their livelihood with collective action, but whatever strike force the weavers had possessed in the eighteenth century now rapidly dissipated, their power to withhold labour overshadowed by the potential for putters-out to turn to others in the overflowing market. Any labourer was fully disposable. Moreover, the wide dispersion of weavers in space – each in his own domicile, scattered across valleys and hills – impeded coordinated action, again in contrast to the concentrated spinners; in negotiations over piece rates, the master could pit one weaver against another without the knowledge of either one. The lack of other employment opportunities in rural areas, the casual nature of much of the labour – many weavers keeping one foot in agricultural work – and the large presence of women, children and the elderly in weaving families pulled the earnings further downwards.[41] It all added up to *an extreme cheapness of the handloom weavers' labour*.

The cheaper that labour became, the less reason to replace it with machines. Even in the early 1790s, when wages were still comparatively decent, experiments with power looms resulted in commercial failure due to the high price of steam. In 1793, the proprietors of one weaving firm requested that Boulton & Watt help them dispose of the engine they had installed to impel their

looms, lamenting that the cost 'of coal in our Neighbourhood damps every idea of Benefit': it would be more profitable to revert to putting-out.[42] The cheapness of the handloom weavers appeared in relation not only to coal, but also to the fixed capital required in a loom factory. A putter-out needed to plough his capital into a warehouse but not much else, whereas if he erected a weaving mill, he would have to fill it with his own machines – and his own prime mover. In 1818, John Kennedy of McConnel & Kennedy found that while the latter option increased productivity, 'it is still problematical whether this saving of labour counterbalances *the expense of power and machinery,* and the disadvantage of being obliged to keep an establishment of power-looms constantly at work'.[43] As long as weavers were thinly spread over wide landscapes, their role as prime movers inextricable from their bodily metabolism, manufacturers could move between them, enlisting one, discharging another, dancing along with market fluctuations without encumbering themselves with massive investments in machinery. Keeping the prime mover indistinguishable from the worker, then, remained rational from the standpoint of capital *even when steam-powered weaving had proved its technological proficiency* in the early years of the century. It was the *superabundance of animate power* that postponed the transition to the stock – not the nonexistence of steam-powered weaving technology, nor its comparative inefficiency, nor any lack of knowledge about it.

That superabundance cannot, however, be explained by any inherent characteristics of animate power. It was rather a function of the concrete circumstances of class relations at the time – the presence of a propertyless population, the aversion to factory discipline, the difficulties of unionisation in a rural environment – and of the low-skilled nature of the work itself. But this raises yet another question: why did the shift to steam eventually take place? Did the weavers suddenly become scarce and dear? This is what the Ricardian-Malthusian paradigm would have us expect, but the reality was, in fact, rather the opposite. The crash of 1825 was the 'final calamity' for the handloom weavers, as Baines aptly put it. Forced to cut costs, the masters unleashed new rounds of merciless cutting of piece rates, invariably emulated by their competitors lest they be undersold. The weavers reacted by producing more pieces to try to secure a living, the effects of which were only longer working days – reportedly extending to fourteen, sixteen, even eighteen hours – and exacerbated gluts. Wages continued to tumble, until in the mid-1830s the witnesses of the Select Committees investigating the plight of the weavers announced the dismal range of an average weekly income: 4 to 5 shillings, with the best paid fancy weavers reaching no higher than 7; quite literally, hundreds of thousands of workers were being reduced to the bare bones of human existence.[44] Animate power became *more superabundant and cheaper than ever*.

When the Combination Laws were rescinded, the weavers' unions were already broken, but as pauperisation proceeded, the unorganised labourers resorted to the one weapon they still possessed. *'Let it not be supposed that the Weaver is without his retaliation*. Embezzlements, unparalleled in any other business, are perpetrated, and Manufactories are notoriously carried on solely out of embezzled materials,' stated a committee of weavers and sympathetic masters from Bolton in a petition to Parliament.[45] An experienced weaver might develop a knack for manipulating the commissioned pieces of cloth, stretching them out, using up less thread than necessary and putting some cotton aside. Instead of returning the stockpiled yarn to its legitimate owner, he could then sell it to a third party. There was rarely a shortage of manufacturers willing to buy such booty, purveyed at a lower price than the lawful products: a black market arose under the respectable surface of the cotton industry. Needless to say, this was a considerable nuisance

for the 'honest' manufacturer, who lost some of his property to the black hole of fraud and his already low profits to the discrepancy between purchase of thread and actual output. Workplace bargaining power they might have lacked, but the weavers had their own way of sabotaging accumulation.

It functioned as a sort of illicit redistribution of income. While embezzlement required participation by 'dishonest' manufacturers, it originated in the need – and opportunity – for weavers to earn just a little more money, in the best case enough to keep afloat. In the eyes of Baines, the scourge stemmed from the very special self-rule of this group of workers:

> They are more independent than factory operatives; they are their own masters; they receive their materials, and sometimes do not take back the web for several weeks; and – what is a lamentable, but far too common occurrence – they have the power, in case of urgent necessity or strong temptation, to embezzle a few cops of their employers' weft in order to buy bread or ale.

Almost as irritating was the insecurity over the delivery of cloths at the required date and hour. 'Their time is essentially under their command,' continued Baines's litany: 'they may begin and leave off work at their pleasure: they are not bound punctually to obey the summons of the factory bell'; working under no power but their own, the weavers contracted the most 'idle, irregular, and dissipated habits'.[46] There was a palpable contradiction between the putting-out and the factory systems – between unmechanised weaving and mechanised spinning – kept at bay only by the ample margins of the pre-crash era. Indeed, embezzlement more or less *inhered* in the putting-out system, complaints over the offence having been common since the sixteenth century. After 1825, the practice appears to have escalated in tandem with the weavers' poverty, generally understood to form the main incentive: when the weaver 'has not a farthing in his pocket nor a mouthful of bread in his cupboard, what will he not do to satisfy the cries of his children,' reasoned muslin manufacturer John Makin. 'It is absolute distress [that] pushes many men to do it,' testified one Aberdeen weaver before the Select Committee, which established, in 1835, that 'the dealing in embezzled warp and weft has become a trade exceeding all calculations.'[47] Just as it reached epidemic proportions, the phenomenon as such became more damaging to the hard-pressed class of masters as a whole. But a remedy analogous to the Iron Man waited in the wings.

In the mid-1820s, newspapers in the cotton districts began to call for a switch to power looms as the only way to stamp out the racket of embezzlement. A decade later, Makin pointed to some straightforward motives behind the rise of the machine:

> I do not think that the power-loom does actually cause the cloth to be cheaper; the advantage of the power-loom is in being able, and that is a very great advantage, to produce a certain quantity of cloth in a certain time, so that you may with confidence make your contracts complete, and also that you keep a control over the manufacturing materials; those are the two great considerations which have built up the power-loom.[48]

The Bolton committee was equally confident that if 'the expenses of Building, Power, Machinery, Gears, management and preparation' were taken into account, weaving by power would still be more costly than weaving by hand, but the former had the winning benefit of securing 'a quantity of work under more immediate control and management, and the prevention of embezzlement'. In a similar vein, a royal commission in 1840 concluded that 'the cost of production to the manufacturer is much increased, and consequently, *the demand for hand-loom*

labour much diminished, by the embezzlement of woven goods.'[49] And indeed, the wailing over pilfering workers fell silent after the shift from muscle to machine.

This all points to a remarkable conclusion. *Not any scarcity or high price of animate power, but rather its excessive cheapness pushed manufacturers in the direction of machinery powered by the stock*. Because earnings after 1825 were so low as to frequently fall below subsistence levels, the handloom weavers were driven deeper into the survival strategy of embezzlement, which, in turn, caused mounting losses and ruinous competition among manufacturers. To *raise* the piece rates – to pay more for the animate power at the looms – was, of course, out of the question under conditions of structural crisis and an extremely skewed balance of forces between weavers and putters-out. For an individual capitalist, the shift to power looms would then have been the safest insurance against theft; for cotton capital as a whole, it seems to have gone a long way in eradicating the black market and consolidating control over labour.

But if protection against embezzlement was the *sole* aim, the masters could just as well have collected handlooms in sheds and brought the weavers there, to work as before but under the watchful eyes of overlookers. As one putter-out in Manchester explained to commissioner Tufnell, however, the weavers were propelled to labour at a steady pace only 'in those mills worked by steam engines': only by subjecting the weavers to *a central prime mover* could their idiosyncrasies be pruned away, their speed and regularity trimmed to the demands of the factory system.[50] No similar power would be mobilised by the mere assembling of hands. Moreover, power looms produced at least three times more cloth per unit of time, a most precious improvement in years of narrow margins. The edge in productivity might have been there since the turn of the century, but it increased further in the 1820s and the 1830s, at the same time as the epidemic of embezzlement turned the cheapness of handloom weavers – once trumping that edge – into a plague. 'Machinery propelled by steam, producing goods *at less trouble and cost* than even the most ingenious artisan, may thus be looked upon in the light of the most dexterous workman,' the Select Committee of 1835 claimed as it digested the gains.[51]

A first spree of installations took place in the bonanza of the mid-1820s. At the end of the decade, a bourgeois consensus had emerged as to the future of the department: 'We have not, indeed, the slightest doubt, that weaving by machinery is destined, and at no distant period, entirely to supersede weaving by hand,' J. R. McCulloch declared in 1827. A second spree on a vastly grander scale coincided with the general boom of the mid-1830s. Now the grounds were shifting quickly, and for good: 'Almost every week,' reported one Manchester putter-out in 1835, 'the power-loom is making encroachments on the hand-loom, and supplanting the hand-loom in one fabric or another, and that to a very great extent.' A third push from hand to power occurred in the mid-1840s, in conformity with the business cycle, and by 1850, the shift had been virtually completed: 250,000 power looms now outshone 40,000 handloom weavers. Twelve years later, only 3,000 individuals remained in the dying profession.[52]

Thus the self-acting mule and the power loom went hand in hand in their diffusion, as weaving was finally brought into the fold of the factory system: 'and the weavers, chiefly girls, were employed under regulations the same as those in the other part of the mills.'[53] Twin of the Iron Man, the power loom likewise had the merit of requiring 'only' young, female operatives to attend it; the vast majority of power loom weavers were women in their teens and twenties. Two closely related vultures were killed by one mechanical stone, or, in the words of an overlooker at a cotton mill near Leeds:

> Many of the recent improvements in machinery have been accelerated in their introduction nearly as much by *the vexatious conduct of the workpeople* formerly employed in labour more partaking of the character of manual labour, as by the wish to bring goods into the market at a cheaper rate. I would instance machine printing in the calico trade [of which more later], the power-loom, and the self-acting mule.[54]

The 'vexatious conduct of the workpeople' could take the shape of four-month strikes or a ton of embezzled materials, idle machines as well as vanishing threads. Both strategies denied the manufacturer full utilisation of his property and demonstrated the dangers of *the irregular worker,* universal archfoe of early British cotton capital. Both were beaten back in the mill whose central prime mover impelled spinning *and* weaving.[55]

There arose 'the combined factory'. Giant of a new generation of mills, it integrated the whole production chain in one sprawling complex and, more particularly, amalgamated the self-actor and the power loom in a technological spearhead running, overwhelmingly, on steam. Already in 1841, combined factories accounted for 58 percent of all operatives in the Lancashire cotton industry. Power pulsed through them in ever-greater quantities: the automation of cotton production increased the ratio of hp to worker across the board, from 1 to 4.54 in 1835 to 1 to 3.1 in 1850.[56] Here the power loom represented more of a qualitative change than the self-actor, in that it attached weaving to a non-human prime mover for the first time, laying new claims on mechanical energy, most of it drawn from the stock. 'In the power-loom the entire motion is effected by steam,' an MP could state casually in the early 1840s.[57] Just as in spinning, capitalist victory materialised through the mobilisation of power: protection against embezzlement, regulation of the work rhythm, higher productivity, the exploitation of female and juvenile labour, larger profits or smaller losses, coalescence of the two great departments of cotton production under the aegis of one and the same capital – all hinged on *unlimited access to mechanical energy*. For the handloom weavers, this was an extinction event. In their department, steam functioned as ammunition in an even more profound sense than in spinning.

But why steam? Why not water? Several of the first and largest combined factories were powered by rivers. The transfer of spinning and weaving away from the human hand *could have* landed on water – no technological obstacles barred the way – so why did automation rest on the stock? Had the energy hunger of the cotton industry now reached a point where the flow could no longer satisfy it? Did the unity of self-actors and power looms crave more than the rivers of Britain could possibly give? It is to these questions that we now turn.

CHAPTER 5

Puzzles of the Transition: The Lasting Advantages of Water

Chronology of the Transition

Before we proceed any further, we need to pause and try to specify exactly when the transition to steam power in the cotton industry occurred. What would count as an accomplished transition? In *Technological Change and the British Iron Industry, 1700–1870,* Charles K. Hyde claims 'that an innovation has superseded an older technology when roughly 90 percent of output is produced by the new process'.[1] Translated to the cotton industry, this would imply that the shift was realised when steam power accounted for roughly 90 percent of output – or rather of *total horsepower*. The ceiling is high and the criterion rigid, demanding a nearly absolute supersession of the old prime movers by the new. A laxer yardstick might be 50 percent: when steam had passed the first threshold of *half* of all horsepower, it would have become predominant. But one could also think of two more qualitative, less arithmetically precise definitions. If an old prime mover remained a viable and attractive option for *fresh investment* at point X in time, but no longer at point Y, when practically all investment was directed to the rising contender, the transition had demonstrably occurred. Or, the *key political decisions* driving manufacturers from one energy source to another marked the leap. When it comes to the rise of steam power in the British cotton industry, the fulfilment of all these criteria overlapped fairly closely in time, but we shall focus on the common-sense boundary of 50 percent, when the ascending prime mover came to produce *most* power.

'There can be little doubt,' averred Stanley Chapman, the leading historian of the cotton industry in the 1970s, 'that water wheels provided most of the power for the cotton industry *until after 1820.*' Then a rapid shift supervened. As late as in the early 1820s, most mills in Manchester were still waterpowered, and 'there was indeed little change in the pattern of mill buildings down to about 1825' – but ten years later, steam had 'become the predominant form of power in every cotton town in the North of England,' water mills holding out only in the countryside.[2] Over the course of a single decade after the crash, a concentrated conversion would have swept the core cotton districts. Chapman drew his picture based on extensive knowledge of the industry rather than specific data; vague in its contours, his argument suggested an abrupt transition from water to steam in the English cotton industry between the early 1820s and late

1830s.

As we have seen, however, steam rose at the expense not only of water. Human bodies were the competing prime mover in the weaving department. Any chronology of the transition should take into account *both* waterpower in mechanised *and* human power in non-mechanised cotton production, animate power as well as flow. G. N. von Tunzelmann, whose work on steam are the shoulders upon which all further research stands, added a surmise on this point in his 1978 classic *Steam Power and British Industrialization to 1860:* 'Even in the cotton industry,' he wrote, 'it is likely that *human beings supplied more motive power than steam-engines up to the 1820s.*'[3] If the forces of waterwheels and human muscles each generated more power than steam at this point in time, the engines would still not have grown beyond a fraction of the total (say, 30 percent).

Including handloom weavers in this calculation – a necessary step – postpones the transition to steam, however it may be defined. It also complicates the statistical procedure: estimates of the horsepower produced by the weavers are bound to be even more conjectural than for water-wheels. Von Tunzelmann did not reveal the supporting evidence for his statement, but as we have seen, there were still more than four handlooms to every power loom in 1829. Does that mean that handloom weavers also produced four times the amount of mechanical energy consumed by the power looms? It is hard to know. An approximation of their total hp would have to multiply the average hp from the muscular effort exerted in a unit of time – a notoriously hazy variable for all human work – with the time of actual labour, infamously irregular among the handloom weavers. A healthy adult, however, is commonly considered to generate about 0.1 hp during sustained periods of manual labour, and judging from the accounts of the period, handloom weavers were working hard to combat poverty.[4] As a rule of thumb, we may therefore assume that each of them generated 0.1 hp at the loom.

Now in the mid-1830s, ten power looms were thought to require 1 hp of steam power to revolve at proper speed in an average factory, giving a ratio of 1 power loom to 0.1 hp – as it happens, identical to that in cottages and cellars. Ten handloom weavers were on par with ten steam-powered looms in terms of energy output and requirement.[5] Disregarding potential differences in the average number of hours during which the two types of looms were typically in operation, we may thus hypothesize that the ratio of hand-looms to power looms *roughly corresponded* to the ratio of human power to non-human power, most but not all of which came from steam engines. If so, human beings may indeed have supplied four times the motive power of steam in the department of cotton weaving as late as in 1829.

What about the cotton industry as a whole? On the assumption of 0.1 hp per handloom weaver, there would have been some 24,000 hp generated by human beings during the high plateau of handloom weaving in the 1820s – excluding the residuals of animate power in spinning (and thus a conservative estimate). This might be compared to a total of 46,309 hp from steam engines in the cotton industry in 1838, when the factory inspectors gave the first trustworthy estimate. Eventful years separate the two figures, but only if we postulate an extremely rapid extension of steam power capacity can we deem von Tunzelmann's conjecture – more power from humans than from steam up to the 1820s – plausible. Extreme though the spread might be, however, there is reason to believe that this was in fact what happened.

Soon after von Tunzelmann's classic was published, John Kanefsky submitted a dissertation that mined historical records on the diffusion of British industrial power technology between 1760 and 1870 more extensively than ever before. Though Kanefsky dealt with the cotton

industry at length, his main figures concerned the power capacity of *all* of British industry. In 1800, water mills generated slightly more than 70 percent of the approximately 170,000 hp from non-human prime movers, steam engines slightly more than 20 percent, windmills the remaining 9 percent. Kanefsky chose to continue his estimates with data from the year 1830: by then steam had caught up with water, both accounting for about 165,000 hp or 47.1 percent of the total, the absolute amount of wind power peaking at 20,000 hp while its share had fallen to 5.7 percent.[6] If we stick with the common-sense criterion, the 1830s would then have marked the shift to steam power on a national scale, in all industrial branches: 'According to my best estimate,' Kanefsky concluded, 'steam power advanced to half the total capacity between about 1835 and 1840.'[7] This limit must have been exceeded at an earlier date in the cotton industry, for other manufacturing branches – including in the textile sector – were far slower in adopting steam.

Kanefsky made no effort, however, to quantify the contribution of human bodies. Nor did he venture any estimates of power capacities in the cotton industry prior to the Factory Returns of 1838. If we proceed backwards from that date, with caution and restraint, we may reach somewhat safer ground. It is firmly established that steam galloped at a speed without precedent in the middle of the 1830s: in the key twin counties of Lancashire and Cheshire, the engine capacity in cotton mills rose by a stunning 62 percent between 1835 and 1838, amounting to an addition of 15,377 hp in three frenzied years.[8] Subtracting this figure from the *total* figure for the cotton industry in 1838, we get a maximum potential steam power capacity of 30,932 hp in 1835 – an improbably high number, since that capacity naturally increased in other counties as well. What could flow and animate power have set against roughly 30,000 hp from the stock in 1835? If we take a low estimate of the number of handloom weavers in that year and add the hp of waterpower in 1838 – assuming it had ceased to grow – muscles and wheels would together have accounted for around 30,405 hp in 1835, *virtually equivalent to the power of steam engines* (on assumptions mostly working in their favour).[9] In other words, the stock must have passed the 50 percent mark between 1834–5 and 1838, *on the heels of the mid-decade boom*. Such a chronology is based on what are, of course, controlled conjectures at best, but it fits well with other evidence and assessments. The rise of steam, we may infer, was clinched in the mid-1830s.

The next boom instigated a second sprint. After another round of investments in the mid-1840s, the new prime mover came close to the high ceiling of Hyde, even when accounting for human muscles: in 1850, 82 percent of total hp in the British cotton industry derived from steam, 13 percent from water, 5 percent from humans.[10] Though not quite reaching 90 percent, the stock had clearly turned the tables on flow and animate power since the 1820s, and it would not take many more years before that final threshold would be crossed.

As significant as human muscles were for the departure to steam, however, water was the only real competitor to it as a source of energy for *mechanised* production. For the bilateral shift from water to steam, the fulfilment of our two qualitative definitions might therefore carry greater significance: a point in time when the waterwheel was considered obsolete and unable to drive further capital accumulation would have marked a closure, radically different from a moment when it was still tasked with expansion. Political decisions may have cut manufacturers off from water and rendered continued use of it unfeasible. As we shall see, both of these junctures were, like the crossing of the 50 percent threshold, located within the second quarter of the nineteenth century. Even while the Hydean ceiling would be fully reached only a few years further down the road, we may conclude that the transition to steam power did indeed occur during the structural crisis, and that it coincided with the automation of cotton production. We can then proceed to test

several hypotheses as to why this was the case.

Scarce Water?

The core of the Ricardian-Malthusian paradigm is the belief in scarcity as the mother of the fossil economy, extended, as we have seen, to the transition with which we are concerned: British manufacturers ran into a wall of water shortages, leaving them no other choice but to switch to the track of steam. The hypothesis was first submitted to proper testing by Robert B. Gordon in a 1983 article in *The Economic History Review,* entitled 'Cost and Use of Water Power during the Industrialization in New England and Great Britain: A Geological Interpretation'. 'If it can be shown,' Gordon wrote,

> that nearly all the water power physically available in the industrial regions was exploited before steam power was much used, the energy crisis hypothesis would be proved. But if there were unused water power resources throughout this period, it would be necessary to appeal to the social factors for support of this hypothesis.[11]

To be exact, the latter result would disprove the hypothesis in its entirety. It would call for a completely different – social – explanation for the turn to steam.

Gordon proceeded to carry out a meticulous reconstruction of the meteorological, geological and topographical conditions in the industrial areas in question. Excluding sites where the costs of establishing a mill would have been punitive, he identified the available watersheds of eleven rivers in English manufacturing districts. He then computed the drainage areas, fall gradients and volumes of water in order to assess total power potential, and came up with the following results – not for the 1780s or the 1790s, when the adolescent cotton industry was still growing alongside the rivers, but for the year of 1838:

Water Power Potential Used in England

River Basin	*Total Power Potential, MW*	*Fraction utilised in 1838, %*
Derwent	44	1.7
Dove	30	0.8
Irwell	4	3.4
Ribble	52	3.0
Spodden	6	7.2
Mersey	56	6.5
Aire	38	4.1
Trent	111	1.4
Tame	15	1.0
Erewash	2	1.9
Leen	1	3.4

The estimates, Gordon pointed out, were built on conservative assumptions. To calculate total power potential, he assumed an energy efficiency of waterwheels of a mere 40 percent, but a top-quality model could easily double that by the 1830s. Even so, most of the eleven rivers would

only have been utilised at 5 percent or less of their potential in 1838, the year when the absolute amount of waterpower in the British textile industry *culminated*. If one assumed that only 15 percent of the potential could be exploited at low cost, Gordon further argued, this would still have left a vast margin of unexploited supplies, leaving the conclusion unambiguous: 'No energy crisis occurred.' In more general terms – applying to New England as well – Gordon stated:

> More water power could have been obtained by continued geographical extension of the industrial districts without encountering either high initial costs or excessive variable, transportation, or other costs. It follows that physical bounds on the availability of water power at low cost was not a limitation on the development of industry.[12]

In his *Water Power in Scotland: 1550–1870,* published one year after Gordon's article, John Shaw gave a similar appraisal for this part of the kingdom. 'The potential of water power in Scotland was never fully realised, except in a few localities favoured by other attributes.'[13] These two studies would thus seem to point in the very opposite direction of the Ricardian-Malthusian hypothesis: no water scarcity loomed on the horizon, no general shortages appeared – not even in the central cotton districts. Rather, the shift from steam happened in spite of an *overall abundance* of unexploited watersheds. We shall inspect much more evidence supporting this conclusion; it should be pointed out, however, that the total power potential of British rivers may well have fallen short of the total power needs of British industry at a *later* date – say, in the early twentieth century. But that would have no bearing on the causes of the transition. Anything that took place *after* it cannot explain its occurrence.

Expensive Water?

If water was scarce, its price should have been high and rising. 'A necessary test of a shortage of a commodity is a rise in its price in a free market relative to the general price level,' declares Brinley Thomas, a fervent Ricardian-Malthusian.[14] Only if demand for water exceeded supply and thereby pushed up its cost would talk of an energy crisis be warranted; if steam power constituted the solution to that crisis, it should have been decidedly *cheaper*. More than Ricardianism-Malthusianism is at stake here, however. Followers of the paradigm are not alone in presuming that shifting relative prices drive technological change: according to textbook neoclassical economics, altered resource endowments cause some factors to rise in price, prodding firms to substitute the cheap inputs for the dear by means of new technologies. The axiomatic model has been applied to the British Industrial Revolution in countless variants. In his standard account *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present,* David Landes asserts that the readiness to shift from high-priced to low-priced goods, even when implying a painful abandonment of ingrained customs and securities, was the very earmark of 'a larger rationality' that set Britain apart from other countries. As a rule, technological change happens only when there is 'a need for improvement created by autonomous increases in factor costs'; British industrialists displayed their enlightened 'cost-mindedness' by promptly acting upon the need and swapping the expensive for the economical.[15] Bourgeois logic demands such measures.

In the climate of the early twenty-first century, there might be an additional reason to believe in the low costs of fossil fuels as the original cause of their mastery. A major perceived drag on

renewable energy today is its relative expensiveness: fossil fuels continue to rule because they are so irresistibly cheap. In the search for parallelism between the transitions to and away from carbon, this theme is rarely far from view: applying standard neoclassical tools to the rise of coal, Allen infers that 'the timing of the shift to coal, and the invention of technologies to expand its use reflected the prices of coal, labour, and capital.' Coal was in demand because it was so alluringly inexpensive. In *The Most Powerful Idea in the World: A Story of Steam, Industry, and Invention,* a popular account of steam suffused with technological optimism, William Rosen offers a similar cautionary tale for a warming world in which coal costs 'one-tenth as much' as 'wind, water, and solar power': 'If the history of steam power teaches anything, it is that *the lower-cost fuel option always wins*'.[16] But is this the correct lesson?

A waterwheel might require substantial investment. There were several fixed costs: the wheel itself, its foundations, a wheelhouse, a dam to store and regulate the flow of water. Colonising a site de novo, the manufacturer would have to pay for the building of a system of conduits – leats, sluice gates, tailraces – to bring the water from the dam to the wheel and back to the river; 'these conduits,' wrote William Fairbairn, one of the most distinguished British engineers of the nineteenth century and a major architect of cotton mills, 'are not infrequently as difficult of construction and as expensive as the weir. In several large works with which I have been connected, the cost of conduits has extended to many thousands of pounds.'[17] Some landscapes being more hospitable than others, these fixed costs varied widely. Cutting leats and dams through rock would be more expensive than if the soil was clayey; sites providing naturally steep gradients and rapid streams demanded comparatively little modification. Needless to say, the larger the waterpower installation, the greater the cost would be.

A steam engine consisted, first of all, of the engine itself: payment for it covered the iron, the brass and the copper, the flywheel and the boiler and the steam pipes. But the mill-owner would also have to remunerate the handicraft labour employed in moulding and furnishing all of the components, and the engine had to be placed in a solid framing to keep it upright and reduce the vibrations, inside a special enginehouse attached to the factory – and as if this were not enough, the engines of the late eighteenth and early nineteenth centuries had a propensity to break down and demand extensive repairs, often lasting for up to a month. Depreciation rates far exceeded those for waterwheels. New wooden wheels had a life expectancy of twenty years, while the best iron models could stay in operation for over a century, an age to which steam engines could not come close.[18] The fixed costs of steam were, indeed, more fixed than for water: old engines were scrapped, not renewed. Engine systems were oblivious to variations in the landscapes.

But the costs that did most to determine the overall balance were of a different nature. They pertained to the fuel. The price of coal varied with the distance from and transport links to mines; water itself was gratis, but the right to use it often presupposed a lease. Around the turn of the century, the fuel costs of waterpower were, as we have seen, so low as to render it superiorly cheap in the eyes of many a cotton manufacturer: 'It is well known, that the power of a steam engine is obtained with great expense,' affirmed John Sutcliffe, a Halifax millwright with broad experience of cotton mills, in 1816.[19] Had the balance swung in favour of steam by the time of the transition? To explore this possibility, we may begin by looking at a few cases from what could be called the *second generation* of water mills. In the early 1820s – some beginning in the late 1810s – many proprietors of already large mills threw themselves, easy credit and all, into further expansion and renovation. Unluckily for this second generation, however, it was born just before the cotton industry retired water: the mills built in the early 1820s were outrun,

languishing or failing in the decades of the transition to steam. They are ideal candidates for testing the hypothesis of shifting relative prices.

Kirkman Finlay, son of wealthy Scottish merchant James Finlay, invested in three waterpowered factories in the early years of the nineteenth century: Ballindaloch on the river Endrick, Catrine on the Ayr and Deanston on the Teith, the latter two jewels in the crown of James Finlay & Co. In 1824, the manager of Catrine paid a visit to William Fairbairn and asked him to retrofit the mill. Steam engines were, of course, an option in some vogue, but the parties agreed to install two giant wheels later known as 'the Lions of Catrine' with a total capacity of 240 hp. 'By a proper form of bucket, and a judicious application of the water, they were considered amply sufficient to turn the whole of the then existing machinery without the aid of steam,' Fairbairn wrote in retrospect; moreover, the conduits and the gearing were expanded to make room for two extra wheels 'in case of an increase of the machinery'.[20] Celebrated feats of engineering, the Lions of Catrine were, however, overshadowed by an even more powerful structure at Deanston. At the site of this mill, the Teith was said to flow 'with a rapid course,' its waves 'crested with a beautiful silvery curl'; in the early 1820s, plans were drawn up for diverting the stream into a new canal, building another dam, raising the fall and installing no fewer than eight wheels under the oversight of Fairbairn. In 1832, three wheels had been put up and a fourth delivered to the site, waiting for the power needs to grow. Around this time, the Deanston wheels were collectively baptised 'Hercules' and described with awe by the *Chambers's Edinburgh Journal:* 'They are the most gigantic-looking things we ever saw, and distribute, by innumerable shafts, the whole of the vast concentrated power over the different apartments,' amounting to a total of 320 hp or slightly less. Fairbairn called them 'perhaps the largest hydraulic machines in existence'.[21]

The Lions of Catrine and Hercules of Deanston powered the Finlays' rise to the position, in one count, as Britain's largest cotton spinning firm. In the 1830s, the company had more than 2,300 workers employed in its three factories, putting it far ahead of, for instance, McConnel & Co. – previously McConnel & Kennedy – with 1,500 operatives in their steam-powered Manchester mills. Power looms were introduced at Catrine already in 1806, making it the first combined factory in Britain; Deanston followed in 1807. Soon after Roberts, the managers of the two factories invented their own variants of the self-acting mule, to be moved by the Lions and the Hercules and exported far afield, and in the early 1830s, Kirkman Finlay was still sanguine about the future. At the pinnacle of the industry, he was still in the process of extending his works like monuments to the enduring, still not fully exploited powers of water. Interrogated by the crisis inquiry of 1833, he aired his expectation that lesser competitors would be weeded out, while the most advanced firms, such as his own, would stay in line and wait for 'reasonable profits' to return: 'It is,' he explained,

> upon that conviction that I expend money now in erecting works, *having the power for nothing, and in abundance;* it is upon that conviction that I proceed to expend money in the erection of works such as I have been describing.
>
> Your works are turned by water, and you have abundance of power not employed?
>
> – Yes.
>
> Supposing you had to get to the expense of erecting a steam-engine for turning the machinery in these new works, is the trade such as would encourage you to do that?

– I would not go where an engine was necessary; such a situation would not be suitable to my view of what an establishment of that kind [i.e. a cotton mill] ought to be.[22]

The Lions and the Hercules were among the most expensive waterwheel structures in the kingdom, the weirs and tunnels, canals and sluices, wheel-houses and tailraces built to the tune of tens of thousands of pounds. Once in place, however, their maintenance and repair cost trifling sums, and more importantly, the fuel came 'for nothing,' as Finlay put it.[23] In the late 1830s and early 1840s, coal could be brought to Deanston from a nearby pit at the price of 6 shillings and 2 pennies per ton, similar to the price in Edinburgh, lower even than in Birmingham. There was 'a good quantity of coal' to be had; 'the Road all the way is good and level,' keeping down the expenses for carting the coal to mill – and yet the manager asserted that 'the expense of fuel renders it impossible to use steam.'[24] Even in the light of such monumental fixed capital, waterwheels came across as the only reasonable prime mover *on account of fuel prices*.

In early 1844, the Finlays commissioned an independent valuation of their three water mills. Submitting a report from the capital of the Scottish cotton industry, the valuators claimed to have performed 'a minute investigation of their capabilities and the quality of the machinery & its efficiency, compared with Works situated in Glasgow' to ascertain 'their real value'. A key item was the cost of motive power. For Catrine, 'the same power in Glasgow, including full duty on the ground required, coals, tear & wear, carriage and all sundries connected' would have cost an extra £242.13.10 per year: by saving on such expenses associated with steam, the Lions brought a significant *gain* to the Finlays. 'Viewing the power in the same way as at Catrine there is an apparent saving at Deanston of about £700 pr annum,' the valuators continued.[25] Even so, they considered cotton mills of equivalent sizes to be more profitable in Glasgow; indeed, as we shall see later, their valuation certified the *inferiority* of the Catrine and Deanston works in relation to steam-powered factories in Glasgow – but on a completely different count than energy supply. In terms of cost per hp generated, Catrine and Deanston accorded valuable *savings* to their proprietors as late as in the mid-1840s.

A short horse ride from Manchester, Samuel Greg had founded the Quarry Bank Mill in the landmark year of 1784; according to the company's memoranda book, 'no power for turning mills was then known but wind and water, and S. Greg used to describe how he rode about the country in search of water.' In the bonanza of the early 1820s, when another form of power was very well known, Greg and his sons again decided to order a wheel – not a couple or a triple, as at Catrine and Deanston, but one single iron wheel of some 100 hp.[26] The dam was augmented and raised, while the wheel was placed in a deep chamber underneath the mill, drastically raising the fall of water, which was then led back to the river through a tunnel nearly one mile long. More than doubling previous capacity, the new wheel was yet another hydraulic marvel of the day: 'It has few equals in the country in point of size and efficiency,' wrote one visitor, observing that the 'slow and stately revolution seemed the very embodiment of power and dignity' and 'had been the pride of the owner to exhibit and the wonder of the spectator to behold'.[27]

Quarry Bank Mill was an unusually large plant, owned by a firm at the peak of the industry. Counting the quantity of cotton spun in all its five mills – among which Quarry Bank remained the cynosure – Andrew Ure dubbed Samuel Greg & Co. 'the largest concern in the kingdom,' while distinguished MP Lord Ashley could refer to it as 'the largest establishment in Europe'.[28] Self-acting mules were purchased and two sheds for power looms attached to the mill in the mid-

1830s. Ever keen to follow the relative costs of water and steam, the Gregs wrote down their comparisons at regular intervals: in 1828, the 'Water Wheel, Race, Dams cost as much as a Steam Engine of equal power,' but an 'Engine costs £12 per horse power for coals,' and that made all the difference. In 1849, the manager of Quarry Bank calculated that it would cost £274 more per year to derive the 100 hp from steam. The exercise was repeated seven years later, when the capacity of the wheel had been increased to 172 hp: to replace so many horsepower with as much steam, 'we should require 23 tons of coal per week or 1196 tons per year at 9/5 per ton is equal to £563.2.4 per year in coal'.[29] Over these four decades – well into the second half of the nineteenth century – the waterpower of Quarry Bank Mill consistently came out as a pecuniary advantage, highly prized by the Gregs, the potentials for further relative gains still not exhausted.

The brothers Henry and Edmund Ashworth ran two mills on the Eagley Brook, a tributary to the river Irwell near Bolton. Following the now familiar sequence, they enlarged their assets and erected fresh mega-wheels in the 1820s: at the Egerton mill, a creation of Fairbairn – briefly a partner of the firm – revolved three times per minute and produced up to 140 hp; Cooke Taylor reported that the 'immense water-wheel is one of the wonders of Lancashire, and draws crowds of visitors'. Total plant size of the Ashworth brothers multiplied by fifteen or sixteen times between 1818 and 1834, making the company a leader in the branch of fine yarn spinning. Under the star of Henry, a combative and impetuous character involved in innumerable political controversies, it would also become a pole of resistance against the pressures from steam. Henry claimed to be happily married to water. He once informed a visitor that the wheel of Egerton saved him £20 per week in outlays on coal, which, if true, would have surpassed the feats of Hercules; in 1843, Fairbairn put the annual gain at a more modest £560.[30]

The Finlays, the Gregs and the Ashworths were not representative for the cotton industry of the second quarter of the nineteenth century: they were heavyweights of the trade, waterpowered titans standing out above a forest of small and medium-sized mills. A multitude of other statements, however, confirmed their experiences in the field of fuel. Interviewed by the Factories Inquiry of 1833, John Cheetham, whose three spinning mills in Stockport were all steam-powered, declared that a manufacturer with waterpower enjoyed an 'advantage over his competitors'. Staying on the topic, commissioner Tufnell wondered:

> Why do you think he has till now enjoyed an advantage over his competitors in trade?
>
> – Because it is a well-ascertained fact that water-power is cheaper than steam.
>
> Then if a mill-owner wishes to set up a manufactory, he can always do it cheaper by purchasing a waterfall than a steam-engine?
>
> – Yes; if he does not pay too high for his water.
>
> Suppose he does not pay too high for his steam-engine, would he be in the same condition?
>
> – No; because the price of fuel is a greater object than the price of a steam-engine.
>
> Why is it cheaper to purchase a waterfall than a steam-engine?
>
> – On this ground – *the constant supply of water is much cheaper to turn an engine* [sic] *with than the supply of coal*.[31]

The ‘well-ascertained fact’ was indeed reiterated by others in the inquiry. Thomas Worsley, a Stockport shopkeeper previously employed by trade unions as their own amateur inspector touring the district to monitor compliance with various acts and regulations, compared proprietors of waterpowered cotton mills to their steam competitors:

> They work cheaper: though it may be difficult to prove why this is the case, it is generally acknowledged that somehow or other it *is* the case. If I wanted to hire power to-morrow, or, as it is called hereabouts, to take turning, I can procure it in the country parts round Manchester one-third under what I should have to give for it in Manchester or any of the manufacturing towns; therefore, somehow or other, the owners of water power can work cheaper than the owners of steam power.[32]

A decade later, in 1842, the *Preston Chronicle* could publish a recommendation to choose a wheel over an engine of equal power on the grounds that it would save the investor ‘at least £500 per annum’.[33] Notably, this estimate of the annual gain fell neatly within the range of the figures from Catrine and Deanston, Quarry Bank and Egerton; not necessarily a huge sum for an individual firm, it nonetheless represented a clear-cut differential in favour of water.

How, then, did the cost of fuel evolve at the time of the transition? Even if water remained cheaper, perhaps the price of coal *fell?* That would, at the very least, have reduced the gap and increased the appeal of steam power in strictly economic terms (as would greater fuel efficiency, a variable to which we shall return). After the end of the Napoleonic Wars, coal prices did indeed fall, but general price levels fell *even faster* in the deflation of the post-war period: up to 1830, coal prices decreased by one-third less than a mean of indices – translating into a relative *rise* in the cost of coal. In the following two decades, coal prices stood out by their stability. What determined them? Labour, above all. In the years 1830–1860, 51 percent of total costs in British coal mining consisted of wages, the largest share by far, to be compared with 9.6 percent for supplies and 7.8 percent for ground rents.[34] When proprietors of steam mills purchased coal to feed their engines, they paid primarily *for the living labour* required to bring the coal out of the ground. There is no sign of any substantial fall in coal prices in the decades of the transition, nor of any technological revolution in coal mining, nor of any narrowing of the gap between water and steam in terms of pure fuel costs: labour kept the value of coal safely above water.

Water was not exactly gratis. Leases might have to be secured and rents paid to the landlord, unless – a not uncommon situation – the proprietor of the mill also owned the land around it. Information on the costs for such arrangements is sparser than data on coal prices, but all available figures indicate that they stayed relatively low. An estimated average of £5 per hp per annum in water mills compared to £15 for a 25 hp steam engine, or £12 for a 100 hp engine, in the 1840s. In other words, the cost for obtaining a quantum of mechanical energy from steam would have been at least *twice as high* this far into the transition.[35] In the words of Kanefsky, water was ‘preferable to steam *even in 1870 if cost factors alone were under consideration*’ – and indeed, as late as in 1873, the *Bradford Observer* could run an article on the relative costs of the two energy sources and proclaim that ‘mills which are provided with water power have a marked advantage over those which are wholly dependent on the use of steam.’[36] But by this time, the transition had, of course, been accomplished long ago. The evidence presented here dovetails with all modern reconstructions of power costs – including equipment, installation, fuel and all other components – in the critical decades.[37] The tentative conclusion, to be confirmed by more evidence, is highly significant for the history of the fossil economy. *The transition to steam in the British cotton industry occurred in spite of the persistently superior cheapness of water*.

At bottom, this appears to have been a function of the spatiotemporal profiles of flow and stock. Embedded in the landscape, the flow required no human labour to call forth its powers; a lease or ownership title secured legal access to the land, and then the water came, as it were, gushing for free. In dormancy, outside the landscape, the stock could be transformed into an actual source of energy only through massive inputs of human labour, mobilised in a long chain stretching from deep inside the mine, through the pithead, via transportation, to the side of the engine converting steam to rotative motion. Unlike water, coal circulated on the market in physical freedom as a commodity that had to be bought again and again to feed the prime mover. The price of the fuel varied with location and communications; close to a pit, or well connected by a canal or road or railway, a cotton manufacturer would find it relatively cheap – but he would never find it for free.

Small, Uneven, Inefficient Waterwheels?

One remaining possibility is that waterwheels simply were incapable of generating as much power as steam engines. To convey such an impression, Kander and her colleagues juxtapose the capacity of the average *medieval* wheel – a mere 3–5 hp – to the largest engines *in the year 1900,* which reached 12,000 hp.[38] Scholarly deceit, one might retort. Setting the maximum performance of a high-speed train in 2014 against the mean velocity of a horse cart in ancient Egypt will tell us very little about why transport systems were revolutionised in the early nineteenth century. To be at all useful in analysing the dynamics of the transition, the comparison must, of course, be conducted *for the years when it actually happened:* in 1838, the wheels in the English cotton industry generated an average of 16.6 hp, the engines 28.5 hp. In the mills of Scotland, on the other hand, 37.4 for wheels contrasted to 29 for engines.[39] These were averages, containing numerous miniscule wheels erected by petty spinners in the nearest streamlet, but the *very biggest* power installations still tended to ride the rivers: in the early 1820s, a 60 hp mill-engine was considered large, when Fairbairn and other engineers designed wheels of double the capacity. The largest steam engine in Manchester in 1844 made precisely 300 hp, but such a rate was exceptional; by that time, water engineers were approaching a similar maximum per piece. During the crucial decades of the transition – from the 1820s to the 1840s – the largest cotton mills remained waterpowered, often with stupendous wheels placed in pairs, triplets or even greater sets.[40]

Disregarding the vagaries of the weather, did wheels produce less *even* power than engines? 'The water-wheel,' William Stanley Jevons wrote in *The Coal Question,*

> possesses a natural tendency to uniformity of motion, even more perfect than that bestowed on the engine by Watt's 'governor'. Water power is, in this respect, the best motive power, and is sometimes used on this account, where a very delicate machine requires to be driven at a perfectly constant rate.

That assessment was made in 1866; four decades earlier, Farey conceded that a 'steam-engine can never produce a perfectly uniform motion,' no matter how large. 'If it is rigorously examined, the movement of any mill or machinery which is worked by a steam-engine, will be found unequal in some degree,' granting another edge to wheels – not in the Middle Ages, but right on the threshold of the transition.[41]

Throughout the 1830s, Kanefsky gathered, 'cotton produced by water mills was still regarded

as being generally superior to that produced by steam power,' due to the unequalled evenness of motion in the former.[42] Well into the second half of the century, wheels were less prone to mechanical glitches and breakdowns, as long as they were protected from floating sticks and other disruptive objects. They had no propensity to suddenly explode or catch fire – widely publicised mishaps of steam – and neither were they difficult to understand or operate. Were they badly inefficient? Perhaps steam power provided a relief to the British people by arming them with a much higher efficiency in energy extraction? On this count, not even Kander and her colleagues fail to note the real differences: by the time of the transition, modern wheels transmitted 85 percent of the mechanical energy of falling water to the machines, whereas steam engines normally converted less than 2 percent of the energy in coal to motion, reaching 4 percent in the best specimens.[43] Neither in absolute capacity nor in evenness or energy efficiency did the engine excel the wheel. The opposites are closer to the truth.

Beyond Numbers, Mystery

An inference with rather startling implications for the history of the fossil economy seems inescapable. The transition from water to steam in the British cotton industry did not occur because water was scarce, more expensive or less technologically potent – to the contrary, steam gained supremacy *in spite of water being abundant, cheaper and at least as powerful, even and efficient*. But for the moment, we shall accept this only as a tentative conclusion; more evidence is required for its solidity and magnitude to become clear. It merely serves to deepen the mystery. If not for these expected reasons, then *why* did cotton capitalists swing towards the engine? Why on earth, more particularly, would they turn to a prime mover all but universally regarded as more expensive?

Surprisingly little has been done to provide a solution: Gordon did not follow up his demonstration that physical bounds never limited water. Shaw concluded his work on Scotland by stating that 'the end of the Age of Water Power came about not so much on account of any inherent weakness as through changes in the scale of industrial units, in work patterns, population distribution and economic goals,' but he never tried to specify the nature of those nebulous changes or how exactly they brought about that epochal end.[44] Having demolished standard explanations for the rise of steam, Chapman, von Tunzelmann and Kanefsky likewise left the question hanging in the air. The shrouds surrounding the causes were thickened, not dispelled.

A scientific failure – as it must be deemed – the inability to explain the transition has been partly rooted in the obsession with *counting* nowadays so characteristic of the discipline of economic history. Working with numbers, von Tunzelmann, Kanefsky and Gordon produced some formidable calculations, cleared away sloppy claims about what happened and sketched the contours of the stage, but they did not fill in *the causes of the manufacturers' movement from one point to another*. To do this, other tools than calculators are needed. General equilibrium models, in which power and antagonism are hidden in the attic, can only take us so far. Struggles between managers and operatives on the shop floor, fervent promotion of machinery and dogged resistance to it, the indifference towards some technological promises and the itch to profit from others and so much else of what went on in the Industrial Revolution simply cannot be captured arithmetically.[45]

Von Tunzelmann began his dissertation – the basis for his classic study – with an epigraph

from Dickens's *Hard Times:*

> So many hundred Hands in this Mill; so many hundred horse Steam Power. It is known, to the force of a single pound weight, what the engine will do; but, not all the calculators of the National Debt can tell me the capacity for good or evil, for love or hatred, for patriotism or discontent, for the decomposition of virtue into vice, or the reverse, at any single moment in the soul of one of these its quiet servants, with the composed faces and the regulated actions. There is no mystery in it; there is an unfathomable mystery in the meanest of them, for ever.[46]

As if to validate Dickens's diagnosis of the industrial mentality and speak in the language of Mr. Gradgrind, von Tunzelmann stayed within the realm of so many pounds of weight and horses of power. Towards the end of his dissertation, he admitted 'to having had nothing to say on social issues since quoting Charles Dickens at the very beginning.' Kanefsky made a similar late confession: 'Undoubtedly the greatest imperfection of all is in the treatment of *the factors which affected the diffusion of power';* more particularly, 'it would have been desirable to have been able to discuss the non-economic' – in the sense of non-arithmetic – 'influences on the choice of prime mover'.[47] It is only in this realm that the puzzles of the transition can be solved. A different methodology is required: a more qualitative approach, venturing deeper into Coketown, notebook in hand.

CHAPTER 6

Fleeing the Flowing Commons: The Expansion of Waterpower That Never Happened

The Watt of Water

Sometime in the late 1770s, a team of manufacturers were scanning the Scottish countryside for suitable millsites when their eyes fell upon the Isle of Bute. Located in the firth of Clyde, in the shadows of steep and often snowy hills, the island was rather flat, with a sparse populace of farmers, fishermen and linen-weavers congregated in Rothesay, the one village to speak of. But it did impress the men with the key asset they were searching for: plenty of water. Taking their cue from Arkwright, they chose the village for the building of a five-storey cotton mill, the first or second of its kind in Scotland; before long, however, problems surfaced. 'I despair of seeing, even in rainy seasons, a constant regular supply of water, sufficient to drive the mill both day and night,' the manager complained in 1785: later in the same year, the Rothesay factory was put up for sale. The new owners struggled to make it a profitable venture. Having added a second building and larger mules, they decided around the year 1800 to boost the power capacity with two steam engines, only to find themselves going from bad to worse, for whereas water had originally been considered a natural advantage of the Isle of Bute, coal brought in from Glasgow commanded an unusually high price. The fuel expenses broke the back of the firm, and in 1813, the Rothesay Mills were again sold for a pittance.[1] Now began their golden era.

As a young student of mechanics, Robert Thom had his passions channelled towards 'the whole theory of hydraulics, and particularly, from the nature of his avocations, to the properties of water as a moving power'. After a stint as a manager of cotton mills, he saw an opportunity to realise his own fortunes and grand visions in the advertised bargain of Rothesay: here were potentials waiting to be realised, if only the question of power were handled with wisdom. Thom resolved to eliminate the need for steam engines and turn the whole Isle of Bute into a testing ground for avant-garde water management schemes. Far from all precipitation over the island made its way to Rothesay: to catch more of it, Thom began to crisscross the fields and hills with aqueducts or 'cuts,' intercepting the runoff and redirecting it towards a central dam. The terrain being flat, he had to operate with low gradients and build fairly wide cuts to carry the water, but

he was at pains to make the system unintrusive and supple. Where other engineers would see the need for bridges and tunnels, Thom would operate on a principle 'quite the reverse of all this; it is simply to follow the line which nature points out.'[2] Aqueducts of his design, the proud inventor later explained, 'are never carried over valleys by bridges or through high ground by deep cuttings but they invariably are made to wind along the sides of the sloping ground however tortuous the course that they may thus assume'. Gently lowered into the declining ground, passing through a series of ancillary reservoirs, the channels would collect the gifts of the sky without doing damage to the earth: 'Care is taken not wantonly to cut up and injure the ground.'[3] For Thom, dancing with the water as it flowed through the landscape appeared a form of art.

The next step was to secure a perfectly steady supply of water, regardless of season and day, and to this end, Robert Thom, loyal to the ideals of the time, developed his most spectacular creation: the 'self-acting sluice'. Like so many other mechanical inventions, it hinged on a deceptively simple idea. When the volumes swelled in an aqueduct leading towards a mill and the wheel received more water than it could take, the flow needed to be reduced. Thom positioned a float in the aqueduct, connected it to a lever and fixed the lever to a sluice: as the water-level rose, so did the float; the lever was depressed and the sluice shut down. Less water would then pass into the leat and reach the mill. Conversely, when the water level fell below the point where the wheel would slow down, the float would fall with it; the lever would rise and the sluice open. Tailored to sense the fluctuating levels and react in accordance with the needs of the factory, the self-acting sluice 'will always open of its own accord, and let down the quantity of water wanted by such work and no more'. Any surplus from heavy rain would be detained in the ancillary reservoirs; preventing inundation of adjacent land, they would release the water in drier days by means of similar automatic sluices – indeed, Thom likewise spoke of these dams as 'self-acting'. Here was, he claimed, an optimal delivery system, geared to work 'with perfect regularity,' always matching the supply of water to existing demand.[4]

Completed in 1824, the Rothesay water system astounded contemporary observers. An account published in *Mechanics' Magazine* relayed the successes to a wider audience: 'By such means, the water power of Rothesay Mills was more than doubled, and the proprietors were enabled to lay aside their steam-engines entirely, thereby saving an expenditure which had rendered their works hitherto so unprofitable.'[5] Equipped with the amplified powers of water and relieved of the burden of coal, the Rothesay Mills finally became a prosperous business. Under Thom's ownership, some 700 operatives were employed in the spinning of yarn, put out to 200 handloom weavers scattered across the island, whence first-class calicoes were shipped to distant markets.

In 1821, the Royal Society of Arts awarded Thom the Large Silver Medal for his 'self-acting hydraulic apparatus,' and around the same time, he received a visitor from the sleepy seaport of Greenock, a merchant by the name of George Robertson. Greenock was then in the throes of a severe water crisis: in summertime, carts of water had to be brought in to supply the inhabitants. The position of the town on a narrow plain, squeezed between the sea in front of it and high hills rising behind, seemed to obstruct access to nearby water; the hills 'formed an apparently insurmountable barrier' to the plentiful streams beyond. Robertson had long sought a solution to the problem, once approaching none other than James Watt, the town's most illustrious son, born in Greenock in 1736. But when the merchant and the inventor had walked through the hills, Watt had declared the mission impossible. The mountain streams were forever out of reach.[6]

Touring the cuts and reservoirs on the Isle of Bute and seeing what Thom had achieved,

Robertson now broached the matter with him. Might he save Greenock from its ordeal? Thom inquired about the topography of the area, heard of the hills and the streams so close yet distant, and responded that it seemed entirely feasible to copy the Bute system on a larger scale and carry the water to the town. A preliminary exploration of Greenock's surroundings reinforced his optimism: there was 'an immense number of fine springs flowing from the face of the hills' – indeed, 'I have never anywhere seen such a quantity of fine, pure, well-tasted spring water.'[7] But the springs held greater promises still. In the view of the commercial and public men of Greenock, the town suffered from another, no less serious crisis: a scarcity of factories, particularly cotton mills.

Delayed for another few years by continued work at home, Thom submitted his full report on Greenock in 1824. He addressed it to Michael Shaw, lord of the manor, among whose properties was the 'Shaws water,' a major stream in the hills; the lord had taken an active interest in the project. Thom struck a confident note: 'A plentiful supply for the town and its public works, as they exist at present, is a matter of comparatively easy accomplishment.' First a large reservoir for multi-year water storage would be constructed, preferably on a meadow just on the other side of the hills. Then an aqueduct of six and a half miles would be laid down, 'leading the water *round* the barrier which it could not pass *over*' – the obstacle Watt had deemed impassable – and, fully equipped with self-acting sluices, conveying it to a second 'regulating reservoir' right above the town.[8] Looping around the hills, the water would then be immediately accessible to both the people and the 'public works' currently inhabiting Greenock.

'It appears to me, however, that you should not stop here,' Thom continued. Not only was the satisfaction of the most basic needs of the Greenockians easily obtained, but the town offered singularly propitious circumstances for the establishment of cotton mills. Thom proposed to dig two artificial mini-rivers from the regulating reservoir: one eastern line and one western, running down the slopes towards the sea, offering, in one stroke, an estimated 1,666 hp of waterpower to prospective investors. Dividing the figure by thirty-three factories, each of them would have access to 50 hp, a solid basis for a vibrant local cotton industry (bear in mind that the average capacity of steam engines in the Scottish cotton industry was 29 hp in 1838). The system would, Thom projected, attract total capital of 'above a million sterling' to the new mills; the face of Greenock would change forever; properties would gain in value; 'villas would be seen rising in every direction,' landowners and farmers alike sharing 'in the general prosperity'. And all of this without the very unpleasant attributes of steam.

> Here you would have no steam-engines, vomiting forth smoke, and polluting earth and air for miles around; but on the contrary, the pure 'stream of the mountain,' flowing past in ceaseless profusion, carrying along with it freshness, health and vigour; whilst, in its progress through the town, every thing, having a different tendency, would be swept before it into that reservoir of health, and purifier of the elements – the ocean. In a word, were these works judiciously placed and tastefully constructed, they would present by far the grandest object *of art* to be seen on the banks of the Clyde.[9]

The idea, Thom admitted, might seem implausible to the untrained eye – perhaps Watt should count among the ignorant – but there was even more in store behind the hills. The scheme now outlined was 'far from exhausting the water power within the resources of Greenock': Thom considered a doubling of the capacity to upwards of 3,000 hp a lower bound. At that extent, the system would provide Greenock with 'nearly as much power, from water, as is now given by steam to all the public works in and about Glasgow'. A new Cottonopolis would be called down

from the streams above. When the report was disseminated to the respectable men of Greenock, 'every one was taken by surprise; some were equally astonished and delighted with the proposal; but most were disposed to treat it as a dream.'[10] It did not last long, however, before Thom, Robertson and Shaw – the trio of inventor, merchant and landowner behind the scheme – had succeeded in convincing both municipal and national authorities. A joint-stock company was formed in late 1824, incorporated by Act of Parliament and amply funded to execute the plan under Thom's guidance: these were, after all, days of industrial rhapsody.[11]

On 26 November 1825, an advertisement appeared in the *Manchester Guardian* in which the directors of the Shaws' Water Company – reaching out to the centre of cotton capital – announced 'water power to be let'. The reservoir under formation would hold water equal to

> a full supply for four months in the driest season, independently of what may fall or run into it during that period; and as the flow of the Shaws River is large and constant, there is therefore not the smallest risk of the Works being at any time stopped for want of Water. Single Waterfalls equal to any Power from that of 30 to 120 Horses, may be obtained; or two or more such Falls may be joined, if required, so as to be applicable to the same Factory.[12]

Twelve days later, the first London bank collapsed.

Get Water if You Can and Be Quit of these Smoky and Expensive Engines

The Shaws' waterworks were inaugurated to great fanfare in April 1827. The *Greenock Advertiser* exultantly described how the sluices were opened, first to the regulating reservoir, then to the eastern line, 'and the torrent bounded down each successive fall, and rolled along the alternate levels, with fearful activity.' Several thousand amazed spectators saw their water woes disappear in an instant. 'In the appearance of the aqueduct a complete change had now taken place: what, a few minutes before, was a dry and unmeaning channel, exhibited now an impetuous torrent,' running into a newly erected grain mill, where the 'dizzying' wheel started to revolve. Concluding its report from the historic day, the *Advertiser* noticed an underlying irony of the spectacle:

> We cannot help remarking, as a most singular circumstance, that the birth-place of Watt should have become the theatre for exhibiting the earliest practical demonstrations, on an extensive scale, of a great mechanical power, rivalling the utility of his own; and been the means of adding another name [i.e. Robert Thom] to the bright record of ingenious men, who have proved at once the benefactors of their country and of mankind.[13]

But of the thirty-three prepared sites, only four had been occupied by the time of the inauguration. None of the mills manufactured cotton.[14]

The poor interest in renting the sites was blamed on the panic. 'But for the convulsion of 1826 in the mercantile world,' wrote the *London Encyclopaedia* in 1829, 'the means thus afforded of obtaining a moving power, which is let by the Shaws' Water Company *at about one-eighth the expense of that derived from steam,* would have induced many manufactories to be set down here.' The hopes had not been dashed, however: the *Encyclopaedia* was positive that investors would obey reason and flock to the falls within 'a few years'. While the company waited for the tenants to arrive, construction of the system continued, excavations and expansions proceeding smoothly, the main reservoir soon holding enough water to cover a drought of several years. In

1845, the *New Statistical Account of Scotland* confirmed from firsthand observations the certainty 'of a uniform and abundant supply' of water; the self-acting sluices were said to play their part faultlessly. In the nearly two decades since the inauguration, experience had

> more than realized, in one respect, the most sanguine expectations of the projector. During that period, there has not been the slightest deficiency of water-power for a single day. It has been uniform and unvarying, far more so than any other power in use for impelling machinery.[15]

In row upon row, millsites were prepared between artificial waterfalls, each generating some 54 hp when acting on the wheels. Total power capacity exceeded Thom's original estimates, the figures climbing as the system grew. Some 2,000 hp or slightly more was the maximum capacity ever put into effect at the Shaws' waterworks, but the full potentials were never realised: in the 1830s, Thom and the company insisted that no less than another 5,000 hp could be activated when needed. To give a sense of the dimensions involved, these figures could be compared to the capacity of steam engines in the cotton industry of Lanarkshire, dominated by the city of Glasgow, in 1838: a total of 3,696 hp.[16] Had investors only possessed the interest, a second Glasgow, even larger but entirely powered by water, could have arisen on the Clyde.

Consensus applied to another key point: the waterworks were eminently successful in financial terms, the economic advantages over steam substantial. It 'is undeniable,' proclaimed the *New Statistical Account* in 1845, 'that the water-power furnished by the company is far cheaper than that which is procured from steam': the expense of the latter motive force, 'even in Glasgow, in the immediate neighbourhood of coal, is not less than L.30 a-year for each horse power,' whereas the Shaws' Water Company let out waterpower at the marvellous rate of L.2 to L.4 – 'with this advantage additional, that there is no tear and wear, as in steam-engines, and no risk of failure or deficiency in supply.'[17] The rents were, of course, used by the company to cover outlays on construction and maintenance of the system. It was a gargantuan infrastructure project, the largest of its kind on any British watercourse, and yet it held forth mechanical energy at a fraction of the cost of steam.

Thom believed himself to have written the recipe for the revival of the British cotton industry. Indeed, he professed to having overcome the two potential troubles of waterpower: spatial fixity and temporal fluctuations. With aqueducts meandering through the landscape, coiling around hills and descending almost imperceptibly along plains, mills could be served from a distant source; reservoirs and self-acting sluices abrogated all irregularities. 'We are enabled to convey water from the most remote and inaccessible places,' *Mechanics' Magazine* proclaimed in its first report on Thom in 1829, 'to situations better adapted for the sites of mills, factories, villas, &c.,' and the element of water will now 'work with the same accuracy as a piece of clock-work'. The *Encyclopaedia* hailed Thom as 'the inventor of artificial water-power' and predicted that manufacturers across the country would scramble to copy his plans 'to the exclusion of the far more expensive agency of steam'.[18]

In the first phase of the structural crisis, Robert Thom made a name for himself as the preeminent apostle of water in Britain. Accounts of his achievements were filled with the expectation that this source of energy was now on the verge of a nationwide renaissance, rolling back the challenges of steam and coal, providing a more profitable and rational foundation for industry. Thom raised a bold battle cry. 'Such indeed,' he wrote,

> has been the éclat of the steam engine hitherto, that whenever a work became scarce of water, either from its

> being enlarged or from a dry season, nothing was to be heard but the general cry – 'Put up a steam engine and be independent of water'; and many a striking instance might be pointed out, within fifty miles of Glasgow, where such advice has been acted upon, when less than the first cost of the steam engine would have procured a full and perpetual supply of water. This, however, cannot last; and therefore instead of the general cry 'Put up steam engines and be independent of water,' we may soon expect to hear substituted, 'Get water if you can and be quit of these smoky and expensive engines.'[19]

It is only *post festum* that this manifesto carries a tinge of quixotism. For a brief moment, the race between Watt and Thom was open.

Discord on the Irwell

The gaze of Lancashire cotton capital fell on Thom at an early date. From its citadels in and around the Cottonopolis, this class of people largely viewed the world through the pages of the *Manchester Guardian,* founded in 1821 by a cotton dealer, written for and read by mill-owners: 'to friend and foe alike their *Guardian* was "the cotton lords' bible"', in the words of the paper's biographer.[20] In February 1827, the bible published a survey of the 'Great Hydraulic Improvements in Scotland,' narrating the story of Rothesay and Greenock and heaping praise on Thom. He had conjured up greater powers of water than 'many of our readers would suppose to be possible'. He had regained profits by discarding steam, weathered the drought of 1826 – to which we shall return – with his Bute reservoir still full by the autumn, and extended his services to the thirsty people of Greenock, where the waterworks were scaling the hills. 'Now if these very successful results have been experienced from this plan in Scotland, we do not see any very good reason why they may not also be attained in England.' The *Guardian* went on to propose the importation of Thom's concept into the very heart of the Lancashire cotton district: Manchester and its vicinities. River Irwell would be the perfect candidate.

> If all the water which flows down the river Irwell, in the course of a year, could be equally distributed throughout that period, its *available* power for turning machinery would be prodigiously increased, and its consequent value to the country proportionately augmented … If a reservoir or two, containing two or three millions of cubic feet of water could be formed … it would be money exceedingly well laid out; and the mill-owners could easily afford to pay a very handsome per centage on the capital, for the benefit they would receive.[21]

This reveille set off a spate of schemes for reservoirs à la Thom across Lancashire and the neighbouring counties, holding out the promise of a massive expansion of the power supply to local industry. But the plans of greatest potential were aborted. Instead of a hydraulic renaissance, the 1830s saw a sharp turn towards steam: two routes were open and British capital chose one. Why not the bargains of Thom? Recovering the historical dynamic of the transition requires an exploration of the path not taken; as economic historian Maxine Berg has pointed out, there has been a palpable lack of interest in the 'alternative paths which were, for some reason, blocked off' during the early phases of industrialisation.[22] This is one of them.

Reservoirs are probably as old as water mills. Often used interchangeably with 'dam' or 'millpond,' the term designates an artificially constructed pool connected to a wheel, operating primarily within a diurnal framework: the sluice gate would be closed overnight so as to impound the water and store it for the next working day. In the early British cotton industry, manufacturers commonly built or maintained such structures – sometimes called 'private

reservoirs' – for their own use.[23] The reservoirs inspired by Thom and slated for construction in Lancashire were of an entirely different kind. They might have a diurnal function, but they were also *seasonal,* storing water quantities of another magnitude for release in poor weather. More importantly, they were *collective* undertakings, not by a single capitalist who wished to improve the immediate flow to his mill, but by a *group* of capitalists, a consortium, a joint-stock company or some other umbrella organisation, shouldering responsibility for the energy needs of the manufacturers along an entire river or stretch thereof. In the legal universe of early nineteenth-century Britain, moreover, such projects necessarily assumed a *political* character: they could be implemented only if authorised by a 'local' or 'private' Act of Parliament, much like railway lines, turnpike roads or enclosures of land. On this scale, it was impossible – and illegal – for a mill-owner to go it alone.

At Greenock, as we have seen, local capitals amalgamated in a joint-stock company. The act of Parliament stipulated, in minute detail, the amount of running water to be offered – 1,200 cubic feet per minute, twelve hours per day – the location of the self-acting sluices, the size of the leats, the limited rights of mill-owners to initiate their own earthen-works, all the responsibilities and liabilities of the leaser. Two arbiters must be chosen: one by the company, one by the lessees. From day to day, they would monitor the operation of the sluices and the wheels; in case of disputes, they would appoint an oversman to settle the case. The company had certain rights to penalise a mill-owner who injured sluices or otherwise infracted on the rules, and a measure of local democracy was enshrined: if the proprietors of at least three-fourths of the mills were in agreement, regulations could be altered.[24] With this, energy consumption became a matter of public control and collective decision making, in a triangular relationship of company–lessees–Parliament. On the aqueduct of the Shaws, no capitalist was fully his own boss.

As for Irwell, an even more complex apparatus would have to be put in place. Baines counted 300 water mills on the most intensely utilised stretch, while Cooke Taylor felt 'sure that the valley of this little stream possesses more wealth than that of the largest river in Europe' and added: 'If rivers had feeling, the Irwell would have reason to complain, for it is the most hard-worked and overtasked stream in the universe.'[25] The Irwell basin was for industry what the Euphrates and Tigris were for agriculture: fertile and intensely cropped, home to hundreds of ancient or newly built clanking mills – not only for cotton but for wool, worsted, paper, timber, iron, bleaching, printing – from Bacup in the north all the way into the centre of Manchester. Could all these actors be united under one umbrella?

The attempt was set in train in the summer of 1831, with the initial goal of establishing a collective reservoir in the neighbourhood of Bolton. As the first Lancastrian imitation of Thom, this single tank of water would enable a select group of mill-owners 'to dispense with the assistance of steam-engines' to great pecuniary benefit, the *Guardian* reported.[26] Congregating in a Manchester hotel, the owners and occupiers of the affected mills and falls agreed that a reservoir would indeed kill two birds with one stone: excess water slowing down the waterwheels, and shortages of water having the same effect. The daily discharge would increase overall volumes in the stream. A suitable site had been identified in the townships of Turton and Entwistle, and so it was resolved to apply for an Act of Parliament and elect a committee to prepare the bill, under the technical leadership of Thomas Ashworth. The younger brother of Henry and Edmund, Thomas was an up-and-coming engineer who pursued his family's interests in water-based manufacturing by specialising in hydraulic infrastructure; in the shadow of his hot-blooded brothers, he would have a hand in all the main schemes in Lancashire, starring as the

county's response to Thom. The bill worked its way through Parliament; construction of the reservoir began in 1832.[27]

Placed near the source of a brook feeding into the Eagley river and from there into the Irwell, the Turton and Entwistle reservoir would have only a limited effect on the volumes and regularity of the main river. Manufacturers hooked on the idea and galvanised by the first victory therefore teamed up with Thomas Ashworth to draw up a far more ambitious plan: to cover virtually *all* the tributaries with reservoirs. With a mandate from another general meeting of mill-owners, Ashworth and his collaborator Peter Ewart – once a sales agent for Boulton & Watt, now master of his own steam-powered cotton factory in Manchester – identified a total of fifteen favourable sites 'at a considerable elevation above the sea,' each with the potential to generate 'a great extent of fall'.[28] Several maps of theirs have survived, watercolour and all.

All in all, the fifteen reservoirs of the Irwell scheme were scheduled to contain 241.3 million cubic feet of water and generate at least 6,600 hp, to the benefit of 745 mills already in operation – plus an unknown number of expected future mills on currently unoccupied falls – at a total cost of £59,016. It was a mammoth project. The figure for total power capacity might be compared to the 9,925 hp of *all* steam engines in the city of Manchester in the mid-1830s: smaller by a third, yet still representing an enormous addition of mechanical energy to the area. Thomas Ashworth estimated that several of the reservoirs would double, triple or quadruple present volumes, and 'besides the great increase of power which will be gained, the supply will be made at all times constant and uniform, thus obviating the principal objection to water power, viz: – its irregularity.'[30]

Figure 6.1. Cover of Thomas Ashworth's and Peter Ewart's maps of the fifteen planned reservoirs under the Irwell scheme.[29]

The *Manchester Guardian* was agog with bright forecasts. Articles reading more like advertisements repeatedly highlighted the special advantages of Thomian schemes in Lancashire: in no other part of the kingdom was there 'so much available water-power within the same compass'. 'An immense number of mills dependent upon streams' subject to wild fluctuations stood to be relieved from the inconvenience and, free from any recourse to steam, showered in profit: the *Guardian* compared the scheme to the single Turton and Entwistle reservoir, calculated to generate some 1,500 hp, 'which by steam would require an annual consumption of 60,000 tons of coal, the value of which, at only 5*s*. a ton, would be £15,000'. The far greater value of the multitude of reservoirs now proposed 'may be readily computed from the preceding data'. Reiterating the financial rewards – in which the costs for construction were, of course, included under the expected rents – the *Guardian* concluded that 'there are very few modes of investing capital which hold out fairer prospects of advantage.'[31]

A quasi-democratic entity would be set up to manage the common affairs. According to the Irwell Reservoirs Bill submitted to Parliament in late November 1832, all occupiers of mills supplied by water from any of the fifteen reservoirs would have the right to attend general meetings, but the franchise would be differentiated. Occupiers must pay 'rates' to collectively finance construction and maintenance, from each according to the water used: rates were to be levied 'in proportion to the number of entire feet of fall of water occupied'. A certain number would form the basis for one vote at the meetings; if the mill-owner occupied a larger fall and

paid a double rate, he would be given two votes; if his rates were assessed on the basis of three times the unit, he would enjoy three votes, and so on. Had he failed to pay the rates, his franchise would be automatically forfeited.

Drawn from the ranks of mill-owners, a group of commissioners – to be elected by the general assemblies – would be assigned to assess and levy rates; purchase land and resell land no longer used; survey streams and falls; build floodgates and spill-waters, channels and weirs, dams and embankments and other structures deemed necessary 'for providing and securing a regular supply of water'. Considerable powers were vested in their body. If any person rated for his water neglected to pay, the commissioners were free to obtain the sum 'by distress and sale of the goods and chattels' belonging to him. Persons wilfully damaging any property attached to the reservoirs could be apprehended without warrant and were liable to stiff penalties; the commissioners would have the right to pay informers aiding in their apprehension.[32] What was proposed was not so much a joint-stock company as a sort of riparian government, halfway between municipal authority and corporate bureaucracy, with the right to tax the occupiers, provide for their energy needs, regulate supplies, even hunt down offenders. A mill-owner would receive cheap and regular power, but *not from the hands of his own capital*.

The bill was first read in Parliament on 25 March 1833 – but at this point, the traces of the Irwell reservoir scheme are suddenly lost.[33] Silence sets in. None of the fifteen reservoirs were built: that much is clear. The bill never made it through Parliament, but the fate of the scheme remains shrouded in the fog of history, for there is no direct account of *why* it was scuttled. Normally, a bill for a local act of these dimensions would be the subject of an inquiry; a select committee would be formed, hearing the arguments of interested parties for and against the proposal, documenting the testimonies in handwritten minutes, possibly submitting a recommendation. Such proceedings survive from other, subsequent reservoir bills. But on 16 October 1834, one of the scientific disasters so characteristic of the discipline of history – the tearing of a hole in the record which no laboratories or model simulations can fill – occurred: the Parliament caught fire. In the worst conflagration London had witnessed since 1666, the flames consumed the House of Commons, including countless reports, petitions and books spread over benches and shelves.[34] Whatever materials on the Irwell scheme there might have been went up in smoke.

Our only hope, then, is to tread carefully through the few extant shards of evidence reflecting the nature of the opposition. It appears to have had its strongest base among the capitalists themselves: few were happy about the idea of reservoirs and rates. In the early months of 1833, Ashworth and Ewart took notes from a survey of the mills along the streams: the first manufacturer to be interviewed, in the neighbourhood of Bolton, stated his opposition unequivocally. 'Not only the proposed Reservoirs,' he declared, 'but the Entwistle Reservoir will be of no benefit, either to his Paper Works at Farnworth or to his Cotton Works at Prestolee.' Others argued that their factories were too distant from the reservoirs to reap any reward; even if released early in the morning, the water would still take hours to reach falls far downstream. 'Mr. Seddon is a determined opposer of the proposed Reservoirs, because he reckons the water will be 8 hours in coming to him, 8 miles from Holden,' site of the largest planned lake. The owners of a printworks already possessed all the water they needed and thus would derive 'no benefit' from the scheme; one master thought 'the intended reservoir will be an injury to him by giving him muddy instead of clear water'; another expected all gains to be lost, since the extra water would be 'held up by the Mill above,' while yet another thought a nearby store to 'be of no service to

him if the water be allowed to run past in the night'. The mill-owners were apparently unable not only to unite behind the proposal, but to agree on the reasons for their dissent.

Others were enthusiastic: Mr. Rothwell of the Woods Road Cotton Mill explained that he was often short of water for 'periods of an hour or two or three hours,' and so 'a regular supply would be a very great benefit to him'. Some declared their willingness to pay rates if benefits could be proven. At the venerable Radcliffe complex, one of the oldest establishments from the Arkwright generation, owned by Sir Robert Peel and family, the whole spectrum of opinions was represented: the spinning mill was 'never short of water since they got their new wheel' and therefore did not require a reservoir; the printing and bleaching works saw no gains but could countenance payment if such materialised; the adjoining works for bleaching 'consider they would be greatly benefited'.[35] Even among close neighbours, the energy needs could vary widely. A reservoir would, by definition, embrace them all in an overarching delivery system. The incongruence between the demands of individual mills and the supplies from a large-scale structure began to tear the plan apart.

In January 1832, as the bill was wending its way to Parliament, the *Manchester Guardian* spotted shallows ahead: 'We dare say it will be somewhat difficult to devise a system of rating, which shall charge each mill-owner exactly according to the benefit he may receive; because that must, in many cases, depend on circumstances to which no general rule can be applied.' Nevertheless, the paper – prime cheerleader for the scheme – was optimistic about the prospects for creating a 'tolerably equitable system' if petty self-interest could be kept at bay. 'It is therefore to be hoped that no jealousy of greater benefits to other individuals, will induce any of the parties to withhold their assent to a measure fraught with so many advantages to themselves and to their neighbourhood.'[36] But this seems to be exactly what transpired. Collectively advantageous though it was, the scheme incited individual ambitions to thwart it.

The responsible engineers saw the writing on the wall. In a printed address to the mill-owners in February 1833, Ewart conceded that 'it will be impossible by any practicable distribution of the increased supply of water, so to arrange it that all the works on these streams shall benefit in exactly equal proportions.' This impossibility had already sown seeds of defections: some well-served manufacturers 'are unwilling to join in taking the necessary measures' – that is, to pay for water needed by others. Mismatches between the power needs of mills uphill, where streams tended to be more irregular, and those downstream, where the water would arrive late, further complicated attempts to specify routines acceptable to all. Ewart found himself forced to propose an even more differentiated and complex system for rate assessment.[37] The countervailing claims – some having all water they wanted, others fearing losses from the reservoirs, others still envisioning no change – made for an exceedingly fraught scheme: squabbles appear to have killed it. But we cannot state this with certitude, since the end of the Irwell reservoir scheme was lost in the ashes of the Parliamentary fire, as well as, most probably, in the less spectacular weathering of data.

What is clear is that a water management scheme of Irwellian dimensions faced major collisions of interests. Insofar as it was necessary for the expansion of power capacities on a river such as the Irwell, the scheme raised problems of coordination and resource distribution of which an extra steam engine, a larger boiler, one more ton of coal per day were blissfully oblivious. Indeed, waterpower on this scale, in this time and at this place, appears to have suffered from some peculiar socio-ecological contradictions – all of which evaporated in steam. To learn more of them, we may turn to some other reservoir schemes tabled in the 1830s.

Divisions on the Tame

Undaunted by the failure on the Irwell, mill-owners in the neighbourhood of Saddleworth in the West Riding of Yorkshire, straddling the border between the cotton districts to the west and the woollen areas to the east, launched their own scheme amid the mid-1830s boom. In late 1836, Thomas Ashworth unrolled plans for three extensive reservoirs on the Tame. Two would be placed near its source and one on a tributary; all would feed their payload into the river as it passed through several towns before merging with another stream at Stockport to form the Mersey, then winding its way further through southern Lancashire towards the sea.[38] This time, Ashworth aimed at generating an additional 3,400 hp, to the direct service of forty to fifty mills. Though more modest than its Irwell predecessor, the Saddleworth scheme also set out to soak central textile districts – for cotton and wool – in abundant and regular water; the Tame, Ashworth claimed, was occupied 'with mills from one end of the stream to the other as closely as they can be conveniently set'.[39] Here was a second attempt to beef up some of the most strategic watercourses in the topography of industrial England.

A bill for the Saddleworth reservoirs arrived in Parliament in February 1837, immediately faced resistance from several groups of petitioners and was duly referred to a select committee. Post-fire, the proceedings survive. Thomas Ashworth pointed to a feast of benefits. Presenting elaborate computations, he sought to demonstrate the lucrative savings awaiting manufacturers when they no longer needed to burn coal, leading the chairman to ask,

> Have you any doubt with reference to the character of the country in this instance that they [the reservoirs] would afford the cheapest mechanical power?
>
> – I believe the plan proposed is the cheapest mode of it – giving mechanical power … It would be a great benefit no doubt to every mill upon the stream that is in want of water…
>
> You know a great many [mills] are worked by steam?
>
> – Yes a great many of them but not all.
>
> In what way if they employ steam will they be benefitted – they will lose the interest of their money?
>
> – The saving in the water will be greater.
>
> Will they give up working by steam?
>
> – Yes I have no doubt they will.[40]

Several mill-owners appeared before the committee to confirm Ashworth's assessments. As a hypothetical alternative to the Saddleworth reservoirs, the committee asked the owner of a spinning mill on the main branch of the Tame: 'If any of us were to subscribe to give you a Steam Engine you would be glad of it I suppose?' – 'If you would give me Coal with it,' he tartly answered. A bookkeeper at the Reddish cotton mill near Stockport complained that seasonal shortfalls of water sometimes forced the company to decline large orders; the reservoirs would allow them to take on any orders, and 'of course we should burn less coal if we had more water power.'[41] In the minds of these witnesses, the case was clear-cut indeed.

But then there was the opposition. Anti-reservoir petitions were circulated and public meetings held by an assortment of landowners, manufacturers, canal companies and 'inhabitants,' while in

the interviews of the committee, a tendency of faltering support emerged among the mill-owners themselves. Critics focused on the vast differentials in energy needs of mills upstream, midstream and downstream: factories below Stockport, where the Tame flowed into the Mersey, allegedly stood to gain the least. Champions of the scheme found it difficult to explain how the water would be of any utility to them; released from the reservoir in the early morning, it might be twelve hours late or more, reaching the bottom of the long river when the working day was already over. At one point Ashworth retorted, however, that any such problems could be solved by 'intermediate reservoirs,' by means of which water would be impounded and successively released in time for the morning shift. But that would require *even tighter coordination* among the mill-owners, further centralisation of planning, larger outlays and higher rates.[42]

The most eloquent surviving anti-reservoir manifesto was written by the trustees of one Ellis Fletcher, a prominent capitalist in the area, in whose possession were three mills near the bottom of the Tame. As the first reason for objecting to the plans, they pointed to the egoism of the mill-owners upstream, closest to the proposed reservoir sites: 'The measure is intended for the benefit' of those masters in the hills, 'who by this Act are compelling other parties who receive no equivalent advantage, to contribute to the expense of the undertaking'. As for the Fletcher trustees themselves, they already received enough water 'for every purpose' and had little appetite for paying for others. Rates were proposed to be 55 shillings per feet of fall, but there was no chance they would stay there; additional expenditures and hikes were a certainty, leading the Fletcher trustees to project a financial injury of £3,000 per year from the payment of rates 'forced upon them against their will'. In perhaps the most telling formulation, they claimed that the upstream promoters of the bill,

> from their number as well as from the height of their Falls, will have the power of outvoting and controlling all the Owners and Occupiers of Falls on the lower part of the Stream, with regard to the number and amount of the Rates, thus holding in their own hands the power of levying Taxes on others to be applied for the benefit of themselves.[43]

Power over energy supplies would, literally, be concentrated at the summit.

In his testimony, Ashworth had admitted to a sort of democratic centralism as the intended form of authority: 'The millowners being the commissioners will have the power of making their own arrangement' for the regulation of the flow. Evidently unpalatable to many, the vision cracked. 'Very powerful opposition' from manufacturers on the southern Tame and the Mersey forced the promoters of the bill to abandon their intention to levy rates on all mills, instead throwing the whole expense on the owners higher up the stream.[44] This would have raised the rates for the remaining payers. Did the shrinking base cause the scheme to topple over? We have, again, no way of knowing exactly, for the end of the Saddleworth scheme is about as opaque as that of its predecessor: none of the reservoirs were built; another planned expansion of waterpower had miscarried in the dark. But we do begin to discern a pattern.

Schemes for massive collective reservoirs proved divisive, pitting mill-owners against mill-owners. Some yearned for more and safer waterpower and would gladly pay a rent to finance all the common advantages; others were satisfied with what they already had, suspected future damages to their supplies, resented what they perceived as attempts by other firms to manipulate them or held all these reservations, with as little desire to pay rates as any other taxes slapped on their businesses by government. In more general terms, *the splintering forces of competition contradicted the demand for close coordination inherent in the schemes:* all must share the

flowing water, but the manufacturers kept their immediate private interests closer to heart.

The 1830s saw a brief offensive from the friends of water in the English manufacturing districts, Ashworth at their helm, but the lines quickly crumbled. In the 1840s, the battle for massive expansion of waterpower capacity in this crucial region had essentially been lost. Only a few token victories – minor reservoirs at Turton and Entwistle, Glossop and Holme – indicated what could have been accomplished.[45] What is more, Thomas Ashworth for some reason never adopted the cuts, aqueducts or self-acting sluices of Robert Thom: his schemes consisted of reservoirs solely, with relatively little manipulation of the river systems. Had Thom's more interventionist creation – proven and known at the time – been applied in Lancashire, total power capacities would have exceeded those envisaged by Ashworth for Irwell and Saddleworth. But hydraulic engineering for commodity production was nipped in the bud; abundant and cheap, the potentials of water were left untapped.

Not When Others Derive a Profit

Meanwhile, in Scotland, Thom continued to draw up schemes for virtually all the major centres of manufacturing. In 1829, he finalised a report on the feasibility of a reservoir system – complete with cuts and self-acting sluices – catering for mills in and around Glasgow. Optimistic as usual, he stated that the annoyance of irregular water could be removed 'at a moderate expence,' but there was a snag: how to settle upon the 'best method of conducting the water from the reservoir to the Mills. This is at all times a matter of some difficulty; and has in many cases as well as in this, been productive of much ill blood and litigation, with their usual unpleasant, and unprofitable consequences.' Quarrels could be averted, if supplies were so arranged that every mill would get its water on time according to a strict daily schedule; permanent gauges should be put below every mill 'so that a child may tell, by merely looking at them' whether they had received their shares or not. If these arrangements were adopted, all cause for dispute – so common and destructive – would disappear. [46] But it was rather the Glasgow scheme itself that vanished without a trace in the non-annals of unrealised history.

At Greenock, investments remained conspicuous by their absence. In the mid-1830s, the Shaws' Cotton Spinning Company was set up to establish the first cotton mill, equipped with a mega-wheel of 200 hp in a single piece. By the mid-1840s, however, only eleven other mills were operating on the eastern line, producing flour, corn, wool, flax, paper and other goods, but not the anticipated cotton. Eight sites on the eastern line were still unoccupied, and the western – with thirteen planned sites – had not even opened. It never did.[47] Thom's vision of 'thirty or forty elegant and extensive public works, rising like a crescent, above Greenock' and shining as an example to the rest of Britain did not come true: at the end of the century, it was still the largest waterpower system in the kingdom, one of its kind. Thom claimed to have 'made a great many' reservoirs – 'probably as many as any man living' – but unpublished and neglected, he aged with bitterness.[48] After his death in 1847, he would be as forgotten as his fellow Greenockian James Watt was lionised (although the reservoir above the town still goes under the name of Loch Thom).

He was not exactly alone: several other inventors and engineers came up with creative ideas for how to harness the flow of energy and steer clear of steam. Writing in *The Scots Mechanics' Magazine,* an anonymous 'Ayrshire gentleman' proposed a combination of the powers of water and wind. In situations where water mills struggled with irregular supplies, but 'where the

ingenious contrivances of Mr. Thom of the Rothesay Cotton Works cannot be resorted to' – presumably because the landscape was too flat – the answer was in the air. Wind itself was no more dependable than water, but it could be profitably used to drive a pump and raise water *back* to a reservoir above the mill: when the wind blew, the dam would be replenished; when neither wind nor water was at hand in sufficient quantities, the stored water would be released, serving as a buffer against the whims of the weather. Borrowing from the wind at practically no cost, allowing extensive reservoirs to be built far from hilly country, this solution would, the gentleman argued, give waterpower a new lease of life.[49] Nothing came of it.

One Manchester inventor focused on tidal power. A series of reservoirs would collect the high water and then portion it out to wheels when the sea receded: he suggested that 'at seaports, such as Liverpool and Hull, long river or sea walls be built, so as to impound the tidal water behind them, in reservoirs; and that the corporate bodies of these towns might let the power for mill purposes.'[50] The idea did not fly. A Dundee engineer pondered novel ways of storing up 'the fertilizing showers of heaven' – the potential for 2,000 hp from a reservoir on the river Leven should tempt 'even the most parsimonious mill-masters' to fork some money out – but despaired when trying to describe the colours of water to the blind:

> While all the mill-owners know and feel the evil [of seasonal irregularity], and many of them are convinced that reservoirs of sufficient extent would remedy it, yet *the difficulty of procuring the co-operation of all interested in the improvement of a mill-stream* … [has] in many cases, prevented even the attempt to do what would not only be a profit to individuals, but *a public good*.

The perfectly formed hills and valleys of Scotland stood as 'a reproach to the mill-owners from generation to generation'.[51]

Thom hinted at a similar explanation when asked in 1843 about his experiences with reservoir schemes:

> Did the Mill owners offer to go to the expence of making an embankment themselves?
>
> – Very often, no question about it, but generally speaking they do not do it.
>
> Not when others derive a profit from it?
>
> – *Not for other people certainly*.[52]

The difficulty of procuring cooperation among the mill-owners constituted the Achilles' heel of all the ideas for a more effective application of the flow – water primarily – floated at the critical juncture of the crisis. Free from all such worries, a crude option appeared more attractive. In the first volume of *A History of Industrial Power in the United States, 1780–1930,* dedicated to waterpower 'in the century of the steam-engine,' Louis C. Hunter describes the spread of collective reservoirs in New England (to which we shall return): after some time, the same difficulty emerged. Manufacturers who rented waterpower from central providers 'found their independence of action variously restrained by the system of power supply of which they were a part. Steam power,' on the other hand, 'provided a means *of escape and of independence* … With engine and boiler the millowner could do as he pleased, virtually without let or hindrance.'[53] The straitjacket of water from collective reservoirs – however powerful, however cheap – could be doffed in one stroke of the piston.

A Fossil Flight from the Flowing Commons

The flow of energy did not halt before the fences of private property. It respected no deeds or titles, bowed to no monetary transactions; it continued on its course, unmoved by conceptions of private property because it was always in motion. This had long been recognised in English law. In 1835, *The Law-Dictionary, Explaining the Rise, Progress, and Present State of the British Law,* a collection of precedents from thousands of cases, began the entry 'Water, and Water-Courses' thus:

> It is well settled by the law of England, that water flowing in a stream is originally *publici juris* [of public right]. By the Roman law, running water, light, and air, were considered as some of those things which had the name of *res communes,* and which were defined, 'things the property of which belong to no person, but the use to all.'[54]

In other words, running water, light and air constituted res communes because they were physically impossible to capture for exclusive appropriation and hence must belong to the people collectively: commons ordained by nature. In his influential *Commentaries on the Laws of England* from 1770, William Blackstone proclaimed that 'the objects of dominion or property are *things,* as contradistinguished from *persons,*' but water fell curiously between the two stools:

> For water is a moveable, wandering thing, and must of necessity continue common by the law of nature; so that I can only have a temporary, transient, usufructuary property therein: wherefore, if a body of water runs out of my pond into another man's, I have no right to reclaim it.[55]

So was there indeed something in the *nature* of water, light and air that made their energy incongruous with the principles of private property? It seems so: by its very physical determinations – its spatiotemporal profile – the flow was incessantly circulating through the landscape, ushered in and held back by the weather cycles, unresponsive to human attempts at production: a power created, wasted and regained by nature itself, as Babbage would have it. No purported proprietor could cut it up and cart it away or save it for later, neither entrust it nor dispose of it; only his temporary use could exclude others, until it was their turn. These were the ecological coordinates within which any endeavour at expanding waterpower capacity in early nineteenth-century Britain would have to proceed.

The reservoir schemes examined here were not the only ones to be mooted; in all likelihood, there are others, both shelved and realised, to unearth. All indications are, however, that the mill-owners fell afoul of the projects because of their unwillingness or inability to submit to the *planning, coordination and collective funding* required for expansion of waterpower capacity on this scale. Some foresaw no private benefit and so did not wish to pay. Some, prey to the constant antagonism between downstream and upstream factories, expected interruptions of their flow from other mills; some objected to the centralisation of authority. In all these cases, the opposition stemmed from the fact that river management – for the good of the mill-owners as a group – demanded that they step into the shoes of their neighbours. As flowing commons, the streams could not be extended privately; rather, the manufacturer would find himself, in Hunter's words, 'caught up in a complex network of institutional relationships that left him considerably less than a free agent in matters relating to power supply'.[56] The starting and stopping of machinery would have to be matched against other mills and schedules adhered to, regulations respected and commissioners welcomed, arbitration accepted and meetings attended; individual

plans for larger power capacities needed to be harmonised with common undertakings. The rates to be paid might very well deviate from the exact benefit reaped by the enterprise. Indeed, reservoir systems represented a form of *collectivised prime movers,* the res communes of water precariously imposing its logic on wary manufacturers.

'All narrow and immediately selfish views must be entirely kept out of view,' Robert Thom admonished the parties in his original report on the Greenock reservoir.[57] But this was decidedly not the zeitgeist. The logic of private property was violently accentuated in the structural crisis, the mill a turf to be defended in a war of all against all within the larger war on labour. The reservoir schemes provide a new wealth of evidence that waterpower was in fact abundant, cheaper than steam and technically viable at the time of the transition, but further massive expansion on its basis appears to have foundered on the capitalist property relations of Britain as articulated in the crisis. The oil of private property and water did not mix well.

Animate power and stock had none of these troublesome physical properties. More horses or human bodies could be assembled or contracted privately, without any need for coordination with strangers and competitors – but as we have seen, they were excluded for other reasons. There remained the stock. The greatest proof of the enormous advantage of steam power in this respect and its unlimited social potential to channel the expansion blocked from the rivers is the complete silence on the issue: no proprietors of steam mills can be heard protesting against a manufacturer higher up the road installing an extra engine. No one had his energy supplies directly diminished by his neighbour burning more coal in the morning. No plans for extensions had to be synchronised with others, and whatever price an individual entrepreneur paid for his coal – even if it was far higher than at Greenock or Turton and Entwistle – he could adjust it perfectly to his own consumption. The fire was his own.

Ironically, the same spatiotemporal profile of coal that made it dearer than water also made it more appropriate for capital. Having been brought into the marketplace by means of human labour, pieces of the stock circulated in physical freedom, available for combustion in absolute, indeed necessary detachment from other burners. Here the private property of cotton manufactures found a source of energy congenial to its logic: piecemeal, splintered, amenable to concentration and accumulation, divisible. 'In short, a motive power that in many respects was indeed a welcome gift of nature was often attended by a lack of independence in use and management,' and to make matters worse, it cost, in Hunter's trenchant formulation, *'emotional energy* from which steam-power users were entirely free'.[58] With this, we are very far indeed from the consummate rationality imputed to British industrialists by David Landes and innumerable other scholars. Drainage of emotional energy as a factor in the choice of steam power – clearly the more expensive option? Not what should be expected by enlightened entrepreneurs.

In fact, there was more to shy away from than complicated communal relationships. As Gordon has pointed out – also in the American context, but transferable to Britain – reservoir projects required considerable *skills* in engineering and management (embodied in such figures as Thom and Ashworth). They raised the demands on the intelligence and education of the manufacturers. Steam was the ruder option, more easily understood and manipulated, less of an art: it offered opportunities for 'managerial deskilling'.[59] Reservoirs entangled investors in *too much* of a scientific – and thus also cooperative – endeavour; with steam, they would not need to actively engage with the science, only receive it from others and switch it on in their own private sphere. In this sense, the engine won over the wheel because it was the *less advanced* productive

force.

The reservoir schemes hinted at a real alternative to steam. In the words of von Tunzelmann, 'if steam-engines had not in fact been invented, it requires little imagination to suppose that more orderly efforts to regulate water supply would have been undertaken.'[60] But 'invented' should here, of course, read 'adopted': it was all a matter of choosing between available technologies. Further extension of reservoirs would, needless to say, have had its own ecological consequences, but our concern is not the environmental desirability or destructivity of titanic hydropower installations: we are dealing with the dynamics of the transition. By the time of the structural crisis, and particularly the mid-1830s boom – around which the reservoir schemes were logically clustered – the power needs of cotton capital in the most central locations had increased to the point where continued use of waterpower required social qualities it plainly did not possess. Steam, however, could hardly have won only by dint of the collectivist drawbacks of water. It must have had some positive merits of its own.

CHAPTER 7

A Ticket to the Town: Advantages of Steam in Space

Where Labourers Are Easily Procured

John Farey was born in London in 1791 the son of a surveyor, land agent and writer on agricultural matters by the same name. Junior inherited Senior's inclinations, but, true to the tendency of the time, turned from the soil to the machine. A talented writer and draughtsman, he began touring English workshops and mills in the early nineteenth century, taking detailed sketches of the latest mechanical appliances and meticulously describing their modes of operation. The textile industry cast a particular spell on him. With stints in two factories, minor patented improvements of several machines, friendship with James Watt and other key actors and extensive field trips throughout the manufacturing districts, he accumulated considerable knowledge of the workings of British industry, soon put to remunerative financial effect.[1]

Together with his father and siblings, John Farey ran a consultancy firm in the field of research and development, as it would be called today. Not unlike his contemporary Ure, he assisted inventors in realising their ideas and, not the least, advised manufacturers on what machines to install; a technical muse in the service of capitalists avid to learn about the best route to profit, he was never short of work, always able to charge handsome fees. According to his biographer, Farey was a 'midwife to other men's ideas,' and precisely in that position, he wielded a special influence over the diffusion of technology: his work 'had an immense impact in spreading knowledge of new machines and processes, which in turn must have had some influence on Britain's industrial and economic development'.[2] John Farey Jr served as a conduit between formal patents – such as those of Watt – and actual users in mills, informing them about the material advantages of one device compared to another.

The sum of Farey's experience and the substance of his interlocutions with mill-owners were put on paper in *A Treatise on the Steam-Engine: Historical, Practical, and Descriptive*. Growing out of his acclaimed article on steam for the *Rees' Cyclopædia,* as well as his entries on such high-profile issues as 'cotton manufacture' and 'water,' the *Treatise* appeared in 1827; intended as a technical manual, it was interspersed with some persuasive arguments in favour of the new prime mover. The genre of handbooks and guides to the world of steam swelled rapidly at this time, and Farey's was not the best-selling specimen; shorter and more accessible texts attained

greater circulation. But other writers would refer to it as 'the most satisfactory work ever published' on steam power, and today, the two volumes of the *Treatise* are placed on a shelf of their own as 'the finest monographs on technology produced during the Industrial Revolution,' in the words of von Tunzelmann.[3] If there is anywhere we can look for the perceived merits of steam accurately stated, it is here.

Following in the footsteps of his father, Farey Jr purveyed a view of technology as beneficial to civilisation in a very distinct sense. According to Sr, the compulsion for the vast majority of the population to undertake incessant toil 'for the benefit and accommodation of others, is as inseparable from civilized Society, as a shadow is from the substance occasioning it'. Index of progress, increasing wealth always presupposes drudgery, as explicated by the father with unusual candour: 'Such Individuals only can be said to be *rich,* or possess property, who can thus command the labour of others, usually denominated *Poor.*'[4] For the son, the aim of the steam engine was nothing less than to expand the substance by widening, or perhaps darkening, its shadow. He opened the *Treatise* with a similarly straightforward declaration:

> Unless the industry of the working class is systematically applied, and aided by the use of machines, there can be but little surplus wealth to maintain an educated class in society, and produce that state of general affluence which is conducive to the progress of civilization, and the development of the intellect.

It was in this sense that the steam engine promoted the highest 'state of wealth and civilization': it facilitated the production of *surplus wealth*.[5]

More specifically, in the introduction to his *Treatise*, Farey juxtaposed water and steam as sources of power. He did not hint at any absolute scarcity of the former. The advantage of steam lay not in being uniquely plentiful, nor in commanding a lower price: nothing of the sort figured in his appraisal. Instead, Farey argued, steam 'is often preferred, because a manufactory by steam power may be established in any convenient situation,' whereas 'water power can only be obtained in particular situations, which are frequently unfavourable in other respects.' Of particular importance,

> natural falls of water are mostly found on rivers in the open country; but steam-engines can be placed *in the centres of populous towns, where labourers are easily procured*. Steam-power is frequently preferred, as a first mover for those mills which consist of a number of small machines, each performing some delicate operation; such machines require considerable assistance from work-people to direct their actions, and supply them with the materials upon which they are to operate. As all manufactories of this nature, require many work-people, they are more advantageously carried on by steam-power in populous towns, than by water-power in the country: this is fully proved by the number of large manufactories in London, Manchester, Leeds, and Glasgow.

Later in the *Treatise*, Farey returned to the point. Steam engines 'supply the place of water, wind, or horse-mills, so that, *instead of carrying the work to the power,* the prime mover is placed wherever it is most convenient to the manufacturer'.[6] With steam, the power could be brought to bear on the work.

Writing in 1833, J. R. McCulloch submitted a similar argument from his platform at the *Edinburgh Review:*

> The real advantage of the application of the power of steam to give motion to the machinery of a spinning mill, or of a number of power-looms, appears to be a good deal misapprehended. It does not consist so much in any direct saving of labour, as in permitting it to be carried on in the most proper situation. The work that is

> done by the aid of a stream of water, is generally as cheap as that which is done by steam, and sometimes much cheaper. But the invention of the steam-engine has relieved us from the necessity of building factories in inconvenient situations merely for the sake of a waterfall. It has allowed them to be placed *in the centre of a population trained to industrious habits*.[7]

McCulloch likewise returned to the point several times: 'Water is a cheaper machine [sic], but then a running stream cannot always be obtained.' The steam engine 'is applicable in every situation; it may be used wherever, from the number of inhabitants or other facilities, it is most desirable to establish manufactures.' But not only were the inhabitants more numerous in certain locations: they had also, as McCulloch repeatedly stressed, acquired an 'industrious' character – in other words, resigned themselves to the discipline of the master inside the mill.[8]

In these sales arguments – exceedingly common at the time of the transition, as we shall see – steam had the prime advantage of overcoming the barriers to procurement not of energy, but of *labour*. The engine was a superior medium for extracting surplus wealth from the working class, because, unlike the waterwheel, it could be put up practically anywhere. The differentials were ultimately rooted in the profiles of the two energy sources. Conditioned by the properties of the landscape, supplies of moving water were found only in some places; impossible to detach from the surface of the earth, their current could not – given the absence of electricity and, we should add, the misfire of Thom's visions – be transferred to distant sites. Water as a fuel was not portable. As Fairbairn pointed out in his *Treatise on Mills and Millwork,* wheels received their

> energy from falling or flowing water, and their power or dynamic effect clearly depends upon the amount of water supplied and the height through which it falls, or its velocity at the point of application. Hence water-wheels are usually placed on the banks of rivers where a large body of water is at hand, and near some considerable natural or artificial fall in the bed of the stream.[9]

Fairbairn counselled the investor looking for a place to build a water mill to calculate precipitation and runoff on the site, survey the catchment basins – moors and lakes would ensure more regular flow – inspect the content of the soil, examine levels of humidity and temperature: all relevant meteorological, geological, topographical conditions had to be mapped. If lucky, the investor would hit upon the optimal mix of profuse rain, a steep fall in the riverbed and, right above it, a gentle slope where large amounts of water were naturally stored. Total power potential was a function of volume *and* gradient, the best mill-sites encountered at the interface between mountain ranges and lowlands, where decent falls combined with ample quantities – such as in the Lancastrian and Scottish valleys.

Even if Britain had the right landscapes in abundance, there was always a sense of waterpower being a hostage to the local variations of nature. 'The best water wheel,' engineer Robertson Buchanan explained in his *Practical Essays on Mill Work and Other Machinery,* 'is that which is calculated to produce the greatest effect when it is supplied by a stream, furnishing a *given* quantity of water, with a *given* fall.'[10] Production had to be chained to those natural givens, and in the eyes of Farey, McCulloch and their peers, that proved an inconvenience. Rivers were neither occupied or exhausted nor expensive to exploit, but immutably local: whatever they gave the manufacturers could not be carried to labourers easy to procure and trained to industrious habits. Steam, on the other hand, rested on the converse profile of the stock.

So far, this case for steam power seems straightforward enough – but exactly what difficulties did the proprietors of water mills encounter in their procurement of labour? Might they not have

enjoyed some benefits, being at a distance from towns simmering with unrest and unions? Were not workers *more* easily controlled in secluded valleys than in the fluid centres of urban Britain? What precisely constituted the advantage of towns in this respect, and did steam power, with its demand for coal and water for boilers and condensers, really cut off the ties to particular spatial locations? Not the least important: why would this factor have operated more forcefully after than before 1825? To accept Farey's and McCulloch's contentions as the truth about the transition, we must identify with much greater precision how the factor of spatial mobility might have been articulated through the structural crisis.

Colonies for Carrying the Work to the Power

Early cotton mills were built where the entrepreneurs struck water. All other prerequisites for mechanised spinning – the raw cotton, the machines, the hands, the bricks, the money – were mobile in space: hence access to water determined localisation, as when Samuel Greg mounted his horse, rode out from his home in Manchester and scoured the rural hinterlands for a suitable riverbank. The same procedure founded Cromford and Papplewick, New Lanark and Rothesay, Deanston and Catrine, Egerton and Radcliffe, all chosen for what we might call their hydro-landscape features. From the days of Arkwright, the gold diggers of cotton spread into the Pennine valleys in Lancashire, the Derwent and its sister valleys in Derbyshire, the Clyde and Teith valleys in Scotland – to name but a few – in search of untouched, spurting supplies of water: a move *away* from towns seemingly inhered in the fuel. Part of the flow, streams could not be piled up vertically, but were stretched out horizontally in branches. The spatial coordinates of water dictated a dispersal of mills over wide areas – or, put differently, reliance on waterpower generated a *centrifugal dynamic* in industry.[11]

Not only did valleys and hills contain great falls and other favourable hydro-landscape features: riverbanks inside towns might become overcrowded. As much as Britain enjoyed a general abundance of water, *local* shortages were a fact of industrial life. Once the best sites around commercial centres had been seized, congestion might arise, neighbouring manufacturers jostling to secure their shares of the water: even while overflowing on the whole, all supplies in a particular locale could be fully exploited. Such mill jams emerged at certain stretches of the Irwell, in Nottingham, around Perth, on the river Aire in Yorkshire and several other favoured locations, where mill-owners at an early date expressed frustration over insufficient elbow room. When a saturation point was reached, expansion on the continued basis of water might be possible only through investment in fresh mills further afield or even outright relocation of existing factories, the centrifugal forces spinning with the growth of businesses.[12]

Now, hydro-landscape features as independent and dominant factors of localisation did not constitute a nuisance per se. Mills had been built where water flowed for centuries. It was no more intrinsically irksome than fishing villages growing up on the coast, shepherds taking their flocks to moorland pastures, corn fields bathing in the sun on flat and fertile plains or the customary embedding of any other economic activity in the landscape: the centrifugal dynamic of waterpower could only turn into a problem *at a historical juncture* in a relation between human beings. The better the water, the fewer, often, were the hands. The farther the manufacturers ventured from established population centres, the lower the likelihood that they would find workforces waiting to be employed: villages packed by denizens craving to enter a factory rarely lined the most powerful rapids. There appeared a mismatch between motive power

and a certain type of 'work-people,' the rectification of which would be the first task of the capitalist.

When Arkwright moved his machines to the backwaters of Cromford, he had, as a foundational act of his enterprise, to gather labour power to the site. Quickly exhausting the meagre pools of willing employees nearby, he placed advertisements in faraway newspapers and called for smiths, carpenters, weavers and spinners to make the trek to Cromford, where they would be furnished with 'good Wages'.[13] The majority of the workforce came to be imported from Manchester, Nottingham and Derby; foreign to the 'fine Stream of Water,' the immigrants had to be lodged somewhere. In the final three decades of the eighteenth century, Arkwright financed the construction of hundreds of housing units – many with attached allotment gardens – a market, a public house and other essential components of a settlement where workers would be willing to live and stay. Thus Cromford arose not only as the prototype water mill, but as the blueprint for the *factory colony,* most simply defined as a village with dwellings and amenities grouped around a water mill, put up and owned by the master. 'Carrying the work to the power,' in Farey's expression, was its raison d'être: where no town existed, a colony would have to be designed to draw in labourers, house them, equip them with tools and provide for their most basic needs. During the Arkwright boom, once the size of the mills had surpassed the local labour supply, colonies often grew to include a school, a Sunday school, a church or chapel, a shop or market for groceries, perhaps roads and bridges, maybe an inn and certainly a mansion for the manager. Without assistance from any authority or public budget, all construction expenses had to be defrayed by the manufacturer himself.[14]

The water-based system crafted at Cromford would, however, prove to be its own undoing. Arkwright's signal invention was not any particular machine, but the arrangement of many machines around a central prime mover: in the factory, he lined up devices for the carding, drawing, roving and spinning of cotton and energised them all by the thrust of the water-wheel. One prime mover gave the impetus to a series of machines, and unlike in the cottage or the workshop, it had to be non-human: 'Power was essential to the factory system,' Stanley Chapman has emphasised, because the 'synchronization of a sequence of highly specialised machines could not be effected by manual power'.[15] It was the mechanical centrality of the non-human prime mover, its *propulsion of an integrated process of production* that set the factory apart: an emergent property of this mode of organising collective labour, which has stayed with us ever since Arkwright.

But the factory system also required 'many work-people' – with Farey – of a rather peculiar training. A weaver, smith or farmer working in his own home, shop or field maintained a pace of his own choosing and performed the moments of production as his own skills instructed him. In the factory, the labourer had to conform to the motion of the central prime mover. She was under obligation to keep pace with it, carrying out the actions directed by its array of machines in unison with a whole team of operatives who had to begin, pause, restart and stop at signals. She must submit to the command of the manufacturer and his overlookers, who enforced compliance with the rules laid down; the hands – as they were so tellingly known – should know how to exert consistent effort, respect tools as the property of others, bow to strangers, work in a closely contained crowd.[16]

The water mill called forth the regime of *factory discipline,* which was, when it first appeared, intensely repugnant to most. Who could possibly be persuaded to enlist in these barracks? 'It is hard for one born in a mature industrial region, inhabited by patient and disciplined factory

workers,' economic historian Arthur Redford wrote in 1926, 'to realize the difficulties involved in the deliberate formation of a factory community.' The traditional culture of relatively free work, cherished not as a distant utopia but as the only known way of life, made even the destitute hesitate at entering the factory, whose architecture and regimentation resembled those of a workhouse. Even if hands did show up at the gates, there were no assurances that they would continue to turn up the next day, keep up the rhythm of work or execute the orders in due order: recruitment of workers acquiescing to the discipline soon proved to be a persistent headache for the first industrial capitalists.[17]

When the Finlays purchased the Deanston works in 1806, previous owners had struggled for two decades to fashion a solid workforce out of the slippery material at hand. 'A few persons professing knowledge in the art' of spinning cotton were, in the recollection of James Smith, manager of Deanston under the Finlays,

> got from Glasgow, and some from England; but those were generally of loose and wandering habits, and seldom remained long in the establishment. The more respectable part of the surrounding inhabitants were at first averse to seek employment in the works, as they considered it disreputable to be employed in what they called 'a public work'.[18]

Alternative sources of labour power were Highlanders and Irish farmers expelled from their lands, roving through Scotland in search of sustenance, but although more desperate than settled Scots, they were at least as ill-disposed to the factory system. 'The inexperienced were suspicious of the works, especially the Highland people, who regarded them as a kind of prison, the interior sound and sights of the machinery at work being in some degree a terror to them,' in the words of a chronicle of Deanston; according to the *Chambers's,* they were 'shy of entering this tower of Babel, with its unknown sounds and sights: they considered it a sort of prison.'[19]

Around the turn of the century, Deanston went out of commission for long periods due to absence of labour. As their most pressing task, the new owners had to catch workers for the long haul, and so one in the new crop of mega-colonies arose on the banks of the Teith, particularly in connection with the Hercules project. 'From 1820 to 1840 will be long memorable as a period of vast construction works. In that short period of twenty years appeared the new Deanston House, Deanston village,' a new lade, dam and vast embankments, 'new roadways, new Gas Works, the New Mill' and weaving shed, 'all of which were constructed at a great cost, under the watchful eye of Mr. Smith, and Deanston became renowned everywhere,' as an internal memorandum put it.[20] Serving their workers with allotment gardens, a church, a school, 'a circulating library' and a 'general shop,' the Finlays finally attained the goal of a reliable supply of workers. 'The population thus collected from various quarters, and being of all shades of the lower class, were gradually moulded into a respectable community; and industry, comfort, and happiness began to reign steadily among them,' in the self-congratulatory words of Smith.[21] But the cost of the achievement would prove high.

A similar process unfolded at Catrine, where the Finlays turned another flagging mill into a profitable enterprise by means of colony construction. In 1833, factory commissioner James Stuart stated that between 800 and 900 operatives worked at Catrine, 'all occupying houses originally built by the company, of a very different and superior description from those generally occupied by persons of the same situation in life in this country. They have a chapel, and every establishment necessary for their accommodation.'[22] But again, the success at Catrine would

become a heavy yoke on the Finlays. Further to the south, Quarry Bank Mill had to grow into a self-contained rural community once the local stock of hands and homes had been soaked up; the very bricks of the new buildings were made on the mill's premises from local clay. Before 1815, £1,300 had been spent on housing; between 1819 and 1831, no less than £6,000 went to the construction of forty-two new cottages and a mansion. Families were attracted to the colony by more spacious dwellings than in the towns, each with a good-sized garden for the growing of vegetables, and during the 1820s, the Gregs added a school, a chapel and a shop, also providing room for various societies of virtuous character.[23] It was a recipe for recruiting labour – but not for lasting financial success.

Following the example of Cromford almost half a century later, the second generation pushed the colony concept to its magnificent extreme: the appropriation of waterpower generally necessitated a process of *ingathering of labour power,* of concentrating workers from all possible directions on the spot. It was the defining feature of the colonies, their very structure intended to attract and keep labourers in place.[24] At first, the mill-owners may have subsisted on local reserves, but as their businesses expanded they would have to scrape together operatives from a widening catchment area and billet them in lodgings paid from their own pockets. The mismatch between power and population inherent in the centrifugal dynamic could be activated with a delay, as *the supplies of water exceeded those of labour power;* the relative abundance of energy opened up spaces for continued expansion, while the relative scarcity of hands forced the masters to conjure up entire villages.

Each worker then represented a living investment. A commodity purchased by more than wage payment, her presence hinged on the fixed capital of houses, gardens, shops and chapels as well as considerable efforts to inculcate skills and a minimum of discipline in her person. But a worker might depart. Already in 1777, the *Derby Mercury* announced that Richard Arkwright had sent a smith to the House of Correction for 'having absented himself from his Masters Business without Leave'; incidents of absconding workers were commonplace at Cromford and other early colonies, publicised in regular advertisements for runaways, referred to as manifestations of 'that restless and migratory spirit which is one of the peculiar characteristics of the manufacturing population'.[25] By this time, labour turnover could rise to excruciating levels in Manchester and other urban centres as well: the factory system was a novelty everywhere, the nascent working class cringing before 'this tower of Babel'. But when workers vanished from a colony, the loss was of a special magnitude, since the gap had to be filled with a new round of recruitment, more ads in newspapers, arrangements for immigration from distant quarters, perhaps even fresh embellishments of the dwellings. A general contradiction reared its head again: the water was in place, but not the labourers easily procured and trained to industrious habits. Before the crisis, however, there was a solution widely available to the proprietors of rural water mills. They could acquire *unfree* workers.

A Shift from Forced Labour to Steam Power

Before the use of steam power, mills 'were erected in situations commanding considerable water-power, but generally in country places remote from inhabitants,' the first Sir Robert Peel recalled in 1816, drawing on his own personal experience in handling the dilemma: 'to work these machines the surplus population of large towns was sought after, and many thousand of parish children were supplied from London, Birmingham, and other populous districts.'[26] When water

mills cried out for operatives in the 1780s, town parishes stood ready to succour them. At this time, poor-houses happened to be bursting at the seams with children; overseers were eager to jettison their urchins and bastards by sending them as indentured 'apprentices' to cotton manufacturers, who would feed, clothe and sweat them as they saw fit. The boys and girls themselves had no say in the agreements, of course. As soon as a child was in the hands of a parish, she could be dispatched if the overseer so wished, and once the transfer had been sealed, she would be the de facto possession of her new master.[27]

For the mills growing along the riverbanks in the late eighteenth century, wage labour on a voluntary basis was not a sufficient option; apprentices had the great merits of being available, denied their free will, accustomed to conditions of strict hierarchy from early childhood in poorhouses and not in a legal position to object to technological or organisational experiments. Unlike families of wage labourers, they required no private cottages and could be lodged in the hundreds in far more cheaply constructed dormitories or 'apprentice houses'. They might be ordered to work at night – something to which free labourers only consented if they were compensated – and whereas unbound children frequently hopped between mills in search of better conditions, the poorhouse hauls were captive for years. An average apprentice indentured from a London parish to a cotton manufacturer in the period between the 1760s and the 1830s commenced her service at the age of twelve and finished at twenty-one, meaning that she laboured for nine years – potentially half of her working life – without any remuneration whatsoever.[28] As Katrina Honeyman argues in her important study *Child Workers in England, 1780–1820: Parish Apprentices and the Making of the Early Industrial Labour Force,* the system gave a 'vital kick-start to enterprises that otherwise would either not have been established or whose subsequent growth would have been constrained'; an indispensable proletariat-on-demand, apprentices were used 'in all types of firms, large and small, successful and unsuccessful,' but particularly in waterpowered cotton mills.[29] The more isolated the locations, the greater the dependency.

At Quarry Bank, the first apprentice arrived in 1785, one year after the opening of the factory. According to the contract, Thomas Royley, an eleven-year-old 'poor child' from the parish of Newcastle, was bound to Samuel Greg until the age of twenty-one. During these ten years, he 'shall serve in all lawful businesses according to his Wit Power and Ability; and honestly orderly and obediently in all things demean and behave himself toward his said Master,' who would provide him with 'meat drink apparel lodging and washing'. The company's Memoranda Book later justified the recourse to this kind of labour – 'from the circumstance of population rarely being found with water power, almost all the early manufacturers were necessarily carried on by Apprentices' – and stated without compunction that the indentured children 'doubtless contributed both by their skill and low wages to the success of the concern'.[30] The same applied to the Peels, employing around 1,000 apprentices in their Bury mills at the turn of the century; to New Lanark, where there were 500; to Catrine, Holywell in Wales, Samuel Oldknow's string of factories in Stockport and hundreds more, all using apprentices to bridge the contradiction between the centrifugal dynamic on the one hand and the population distribution and attitudes towards factory discipline on the other.[31] Simply put, water mills became *dependent on forced labour* for their existence and expansion. But that was not a solution without its own contradictions.

Rampant abuse provoked a slowly rising tide of legal interference in the apprenticeship system. Not only overworked for a standard of fourteen to fifteen hours a day, possibly

undernourished and by definition incarcerated, the apprentices might be subject to beatings with sticks to keep them awake during night work, whippings with leather straps as punishment for underperformance, even experiments in torture. Rural water mills earned a reputation as penal colonies for innocent children. Purporting to engage in compassionate philanthropy, Parliament reacted with the acts of 1802 and 1816, in which some restrictions were first imposed: ceilings on the working hours, limits on the distances over which apprentices could be sent, specifications of the responsibilities of the mill-owners to maintain a modicum of health in their children. But implementation remained desultory, the masters mostly left alone to do with their assets as they wished.[32] In her comprehensive study, Honeyman disproves previous beliefs in the short duration of the apprenticeship system, demonstrating that it continued to grow and fester long after 1800, reached a peak around 1820 and only began to decline thereafter. The political interventions that put an end to the traffic rather occurred in the 1830s and 1840s, under the impact of the labour unrest of the period. In the Memoranda Book, the Gregs would remember the termination of the apprenticeship system with much bitterness: 'As a charitable institution, none could surpass it, but it was finally broken up from difficulties arising from Factory Acts, "Short time Committees" and "morbid philanthropy", or "official" dislike or jealousy of trade, and especially the Cotton trade' – so many references to the movement for shorter working days, the subject of the next chapter.[33]

Before the legal suppression set in, however, a perhaps more important process of spontaneous reappraisal was underway among mill-owners. Apprenticeship did not offer a truly satisfactory solution to the contradictions with which they struggled. Among its drawbacks were the costs for upkeep: although no wages were paid, the bound children were in the permanent custody of their masters, demanding outlays and time-consuming engagements with medical assistance, order in the dormitories, at least some rudimentary education – duties otherwise shouldered by parents and social institutions.[34] In 1833, Henry Ashworth stated his preference for unbound children, for 'I should not like to have the guardianship and maintenance of them'; a manufacturer would, the *Westminster Review* declared, 'naturally choose his young work-people from the population around him, from which he could procure as many as he needed, and of whom he had no sort of charge the moment they left the factory'. The best guarantee for the ability to make that choice was steam power. Through application of steam and relocation to towns, one observer pointed out in 1819, masters were 'released from the care and responsibility' for their child workers, all costs of reproduction transferred to third parties.[35]

A more consistently foregrounded theme was deficient motivation. This included a will to escape. Once apprentices had become experienced spinners, they faced the special temptation of running away to some mill where they would receive payment, a flight most likely to happen in the later stages of their terms – precisely when they were worth most for the masters, who had invested dearly in their maintenance and training. Hence proprietors would go to great lengths to prevent and punish escapes. Robert Hyde Greg, son of Samuel and manager of Quarry Bank Mill, threatened to cut off the hair of every absconding child and operated a solitary confinement cell for the captured; runaways were hunted down through advertisements, police searches and cooperation with parish overseers, indicating just how highly the adolescent properties were valued. Even if total turnover were lower than for free children, the departures of apprentices might well have been costlier.[36]

Over the 1810s and 1820s, apprentices came to be widely regarded as the most inattentive, listless and obstreperous of all workers.[37] Under physical coercion, they possessed no desire to

perform labour. Although appropriate objects for many an experiment, some crucial disciplinary techniques had zero effect: no fines could be slapped on them, their parents could not be warned and – by far most important – they were insulated from the threat of dismissal. The only stick that could be applied with some efficiency was physical. As for carrots, there were few if any positive inducements to dangle in front of apprentices: no wages, piece rates, bonuses or overtime pay. Paradoxically, absolute servitude minimised the means available for the extraction of the maximum amount of labour, as explained by Richard Muggeridge, agent of the New Poor Law commissioners: 'The incentive to industry and good conduct,' he reported in 1836, 'is lost, where the young person feels himself in a state of bondage'; without 'possessing either a motive to improve, or ambition to excel, he probably endeavours to do as little as possible; and the interests of his employer running in an exactly contrary direction, as he would get as much as he can at as little expense,' the conflict would prove incurable.[38] In the maturing factory system, the activation of an *inner compulsion to work* stood as a key objective of industrial management.

The springhead of such compulsion was steam. In the context of the early nineteenth-century cotton industry, the choice between free and forced labour could not be separated from that of prime mover. A spectacular illustration of the dual options was given by James McConnel, the prominent Manchester spinner, whose company had long been known as McConnel & Kennedy: in 1835, right in the middle of the boom, he expanded his business by purchasing a new set of spinning mills near Bakewell in Derbyshire. Two hundred apprentice girls between fourteen and twenty-one years of age staffed the machines. At one point, fifty of them ran away to take up paid work, for 'they thought they were giving their work to the masters for nothing,' leaving behind colleagues who flaunted their discontent, as related by McConnel with palpable frustration:

> For instance, in returning from their work, particularly if it was dark, they sang, in a body, what I may call revolutionary songs, having reference to their own situation as apprentices, and breathing defiance against their masters … The feeling of dissatisfaction manifested itself continually, and in a thousand ways.

Frequent corporal punishment was a 'necessity' in the Bakewell mill, claimed McConnel, but it did not succeed in altering the relative outputs from free and forced labour. There prevailed a 'striking difference in favour of the wage hands,' for 'labour is associated in their minds with reward, and with the comfort of their homes. The apprentices do less work than the other hands, and what they do is worse done,' and so 'capital sunk in buildings and machinery is less productive than where you have an industrious and skilful set of hands.' Why in the world, then, had McConnel opted for apprentices? Because

> if apprentices were not procured to do the work of the mills, the mills could not be worked at all, as they were erected in so secluded a situation, that if the whole population, of suitable ages, within two miles of the mills, could have been pressed into the service, it would have been insufficient to work them.
>
> Why was so retired a situation chosen for the mills?
>
> – For the advantage of water-power.

By expanding at Bakewell, McConnel chose a path contrary to the general tendency of the boom years. A proprietor of some of the largest steam mills in Manchester, he acquired a rural factory for the advantage of cheap water – only to run into the morass of apprentice girls 'breathing defiance'. Most cotton capitalists made the opposite move, and the case of McConnel elucidates

one of their reasons: 'General experience has decided against the [apprenticeship] system.' There was, however, as he himself admitted, the alternative of choosing waterpower *and* free labour, by winning over the latter to a splendid colony – but establishing family cottages at Bakewell immediately upon purchase would have caused 'a serious loss'.[39] At Quarry Bank Mill, the relative diminishment of the apprentice workforce from the 1820s onwards went hand in hand with an expensive upgrading of the facilities, in order to woo unbound substitutes.[40] Increasing reliance on free labour tended, as we shall soon see in more detail, to raise the costs and reduce the profitability of the colonies, thereby further underlining the benefits of the steam solution.

Writing at the height of the boom, Muggeridge offered a poignant explanation for the demise of the apprenticeship system, namely the recent

> application of steam power to manufactories. Unlike the earliest erected factories, which had to be reared where the power was to be found, and to draw a population to them to carry on the works, the steam-power was carried to the population. *Hill or valley, mountain or dale, river or brook, were alike matters of indifference;* the steam-engine could be erected anywhere, fuel (hereabouts [in Lancashire] easily attainable) and population being the only requisites to insure its capacity of adaptation to manufacturing purposes.[41]

The detachment of the stock from the landscape allowed capitalists to seek out waged rather than forced labour: a very considerable benefit. The shift to steam was a major cause of the decline of the apprenticeship system, but causation also went – and this is more significant for us – the other way. When the average cotton manufacturer wished to expand production in the mid-1830s, he would have been well aware of the legal obstacles to full utilisation of apprentice labour raised by the Factory Act of 1833, the first partial victory of the movement for shortening working days, *and* of employers' many negative experiences of pauper child performance. From his standpoint, steam did indeed offer a superior method of energising the exploitation of labour.

Cost and Control in the Colonies

The volcanoes of class struggle erupting in the structural crisis were predominantly urban in nature. Then would not manufacturers have avoided the heat if they relocated to the hinterlands? Robert Thom certainly thought so. One argument for water over steam was 'the superiority of the character of the operatives in the country,' easily ascertained by a glance at the behaviour of workers 'in such crowded and populous cities as Manchester, Glasgow, Leeds, &c. during the late *radical* commotions, as well as during the *combinations* of more recent date,' Thom submitted in 1829. In the colonies, relations were supposedly amicable. There 'the old and natural connexion betwixt master and servant is still maintained unimpaired,' whereas in the towns, the 'perpetual change of hands' dissolved all bonds, resulting in anonymity and hostility between the parties. Consequently, Thom's plan for 'rendering water power more generally applicable' – the reservoirs, the cuts, the self-acting sluices – was 'devised for transferring manufacturing establishments from crowded towns,' cooling the post-1825 social lava.[42]

It is surely significant that the main apostle of water used the same basic argument as the advocates of steam: this prime mover is better because it ensures greater industriousness and order among the hands. Here was a decisive battlefield of the crisis, where the contending motive forces had to prove their mettle. There was, moreover, a certain intuitive appeal to Thom's case: Ure worried that factories concentrating 'a vast population within a narrow circuit' afforded 'every facility of secret cabal and cooperative union among the workpeople,' while Robert Hyde

Greg, like Thom, stressed the 'mutual confidence' between masters and hands in the rural colonies, a feeling no longer present in the towns.[43] Was *water* the solution to class antagonism?

To explore the pros and cons of the colonies from the standpoint of cotton capital, we must first consider their costs more closely. Wages were lower in the countryside than in towns, by a margin rarely smaller than 3 to 4 shillings per week. The fundamental reasons for the gap were old and simple: rural working families often had one foot in agriculture, securing at least a fraction of their needs and lowering total reproduction costs; towns were more expensive to live in, with higher rents. To solicit legally free operatives, colonies had to offer incomes above the level of labourers nearby – in some instances, such as that of the male adult spinners of the Ashworths, they were higher than the regional average – but as a rule, monetary wages in the colonies did indeed stand *below* those in urban factories, dropping with distance from centres such as Manchester.[44]

Monetary wages are not, however, a useful measure of the differentials in living standards for workers, precisely because some food sources and colony pleasures – a cow of one's own, a garden with vegetables – would not have appeared on a pay slip; neither do they tell us much about the costs for the capitalists, for the same reason. Decent wages were rarely sufficient to entice farmers to shed their lifestyles or town-dwellers to migrate: proprietors would gild their pills with employment guarantees, bonus payments, cottages to low or no rentals and numerous other privileges of these hybrids of factory and homestead. At the bottom, all such perks represented investment in fixed capital. The very construction of a village was, of course, a cumbersome undertaking; there were Arkwright-era cases of mill-owners going bankrupt after having ploughed too much capital into workers' housing, and even heavier investments followed in the bonanza of the early 1820s.[45] With free wage labour on the ascent, easy credit and a nationwide rush to expand capacity, some manufacturers incurred considerable debts by revamping and extending their settlements, among them Dennistoun, Buchanan & Co, who took over the Stanley mill on the Scottish river Tay in 1823. The firm immediately embarked on a massive project of labour power ingathering, as described by factory inspector James Stuart:

> Messrs. Dennistoun, Buchanan, and Co., the owners of this splendid Establishment, have recently brought together a population of two or three thousand persons in a fine healthy rural district, in which there were previously no manufactures, have built a large village of handsome, clean, and comfortable cottages, have erected a church at the expense of above 3000*l* … They have permanently endowed the clergyman, and have also built a school and school-house, and given the teacher a salary,

and erected a waterwheel of 200 hp, and three new mill-buildings, and a street through the village, all at their own expense, amounting to a total of £160,000.[46] That would have been eight times more than the cost of establishing the Turton and Entwistle reservoir, or nearly three times more than the expected costs of the entire Irwell scheme.

At around the same time, Henry and Edmund Ashworth spent lavishly on the construction of pleasant houses at New Eagley, largest of their two mills; they were said to be 'built of stone, and contain from four to six rooms each; back-premises with suitable conveniences are attached to them all.'[47] Apart from libraries, chapels and a school, the brothers also established a hothouse for vines, a fountain, a fishpond, a peach house, an orchard, a summerhouse with a thatched roof: everything conceived as part of a palatably rural fond to factory work, a place where people would want to live. It cost them dearly. So did the above-average salaries paid to bring teachers to the schools, as well as the two doctors manning New Eagley and Egerton. Thus the rural water

mills developed a Janus-faced character of overcrowded dormitories in barns and tidy cottages with terraces, forced juvenile labour and spoiled free labour, dungeons of serfdom and lush gardens, punishment and pleasure, the shares of the components shifting with the concrete manifestations of the fundamental challenge: to procure and retain labour on the waterfalls. A summerhouse and a solitary confinement cell were two sides of that same coin. Nearing the end of the apprenticeship system, the Finlays and the Gregs and many others had, as we have seen, to flip to the other side; in the words of one Scottish factory manager, 'proprietors were at that time incurring great expence in assembling families near their works, from the dislike of the peasantry to the manufacture.'[48]

The expenses shifted the balance between water and steam. In 1826, an anonymous 'practical spinner' published a calculation on the prices of the two prime movers in *The Glasgow Mechanics' Magazine,* including as costs associated with water rent to the landlord, outlays on dam and sluices, expenses for transporting raw materials and a manager between mill and market. Even so, the steam engine's consumption of coal resulted in a balance in favour of water

> at the rate of £1.10s. per horse power: but this must be more than counterbalanced by the great advance of capital necessary to start such a work in the country, where a village must be built, loss of time in collecting a regular set of workers, with other innumerable inconveniences, which in many instances requires years to accomplish.[49]

Inside towns, none of these advances were necessary. Houses, streets, schools, hospitals, chapels, churches – if not fishponds and peach houses – were already in place, because, fundamentally, workers were.[50] A mill-owner in a town would not have to pay *directly* for communal amenities. After 1825, this must have made a significant difference: constructing whole villages on greenfield sites would have been the most intimidating form of investment during the crisis, with all its uncertainties and cash-strapped competitors struggling to stay alive. While Thom recommended a retreat to the countryside away from the riotous urban centres, his audience of manufacturers tended to walk in the reverse direction, partly, we may infer, because the crisis made colony projects – and perhaps Thomian reservoirs as well – seem too hazardous. The mid-1820s bonanza was never repeated in this regard.

But if colonies really would have smothered class antagonism, they might well have been worth the trouble. So did they offer capital the safe havens Thom envisioned? Cottages could certainly be remoulded into effective disciplinary tools: a free adult worker in a colony who displeased his or her master might lose not only a job, but also the family home. The threat of eviction was a deterrent against fermentation and combination – one most town manufacturers could only envy. While the owner of a colony had to concern himself with the life of the worker in all its dimensions – stamping out yearnings for flight, checking behaviour outside of working hours – he had correspondingly more powers of domestication at his disposal. A town did not belong to a single manufacturer; a colony did. In its laboratory, the capitalist and his managers could plan the living quarters, write the rules, patrol the streets, inspect the workers in their homes, keep records of their manners, oversee the instruction of reverence in the schools and through numerous other techniques fuse economic and social power in what took on a character similar to that of a totalitarian system. Henry acknowledged that he and his brother 'were sometimes thought to exercise a very despotic authority'.[51]

The colony could be portrayed as something of a latifundium or a demesne: the houses of the operatives in the colonies, wrote Gaskell, 'are built by the mill-proprietor, and in immediate

contiguity with the mill. Every thing connected with their mode of life is immediately under his eye'; here, 'a fixed population has arisen, which is as much part and parcel of the property of the master as his machinery.'[52] There were remnants of feudal relations in the water mills – just as in their reliance on forced labour and, indeed, the very nature of their prime mover. The owner was investor and rentier, landlord and churchwarden, chief of police and industrialist in one person; the workers grouped themselves around his hydraulic centre 'as did the peasants in the olden time, under the protection of the feudal castle,' wrote French journalist Léon Faucher in his *Manchester in 1844: Its Present Condition and Future Prospects*.[53] For many observers aghast at the disintegration of paternalist pyramids and outbreaks of class war, the colonies appeared to demonstrate that the pursuit of profit and the ideals of the old order could still be combined.

Thom, in other words, was not alone in his late bourgeois infatuation with colonies, nor did he fall into reverie when he proposed that factories be transferred from urban steam to rural water for a more effective taming of the working class. Others mulled similar solutions in the 1820s. One cotton master testified that he had sold his share in a Glasgow mill staffed by male spinners and removed to 'a mill in the country which has been worked chiefly by women' as an apparently successful way of getting 'rid of the combination'. During the strikes of 1829, spinners of fine cotton in Manchester were said to be considering a mass relocation to the countryside.[54] For a brief moment, some compasses might have pointed that way – but then the lava began to shoot out from the colonies as well.

Strike Action in the Colonies

Henry Ashworth burned with hatred of trade unions. He referred to the legalisation of combinations as 'this indulgent Act'; not long after it, spinners in his and his brother's factories entered the unions en masse. The peace of the colony was cracking. Tensions came to a head in March 1830, when the Ashworths elongated their mules with more spindles *and* reduced pay rates by 25 percent in the Egerton mill and 9 percent in New Eagley: several spinners refused to work under the new conditions. Soon a full-scale turnout was a fact, instantly renewing the problem of labour supply on the Eagley Brook. After sacking the union vanguard, the Ashworths had to advertise for strikebreaking spinners in Stockport, Ashton-under-Lyne, Bolton and Manchester, in the press and by handbills. They knew there were unemployed operatives inside the Cottonopolis and courted them, but failed to bring over more than a dozen despite handing out free blankets, sheets and quilts.[55]

The core of the strike was entirely homegrown: the young man identified as the leader had been received from the workhouse adjoining New Eagley and educated in the colony school – a viper nourished from childhood in the Ashworth bosom. On 10 April 1830, he directed a mob of some sixty spinners to vent their anger on the installations of the colony. All in women's clothing – some disguised men might have participated – they attacked the cottage of a newly enrolled spinner from Manchester, smashed all the furniture, beat the man unconscious and threw him in the street, proceeding to the house of the New Eagley manager who, under threats to his life, escaped up a chimney. The riot continued at the colony school. The tone of the report in the *Manchester Guardian* was indignant:

> They first demolished the windows of several cottages, and also those of the school erected by Messrs. Ashworth, at their own expense, for the use of the children employed in their mill, and others residing in the

> neighbourhood … The damage done is very considerable, nearly 300 panes of glass having been broken in the cottages and school.[56]

Before the rampage reached its key target – the New Eagley mill itself, below the village – someone rang the factory bell and constables arrived at the scene. Four men and one woman were arrested, the others vanishing in time. After the riot, New Eagley was thoroughly militarised: 'A number of special constables have been sworn in to protect [sic] the persons in Messrs. Ashworth's employ, and the mill is guarded every night by watchmen, well armed,' the *Guardian* informed its readers.[57] Protection was extended to the cottages and the Egerton mill, another 600 soldiers kept in readiness at Bolton in case of attack.

As such, the riot was nothing out of the ordinary at the time, not even making it to the London press; the dispute soon ended to the advantage of the Ashworths, who forced their workpeople to formally renounce union membership. But their victory came at a heavy price. The profits of the New Eagley mill were obliterated: standing at 5.7 percent in 1829, they fell to 0.7 percent in 1830 and, as the hardships continued even after calm had been restored, to 0.0 in 1831. While such a collapse in profits was also in line with general trends, in this case it was a direct result of the costs contracted by Ashworths due to the turnout. Testifying to the Factories Inquiry of 1833, the brothers were fuming:

> The pretended friends of the working classes, not inaptly called the agitators, have for several years kept up a continual strife betwixt our workpeople (who support them) and ourselves; causing serious interruptions to our business; sometimes by disagreements on the subject of wages, at other times by their intermeddling with our authority, or the regulations of our trading concerns, and latterly by their concocting of time bills [i.e. demands for a legal shortening of the working day]. We therefore hope that the result of the present investigation may lead to the enactment or the adoption of proper legislative measures.[58]

Though they shared their bellicosity with many an urban capitalist, the Ashworth brothers developed a national reputation as leading crusaders against organised labour, Henry touring the various theatres of war (including Preston in 1837) to write down the lessons for his camp. In every conflict at New Eagley and Egerton, the brothers insisted on unconditional surrender of the workers and complete renunciation of unions.[59] These were considered matters of survival.

Still the results were meagre, as the workforce remained agitated throughout the 1830s and 1840s. In 1836, his resources strained by the boom, Henry wrote private letters to Edwin Chadwick – previously head of the Factories Inquiry, now a commissioner for the 'rural police' – informing him that 'we have our men under engagement that they shall not belong to any union, but it is proved that they a few of them are contributing to the funds and by way of concealment the names of the Mills are altered.' On Christmas Eve, the brothers sent Chadwick a blacklist of the most troublesome spinners and requested police intervention.[60] In the late 1830s, the hands embraced Chartism, and in 1842, the general strike swept the Ashworth colonies as easily as the rest of Lancashire; in Cooke Taylor's slightly jaundiced summary, the mills were 'visited by a body of turn-outs, the machinery stopped, and the workmen compelled [sic] to go home'. Striking workers likewise approached the dell of Quarry Bank, gutted the house for female apprentices and a provision shop, and 'the Mill was stopped and remained standing for the 3 following weeks.'[61]

Up in Scotland, some 200 workers employed by the Finlays were said to have joined the union in the early 1830s 'for the purpose of forcing their employers to pay them a higher rate of

wages'; when their masters declined, they struck in December 1834. Tempers flared when strikebreaking 'knobsticks' were brought to Catrine. The striking workers tried to 'obstruct the said work-people, by forming a considerable crowd around them, and did throw dirt, &c. at the work-people, and strike many of them, and did make use of threatening and abusive language,' according to the manager's petition to the High Court of Justiciary in Edinburgh.[62] Barely had Dennistoun, Buchanan & Co. pumped their tens of thousands of pounds into the Stanley colony before it became a bulwark of the spinners' union, while the manager of one of seven cotton mills at Neilston, powered by the river Levern, complained in 1837 that 'the management of them has been found a much more difficult task for two or three years past than it was wont to be; and that a spirit of insubordination and dissatisfaction seems to be spreading rapidly amongst the working classes.'[63]

At some point in these years, Robert Thom's proposed project of relocation to the rivers unravelled. The colonies were evidently not sanctuaries from class struggle. To the contrary, the events of the early and mid-1830s threw them onto the very frontline, for they were *more vulnerable* to attack than urban factories, having to fend off strikes, unions and other manifestations of restive labour with greater fury. Naturally, strikes had occurred in rural water mills for decades, but those of the early 1830s appeared in a special conjuncture: let loose by the repeal of the Combination Laws, they hit colonies in which enormous amounts of fixed capital had just been sunk. As the *Guardian* emphasised, the vandalised school at New Eagley had been erected by the Ashworths 'at their own expense,' as had the 300 smashed panes of glass. An urban riot might be equally or more destructive, but outside the factory gates, fewer properties of a mill-owner could be targeted than in a colony *where everything was his*. Precisely because they were costly enterprises in the complete possession of the manufacturers, the colonies could less afford the swinging sticks of workers on the rampage.

Thus the perceived peace around 'the feudal castle' betrayed fragility, not only because the construction embodied so much capital, but also, crucially, because *the master would injure himself by dismissing unruly workers*. Mass layoffs were a favoured capitalist weapon inside the towns; in the colonies, they would turn back the clocks and force the owners to start recruitment all over again. While the threat of discharge against a single miscreant included the deterrent of homelessness, it was, paradoxically, far more difficult to execute for *collectives* of workers than in urban areas, where they could be replaced with comparatively little effort. The same constraints applied to the enlistment of strikebreakers. In the early phase of the structural crisis, the strike waves reached the colonies, unmade their harmony and turned their management into a nervous, potentially ruinous struggle against unions. After the late 1820s, we hear no more of plans to relocate cotton factories to the countryside.

A Spatial Crystallisation of Wage Labour

When the post-panic depression finally gave way to recovery in late 1833, manufacturers relying on water faced a critical test: would they still be able not only to hold on to the same scale of operations, but to *expand?* Could they keep up with their steam-powered competitors as another scramble for extended capacity set it? This was, above all, a question of labour. In June 1834, Edmund Ashworth bemoaned 'scarcity of labourers' and high wages, detailing the predicament of spinning masters like him: 'It is often the practice here, if a mill-owner is short of workpeople, to apply to overseers of the poor and to workhouses for families supported by the parish: of late

this has not always been attended with success.' Robert Hyde Greg snivelled even louder. 'At this moment our machinery in one mill has been standing for 12 months for [want of] hands. In another mill we cannot start our new machinery for the same want,' and so a continued boom would threaten to put unbearable strain on the company: 'Next year will, unless some unforeseen accident occurs, be naturally a year of increase in our manufactures, buildings, &c., and should this prove the case, any further demand for labour would still further increase the unions, drunkenness, and high wages.'[64] For the first time in a cotton boom, water mills could not rely on any publicly organised conduit for the delivery of additional labour power.

Meanwhile, there were the towns. Few transformations of early nineteenth-century British society were so conspicuous and widely commented upon as their explosive growth: 'A new society had arisen, owing to the congregation of large masses of unskilled labour in densely populated towns,' one MP observed in 1844.[65] In 1750, London was the sole English centre with a population exceeding 50,000; half a century later, there were eight such centres; another half a century later, twenty-nine, of which nine had more than 100,000 inhabitants. In 1801, 66.2 percent of the English population still resided in the countryside, but the share fell precipitously, and the 1840s saw the balance reversed forever: the census of 1851 for the first time registered a majority as living in urban areas. Scotland underwent a similar changeover with the rise and rise of Glasgow, passing Edinburgh around 1800, Paisley trailing one step behind.[66]

British urbanisation was a process sui generis: in 1851, the rest of the world remained overwhelmingly rural, perhaps one-tenth of humanity living in towns. The exceptionalism persisted throughout the century. In 1890, 61.9 percent of the population of England and Wales dwelled in towns with at least 10,000 inhabitants, while the figure for the country second on the list, Belgium, was 34.5 percent, France staying at 25 percent, China at 4.4 percent; by 1900, the metropolitan region of Manchester – including satellites such as Bolton, Oldham and Stockport – contained the largest concentration of human population on the planet. At no point in the century, however, did British urbanisation proceed faster than in the period 1811–1825. The first half of the 1820s marked the record with a 2.6 percent annual increase in the urban population of England. Certain towns evinced even more stunning rates, the population of Manchester swelling with an average of 3.9 percent in the 1820s, matched by several other northern industrial cities but outpaced by the metropolis growing faster than any other: Glasgow. Such a pace of urbanisation as Britain experienced in the run-up to the panic would not be attained in most advanced capitalist countries until the decades around 1900.[67] In other words, the years of the most decisive transition from water to steam were *immediately preceded by the greatest burst in urbanisation ever seen in Britain* and probably anywhere else on earth too.

Well underway already in the seventeenth century, the exodus from the English countryside gradually accelerated before culminating in the early nineteenth, when the human flows were dominated by ex-farmers abandoning their villages for the new conurbations of Lancashire. In the forty years from 1776 to 1816, most of the increase of the urban population materialised through this steady drain of people bidding farewell to their valleys and moors. Such newcomers would hardly have been more apt to perform factory labour than if approached in their original homes, perhaps not too far from a waterfall, but they soon begot their own children. The manufacturing towns were disproportionately brimming with youth, the age cohorts most inclined to pack up and move, and all those young women and men – also the most fertile segments of the population, for whom reasons to postpone intercourse tended to disappear in cities – set about reproducing. Immigration gave way to natural increase as the largest source of

urban population growth; as it happened, the shift occurred precisely in the 1810s and 1820s.[68] From this point onwards, the ranks of urbanites swelled primarily with second generations: young boys and girls born and raised in towns with no personal memories of other forms of social existence. Now *this* offered manufacturers an unrivalled – both quantitatively and qualitatively – reservoir of labour power.

But if young women and men moved to towns in search of employment, then why did they not respond flexibly to demand from waterpowered factories, even if these lay in the boondocks? Or, to put it in neoclassical terms: how could labour supplies for water mills be comparatively inelastic, when early nineteenth-century Britain stood out for its high rates of migration? The first thing to keep in mind here is that very few people moved to towns in search *specifically* for positions as spinners, piecers, minders or weavers in the cotton industry. Most looked for *any* unskilled jobs. As pointed out by Richard Dennis in his *English Industrial Cities of the Nineteenth Century: A Social Geography,* the migrants usually

> possessed no special skills and moved either short distances to their nearest town, or to a major city where there was a substantial demand for unskilled labour – in building and construction, on the dockside, in markets, as sweated labour, or as 'self-employed' washerwomen, hawkers and costermongers.[69]

To a fifteen-year-old woman leaving behind her parents in a Pennine hamlet, it was likely a matter of indifference if she found employment as a domestic servant or as a cotton operative: she would settle in the midst of the densest labour markets available. These were invariably urban. Cotton, after all, was an *exceptional* industry, and as qualitatively important as it was for capital accumulation, it failed to absorb anything like the bulk of the wage-labouring population. In 1821, factory operatives in the British cotton industry made up no more than 2 percent of the entire labour force of the kingdom; even in Lancashire, they constituted less than a fifth of the total population, although the share was considerably higher in selected towns.[70]

A colony, then, might be a drop outside an ocean. Towns were the obvious first destinations, and 'once the workers settled, the costs of moving again and the ignorance of conditions elsewhere inhibited the further easy adjustment,' in the words of economic historian Sidney Pollard; naturally, information on conditions in remote and isolated mills would be particularly incomplete.[71] Uneven settlement patterns had a strong self-reinforcing tendency: the greater the influx of migrants into a town, the larger the human base, the more intense the industrial and commercial life and the greater the influx of even more migrants from farther afield. The centres exerted a tremendous pull on workers. One early cotton manufacturer, Charles Hulbert, established a spinning factory on the river Severn in Shropshire in the first years of the nineteenth century, encountered the usual scant supply and found the agricultural labourers slower in learning mill-work than 'young people living in manufacturing districts'. Nonetheless, he hoped that

> wages being lower in those [country] districts, we should make a profit after our hands were instructed from the sole difference in the price of labour: and this was so far correct. But many of our instructed workpeople, notwithstanding all were engaged at regular wages for three years, left us for Manchester, Stockport, &c. We soon found that if business must be carried on to any great extent, where hand labour most easily is required [sic], *it must be in the neighbourhood of like manufactories,* where an advance of wages would speedily obtain the number of hands required.[72]

Workers would abandon water mills in Yorkshire and disappear into the urban mazes of

Lancashire or tramp from nearby colonies into Glasgow to try their luck. The magnetism of towns emanated, most fundamentally, from the broadest possible spectrum of unskilled job opportunities, but other generic appeals of urban life – including meat markets – cannot be discounted. The towns were snowballing unbeatably, producing a stickiness, reducing the elasticity of the labour supply for rural water mills: spatial crystallisations of the wage labour relation, they were antipodes of the empty riverbanks. Wage labourers made up the overwhelming majority of the main towns of Lancashire and Scotland, estimated at 81 percent in Ashton, 90 percent in Stalybridge, 85 percent in Stockport, 84 percent in Oldham in the early 1840s.[73] But in its overall contours, that pattern was established already before 1825. Then is there any reason to suppose that it lured manufacturers to switch to steam more effectively after the onset of the crisis?

The Lure of the Town before and after 1825

The steam engine as a ticket to the town, where manufacturers would encounter plenty of manageable labour, was sold and bought from an early date. In 1818, John Kennedy described how the engine offered salvation from the curse of a constantly renewed parting with labour: 'Waterfalls became of less value; and instead of carrying the people to the power, it was found preferable to place the power amongst the people, wherever it was most wanted.' McConnel & Kennedy being an early giant of steam in the cotton industry, we may assume that Kennedy spoke out of personal experience: *this* was the main reason for choosing stock when most manufacturers still went for flow. In 1823, likewise before the pivotal moment of transition, Robertson Buchanan wrote of the particular value of Watt's engine: 'Power and people might, without trouble, be concentrated on the most eligible spot'; inside the towns, the 'unprecarious supply and steady exertion of such numerous hands' would render operations more profitable.[74]

Writing in the past tense, both Kennedy and Buchanan seem to have suggested that the visiting work of steam power was a prime reason for its application well *before* the crisis. And indeed, this could explain the introduction of steam in cotton mills around the turn of the century, when the abundance and possibly also the cheapness and technological superiority of water were *even greater* than it would be further down the road. Any decision to choose steam prior to 1825 must have been based on a trump card beating those impressive advantages; spatial mobility appears to have carried that weight with some. Already in the 1810s, the establishment of large mills inside Manchester or Glasgow was considered a dress for success.[75]

After 1825, the relative attractions of urban steam multiplied. When a capitalist would decide on the location of a cotton mill in the 1780s or 1790s, factory discipline was a novel phenomenon everywhere, the urban population as unfamiliar with it as any other: then it made good sense to reap the benefit of cheap water. But in the towns of the 1830s, 'the second generation of factory workers had grown up and parents were only too eager for their children to be accepted into the mills,' in the words of Pollard. The rearing of native-born workers produced habituation to a world of clanging machinery, bells and overlookers, the second and forthcoming generations resigned to life in the factory in a way countryfolk – whether southern paupers, northern handloom weavers, Scottish Highlanders or farmers from anywhere – were not (and perhaps would never be).[76] At *this* point, the establishment of a cotton mill in a rural situation, where the recruitment would have to start de novo, might be tantamount to a regression to the 1780s or the 1790s, the manufacturer missing out on the intervening process of acculturation.

By 1846, Henry Ashworth had realised that steam-powered urban mills had secured a historical lead. 'If you are attracted into a country place where there is water power as an inducement, it requires a generation or two before you have made the people apt enough to work profitably, as compared with those who are in towns.' Few manufacturers would have sacrificed several decades waiting for their operatives to throw off an average profit; steam had leapt ahead with the urban pools, and the entrepreneur endowed with a survival instinct had to follow. In 1834, James Fernley, owner of a steam-powered factory in Manchester, waved his upper hand: 'There is always that superabundance of labour in the market that *I can always attain a sufficiency of hands who have been accustomed to the work, and brought up in it,* I suppose; which are always preferred.'[77] Henry McConnel, brother and partner of James, sometimes lacked child workers, but 'there is a great abundance of labourers above eighteen,' and those employed 'are generally educated in our own works, and we seldom, if we can avoid it, engage strangers'.[78] The firm's steam-powered Manchester mills were, in other words, self-sufficient in adult labour power; indeed, neither McConnel & Kennedy nor other cotton manufacturers appear to have had *any* difficulties procuring labour power – as long as they stayed with steam, inside towns.

The 'superabundance' was a particularly great boon and the contrast starker than usual in a boom. Whereas Henry Ashworth complained to Chadwick in February 1835 that 'there is in this neighbourhood a greater scarcity of workpeople than I have ever known,' Mancunian manufacturer Robert Gardner was asked three months later if he saw any such shortages, answering: 'No, certainly not; there is a superabundance of spinners.' While the Gregs hunted high and low for hands to start their machines, Peter Ewart testified from the Cottonopolis that 'we have five to six applicants when a vacancy occurs in our establishment.'[79] *Here were the real bottlenecks on waterpowered expansion*. When the critical hour struck, Fernley, McConnel, Gardner, Ewart and their compatriots of urban steam possessed a springboard into the boom very different from the stumps at Styal and Egerton. Thus the first intensified attraction mirrored a hardening contradiction between the centrifugal dynamic of the flow and the growth of towns, no longer fed by immigration as much as by reproduction in situ.

Secondly, the superabundance to which urban capitalists could refer exploded after 1825. Chronic underemployment of factory operatives was an integral aspect of the crisis, caused not only by stagnation as such but also by technological progress, the Iron Man and his auxiliaries dispensing with spinners and forcing them to loiter in the towns and knock on the gates – and they were as familiar with mill work as any hands could possibly be. The combined effect of post-1825 depression and automation was a virtually permanent surplus of labour power, naturally concentrated in towns, radically enhancing the spatial advantage of steam.[80] Thirdly, and perhaps most importantly, the switch from handloom to power loom practically *doubled* the need for machine operators in the mills. As late as in 1813, there were twice as many handloom weavers as factory operatives in the British cotton industry. Their numbers stagnated with the first diffusion of the power loom in the early 1820s; a bifurcation point coincided, as can be clearly seen, with the onset of the mid-1830s boom. Henceforth, the category of labourers working in their homes would shrink to a minority, soon altogether extinct; 200,000 handloom weavers disappeared between 1825 and 1848, while roughly the same amount was added to the number of operatives – partly due to expansion, but more to automation.[82] The rise of the power loom entailed the destruction of a whole tribe of independent home workers and the concomitant creation of a subordinated infantry of factory hands: automation did not terminate the demand for

labour power as much as it shifted it from one type to another. The new type could best be found inside towns.

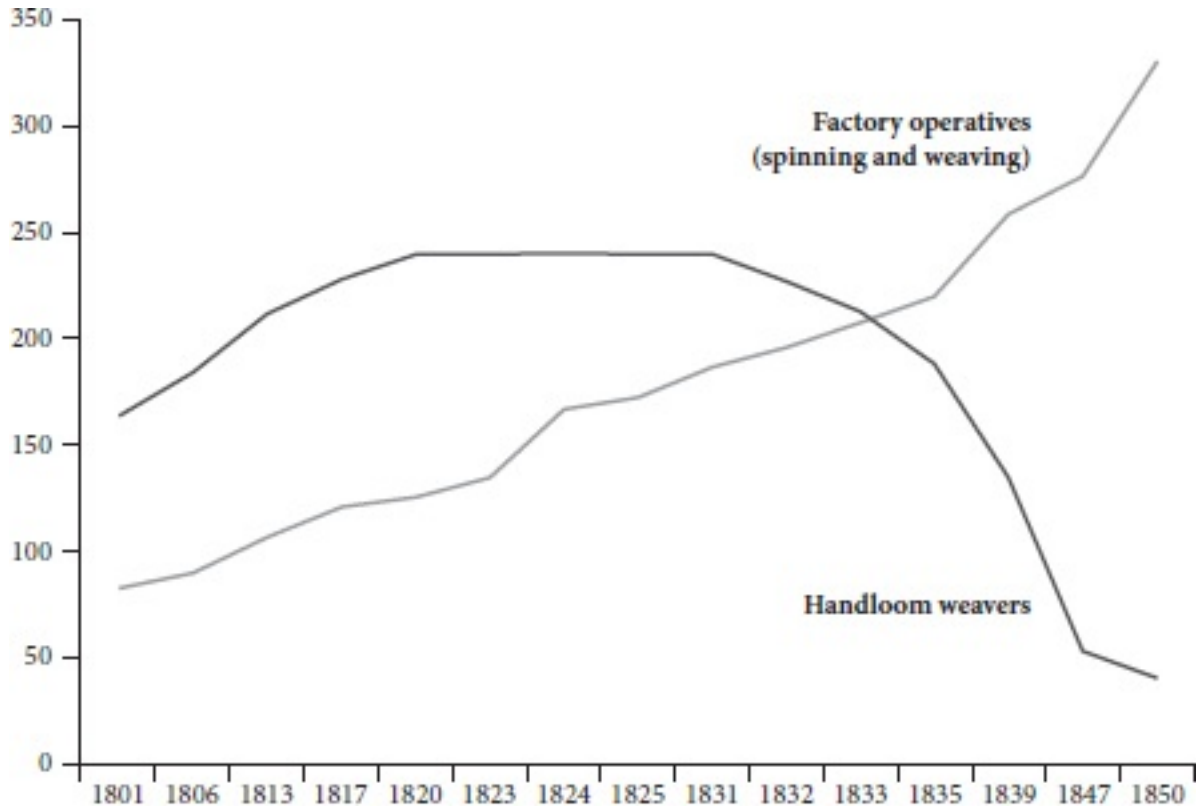

Figure 7.1. Handloom weavers and factory operatives in the British cotton industry, 1801–50. Weavers and operatives in thousands.[81]

Unlike in the department of spinning, weaving by machines was an urban activity from the start. It upset the calculus of localisation. As long as traditional weaving flanked mechanised spinning, the insertion of a mill in a rural backwater remained feasible or even expedient, as surrounding households were often engaged in the industry through putting-out. A combined factory, on the other hand, increased the need for operatives *and* cut the ties to the web of semi-agricultural, semi-domestic workers that populated the northern countryside, at once raising the value of spatial concentrations of people and reducing the need for outworkers. Like the self-acting mule, the power loom demanded of its minders utter resignation to the diktat of the machine. It pulled the industry to the town with redoubled force.

Fourthly, the substitutability of workers inside towns gained added strategic significance in times of fierce class confrontations. An incurable romantic, Sir Walter Scott deplored the decline of the colony and the rise of the urban steam mill, and in the process captured the commercial appeal of the anonymous mass:

> When the machinery was driven by water, the manufacturer had to seek out some sequestered spot where he could obtain a suitable fall of water, and then his workmen formed the inhabitants of a village around him, and he necessarily bestowed some attention, less or more, on their morals and on their necessities, had knowledge of their persons and characters, and exercised over them a salutary influence as over men depending on and intimately connected with him and his prospects. This is now quite changed: the manufactures are transferred

> to great towns, *where a man may assemble five hundred workmen one week and dismiss them the next,* without having any further connection with them than to receive [sic] a week's work for a week's wages, *nor any further solicitude about their future fate than if they were so many old shuttles*.[83]

By dint of its spatial fixity, waterpower obliged the manufacturer to form *personal relations* to his hands, whether they were bound apprentices whose needs he must provide for or free labourers for whom he spun a cocoon encompassing all aspects of life, from religious instruction to basic health care. Estranging him from his neighbour, steam power, on the other hand, allowed the capitalist to treat his workers as 'so many old shuttles'. They could now be discarded at will, replaced with ease, left to fend for themselves on the housing market, unknown and immaterial in any other respect than as a temporarily hired capacity for labour. If the management of workers in rural water mills oscillated between the poles of slavery and seduction, in urban steam mills there was need for neither: here the factory operative more closely approximated an impersonal, objectified *commodity*.

As the repeal of the Combination Laws restricted the options of physical attacks on unions and strikers, effortless replacement of workers became all the more important. The 1837 showdown in Preston is a case in point. The union was defeated not merely by the introduction of self-actors, but just as much by mass dismissals: of 650 spinners working before the turnout, only 367 were allowed to return (many as minders) at its end. Throughout the strike, the mill-owners made concerted efforts to recruit new hands and train them in spinning – a task dramatically simplified where self-acting mules were installed – and as batch upon batch of fresh, non-unionised operatives were set to work, the union fell apart. In Glasgow, the final battle of the same year was brought to the identical conclusion: replacement of male spinners with young women and Iron Men shattered the lines of the union.[84]

In Oldham, the masters felt so confident in their access to labour pools that they refused to immediately reengage even those who capitulated in a late 1836 strike 'in order to acquaint the operatives with the nature of their will'. 'The threat of discharge we conceive as one of the most effectual means of securing proper obedience and due subordination amongst all the hands employed by us,' the proprietors of a steam-powered spinning mill in Dukinfield affirmed in 1834.[85] Inside Lancastrian cotton towns, the masters made it a habit to display the rule of two weeks' notice for all the hands to see – an impossible luxury in colonies, where the masters strove for long-term contracts. Throughout the war between labour and capital in the cotton industry, this ability to pick and choose between workers proved a decisive weapon. Less vulnerable to unrest than colony capitalists, urban mill-owners had far greater leeway in their dealings with the organised enemy, reducing it to so many old shuttles in a way no rural manufacturer could afford.

The license to 'assemble five hundred workmen one week and dismiss them the next' was thus highly treasured after 1825, as was – and this may count as a fifth multiplied attraction – the freedom from having to plough money into colony construction. All that mass of fixed capital tied the proprietor to the site for the very long haul, constraining his liberty to relocate in search of more pliable labour. 'When the nature of the work is such that it is not possible to remove it,' Babbage wrote, 'the proprietors are more exposed to injury from combinations among the workmen.' Prospering manufacturers guarded the potential to escape to places where there were no domineering unions, but some prime movers shackled them to the ground. One released them: 'When the machinery of a factory consists of a multitude of separate engines, each complete in itself, and all put in motion by one source of power, *such as that of steam,* then the removal is

much less inconvenient.'[86] The class contradictions of the crisis could only be resolved – or displaced – on a steam footing. At least five factors increased the lure of urban locations after 1825 – the presence of a second generation of factory workers, the superabundance of unemployed hands, the doubled need for machine operators following the adoption of the power loom, the enhanced strategic significance of the substitutability of workers, the freedom from costly and constraining colonies – and constituted so many compelling reasons for the automation of cotton production to land on stock rather than flow. Only thus could concentrated power be exercised over the people.

And this Preference Is Given, Why?

Already in 1829, the forecast for Quarry Bank Mill was glum. The panic had hit the concern hard, and an ageing Samuel Greg did little to improve its prospects – or so his most enterprising son, Robert Hyde, thought. In a letter to his father, he predicted that 'capital is now so abundant, competition so extreme' as to withhold all profits for the foreseeable future, a situation truly unworthy of the family: 'If others can live, we ought to grow rich.' At the core of the hardships lay 'the Old Mill,' its constant losses a drag on the company; the machinery had become outdated and the buildings a millstone, raising the 'serious question, whether if we'd not be better to abandon the place'.[87] Such a drastic measure was not taken. Instead, the death of the paterfamilias in 1834 was followed by a technological face-lift of the Old Mill, self-actors and power looms coupled to the waterwheels, but there were limits to the expansion: fresh weavers, minders, piecers and other workers would have to be brought to the site. With steep slopes on both sides and some lands susceptible to flooding, the landscape dictated a high cost of further colony extension. 'The nature of the ground round Q.B. mill scarcely admits the possibility of increasing the concern, if desirable to do so. *The small population also forbids any increase of the place,*' the internal memoranda book reflected the reasoning.[88]

Luckily for the Gregs, however, they possessed other options. In their portfolio since the mid-1820s were two combined factories running on steam inside Lancaster and Bury. During the course of the 1830s, Robert Hyde canalised most renewed investment to them; indeed, already in 1832 the one in Lancaster had surpassed 'the Old Mill' in size. Like its sister in Bury, it had one decisive advantage over Quarry Bank and the two smaller water mills of the concern: supplies of labour already living nearby. Free from the colony albatross, the two steam mills consistently generated profits, to the extent that they plastered over the losses incurred on the streams. Quarry Bank Mill survived for another few decades, more as a laggard than a leader; further expansion would be directed towards urban steam.[89] The Ashworths had no similar assets, straggled behind in the race for automation and, as the 1830s rushed by, lost their position of technological leadership in fine spinning. Operatives decamped to Bolton and other Lancashire towns; frequently fined for bad work and exhausted from the hard labour at the elongated mules, they could be kept in place only through relatively high wages. Profits were compressed, expansion plans curtailed. The Ashworths would stay put in the business for several decades to come but never again return to the helm, where more successful manufacturers now chiefly used steam.[90]

Further to the north, the Finlays commissioned, as we have seen, an independent valuation of their three water mills in 1844: comparing Catrine with a typical factory inside Glasgow, the valuators concluded that the water saved the firm £242.13.10 per annum – 'but which sum we do

not consider equal to *the additional cost of management required*'. Likewise, the savings in the cost of coal at Deanston, worth some £700, were annulled by 'the extra cost of management compared with a work in Glasgow'. The smaller Ballindaloch would have fared even worse had it not been for its valuable estate.[91] A fortnight after receiving the judgement on their colonies in black and white – cheaper than steam mills in terms of energy, more expensive on the whole due to the hassles of rural labour – the Finlays advertised all three for sale. Giving up on Hercules, they put a power capacity of at least 600 hp – double the largest steam engine of Manchester – on the table, but symptomatically failed to find a single buyer for either Deanston or Catrine. Only Ballindaloch was sold. The two mega-mills clung to the company like badges of disgrace rather than honour; since both had mostly yielded losses for two decades, their value was written down in the late 1840s, production dragging on in outmoded heirlooms.[92]

Robert Thom made the same bitter experience. In 1834, he looked back on the strikingly successful implementation of his plan for the Shaws' waterworks, with perfectly regular and cheap water on offer to investors:

> Yet notwithstanding all these advantages, the waterfalls there go off very slowly – there being about thirty of them still unlet – while during the time these have been in the market, a great many Steam Factories have been erected at Glasgow, though steam power there costs about £20 per horse power, or nearly seven times the cost of water power at Greenock. And this preference is given to Glasgow, why? Because it is the principal seat of trade in Scotland with a trained population ready for such Factories.[93]

Thus the general contentions of Farey and McCulloch received strong confirmation from practising cotton manufacturers. They were echoed in other steam engine manuals, some of which quoted the creator himself: *'Instead of carrying the work to the power, the prime agent is placed wherever it is most convenient to the manufacturer,'* Watt once claimed of his engine, the emphasis his own. Even more remarkable in its foresight is the following assessment from 1781: 'Our rotative engines which we have now rendered very complete, are certainly very Applicable to the driving of cotton mills in every case where the convenience of placing the Mill in a town or ready built Manufactory *will compensate for the expense of coals.*'[94] It only took around half a century for Watt's prediction to come true.

The saliency and frequency of this kind of statement – from Watt via the manuals to the hydraulic losers – indicate a common knowledge among commentators and capitalists, engineers and economists, mill-owners and millwrights: steam was adopted in spite of its massive drawbacks *because of its mobility in space*. This was such an overriding advantage primarily for its outreach to labour power. The argument was constantly reiterated, even on the other side of the transition; as late as in 1866, Jevons maintained that 'when an abundant natural fall of water is at hand, *nothing can be cheaper or better than water power*. But everything depends upon local circumstances.' Some such circumstances worked to the detriment of this source of energy: 'The necessity, again, of carrying the work to the power, not the power to the work, is a disadvantage in water,' settling the matter once and for all.[95]

Hence the transition was all about power, in the dual sense. *The very same desire for subordinated human labour that animated automation drove cotton capital towards steam*. The semi-feudal visions of Thom and other colony idealists plainly failed to conform to the logic of the period, as the guns of the self-actor and the power loom had to be mounted – and partially created their own platforms – inside built areas. One step further back in history, an irony appears: *the very same desire for factory discipline first spawned by the water mill eventually*

caused its demise. But supplies of labour power were not, of course, the sole magnet of the towns.

Steam and Agglomeration Economies

A waterpowered colony had to collect not only labour, but also raw materials and other components. Once ready for sale, the products had to be brought back to the market. The centrifugal dynamic tended to stretch out distances in both directions, and so John Farey held that another merit of steam was that it 'enables a manufactory to be placed at once in the vicinity of the market for the purchase of its materials, and for the sale of its produce, instead of carrying the materials to a water-fall'.[96] True to its nickname, the Cottonopolis served as the nerve centre for the distribution of raw cotton and finished products, the density of its markets allowing for specialisation in long runs of particular numbers of yarn and varieties of cloths while providing all sorts of services and facilities: banks, warehouses, gas lighting, stock exchange. A growing section of the industry gravitated around it. After 1825, the mills placed farthest into valleys outside of Lancashire, in counties such as Yorkshire and Derbyshire, succumbed in scores to the opposite pressure: the centripetal force of Manchester. Yarn and cloth markets crowded with sellers; in a climate of severe overproduction, the need to stand near outlets became exigent. In the eyes of Faucher, here was a key reason for the lamentable abandonment of the salubrious colonies:

> The manufacturers, instead of going to the prime movers, have forced the prime movers to come to them; and as coal abounds almost in every part of England, they have fixed their location with a view only to take advantage of opportunities presented by the large commercial towns, for the purchase of material and the sale of their produce.[97]

But this was not the *only* advantage. In a paper 'On the Changes in the Locality and Processes of Textile Manufacturers consequent on the Application of Steam to their Production,' Cooke Taylor stressed that the superiority of the central Lancashire district 'consisted in its having a trained population *and* established markets' – and that was still not all.[98]

The steady advance of machinery tended to take place inside urban clusters rather than in the outer colonies. Where factories were grouped tightly together, their owners incited each other to invent and adopt new appliances, the spatial concentration *in itself* fanning competition for the most productive machinery: hothouses of innovation, the great towns bristled with information on the latest models, ideas for new ones and skilled mechanics – such as Sharp, Roberts & Co. – to execute them.[99] While this factor had, like labour supply and proximity to markets, a certain timelessness to it, rendering it part of the explanation for the introduction of steam prior to 1825, its urgency was, again, enhanced in the crisis. Versions of self-actors and power looms rapidly succeeded each other with improvements in technical details; anyone dawdling in adopting them could easily fall off the cliff.

Taken together, these factors fall under the rubric, in modern economic parlance, of 'agglomeration economies' or 'cluster developments'. The basic logic was well understood by contemporaries such as Cooke Taylor. 'Industrial occupations,' he wrote, 'have ever a perceptible tendency to aggregate round a nucleus which has once been formed, rather than to implant themselves in new ground, *even where natural advantages would seem to establish a*

preference for the new locality'.[100] Once the process was set in motion, the synergies of labour supplies, markets, hubs of knowledge, shared infrastructure and other features of the nucleus tended to grow by themselves, further attracting new factories, and so on, spiralling ever further from the original attributes of the place. Steam power was the sine qua non of such agglomeration. The centrifugal dynamic of waterpower constituted its antithesis, in a dichotomy spelled out by McCulloch:

> Any number of steam-engines may be constructed in the immediate vicinity of each other, so that all the departments of manufacturing industry may be brought together and carried on in the same town, and almost in the same factory. A combination and adaptation of employments to each other, and a consequent saving of labour, is thus effected, that would have been quite impracticable, had it been necessary to construct factories in different parts of the country, and often in inconvenient situations, merely for the sake of waterfalls.[101]

Hence the loop took the form of turns to the town, turns to the stock, turns to the town, and so on. Urban centres obviously preceded steam: Manchester as a navel of the cotton industry, the Lancashire towns as seats for manufacturing, Glasgow as a northern star all antedated James Watt. The first mills within their precincts contributed to their growth and brought in train more workers, merchants, engineers and mechanics which, in turn, caused more mills to flock to them, sharpening the edge of steam over water. As in the case of factory discipline, the water mills had themselves set the journey in motion. Most if not all cotton centres had originally been powered by the flow, but at some point, their very position as centres precipitated a shift to the stock. Stockport, for instance, developed as a cluster of first silk and then cotton manufacturing, drawing on the currents of the Goyt, Tame and Mersey. Capital, skills, workers and workshops were assembled in the town, but as the most favourable sites became occupied, further expansion on riversides would – given the absence of water management schemes – mandate an exit from it. The only way to stay inside Stockport and retain the advantages of geographical concentration would then be to shift to steam.[102] In more general terms, proprietors of water mills who reinvested their profits in adjacent commercial outlets, be they machine shops or banks, sowed the seeds of local transitions – or, the production of cotton commodities on the basis of the flow proved to be *a self-undermining enterprise*.

If only hypothetically, the flow here encompassed other sources than water. One day in the late 1860s, as he sat preparing a lecture on the economics of coal, William Stanley Jevons fell upon a newspaper report about the Swedish-American inventor John Ericsson, who 'undertakes to supply a new fuel in the place of coal, and a new motive power instead of steam. For several years he has been experimenting with a view of collecting and concentrating the radiating heat of the sun' in what he called a 'solar engine'. Jevons saved the clip and scribbled down his excitement. It was the 'most sound' of all suggested solutions to what he perceived to be an impending coal shortage,

> and for my part I really do not look upon it as an unlikely notion to be carried out into practice some day. But if it be carried out, what will be the result for us – simply that we shall be replaced, and the seats of industry will be removed to the sunny parts of the earth. In Manchester at any rate we have little sun that we have to manipulate for light … The tendency of things is such that we are likely to find coal a source of sunlight [rather] than sunlight a competitor of coal.[103]

This 'tendency of things,' Jevons thus intimated, did not inhere in the sun or the earth, but rather derived from the ongoing concentration of commodity production to the galaxy around

Manchester. If that process precluded serious engagement with 'solar engines' by British capital in the 1860s, it had a more tangible effect on the use of water. The clash between the tendency of things and the potentials of solar power would be more sharply manifested at a later hour.

A First Relative Emancipation in Space

So far, a steam engine fired by coal has appeared a formula for freedom in space. But coal was cheapest near the pit; far away, its cost might be punitive. Then was steam really all that different from water? The answer must be in the affirmative: the ties of steam to certain locations were of an altogether more flexible nature. For wheels, physical contiguity with streams was an *absolute necessity;* for engines, proximity to mines was a *relative* advantage on the fuel market – a matter of price. But while this difference was indeed qualitative, the magnitudes of the geographical variations in coal price could still exert a binding influence over manufacturers.

As late as in the early 1840s, the price of coal would double ten miles away from the pithead. Defined as 10 shillings or less per ton, the area of cheap coal remained confined to some 15 to 20 percent of England and Wales.[104] Neither canal nor railway annulled the relative benefits of neighbouring pits, and even small variations could have significant implications for cotton capitalists, given that the coal bill was equal to one-fifth of total labour costs at a typical steam mill. Hence towns with pits in their bowels – Oldham, Wigan, Ashton – won their special favour, so that in the process of the transition, there did indeed develop a close correspondence between the localisation of mills and that of mines. It was not lost on contemporaries: 'Anyone who takes up a map of England, having the coalfields marked, may at once point out the great seats of British industry,' McCulloch remarked. In von Tunzelmann's calculation, 96 percent of all textile mills in Britain in 1838 were located within the 10 shilling radius.[105]

Now if coal prices drew masters towards mines, did they also constrain the locational liberties so intensely cherished? Fortunately, a certain spatial convergence guaranteed their experience of liberation: populations trained to industrious habits tended to *coincide* with coalfields. Some of the largest concentrations of workers were to be found living practically on top of pits. Removal into Glasgow, Manchester, Paisley or Burnley promised dense reserves of *both* population and fuel, allowing manufacturers who forewent water to go precisely where they wanted to be, even under the (comparatively gentle) guidance of coal prices. 'An abundant supply of labour, as well as fuel and water for mechanical power, ought to be primary considerations in setting down a factory,' Ure advised; luckily, when the fuel was coal, they could be found in the same places.[106]

Was this merely a happy coincidence? Hardly so. The use of coal in towns had, as we know, a far longer pedigree than steam power; ever since the Elizabethan leap, it had provided heat to the kitchens and halls of urbanising Britain. Coal in the proto-fossil economy had the chief historical function of 'permitting an increase in population density,' in London by means of boats from the northeastern fields, in the manufacturing towns of Lancashire and Lanarkshire by means of carts straight from the pits.[107] The original purpose of coal – heat for the populace – opened a hallway to population concentrations, which subsequently lured manufacturers away from water as a source of mechanical energy in a historical cunning of sorts. Coal in stoves contributed to the pattern of centralised settlements; water mills came into contradiction with this pattern; the conversion to steam resolved it by bringing capital and labour together. The spatial crystallisations of wage labour that played such a major role in the transition to steam *rested on proto-fossil coal consumption* – including, of course, the burning of coal for heat in

manufacturing. In this dialectic, encompassing more than half a millennium, the abundance of coal in the pits of northern Britain was a necessary – but not sufficient – condition at every stage. (We have yet to examine the dynamics of the Elizabethan leap.) Thus the geographical correspondence between supplies of labour and coal in the second quarter of the nineteenth century can be considered neither a geological decree nor a historical accident: rather, it was the product of drawn-out processes at the interface between the two spheres.

A steam engine did not, however, run on coal alone. It craved water, most obviously for the boiler but no less importantly for the condensers, in which cold water turned steam into a vacuum. Then was an engine as dependent on an abutting watercourse as a wheel? Strictly speaking, yes. Out of 107 cotton mills in Manchester and Salford in 1850, 54 percent directly adjoined waterways, while 77 percent were situated within 20 yards and 94 percent within 175 yards of a river or canal. The city was an industrial Venice, traversed by the rivers Irwell, Medlock and Irk, five major canals and countless 'private' canals branching off from the main thoroughfares. A mill-owner could simply cut a line of water to his works in order to feed his engine, and the same applied to Preston, Oldham, Bolton and other Lancashire cotton towns, where he would dig out his own lodge and fill it with any water at hand – even sewage water.[108]

Such practices proved just how very different the steam engine was in its dependence on the liquid. It needed no *falling* or even *moving* water and no particular hydro-landscape features – just water, be it level, stagnant, even putrid. Water of that kind was within easy reach nearly everywhere, particularly after the 'canal mania' of the 1790s, when 'a complete system of water communications was speedily established' in northern England; subsequent sewage systems ensured even greater coverage.[109] In any case, most towns were located on rivers or streams, the legacy of the original location now utilised, via canals and pipes, for the consumption of engines, which were much easier to satisfy in large groups than wheels. With boilers and condensers, no centrifugal dynamic arose. Water was carried to their sites with the same ease as coal. Both resources kept cotton production a terrestrial activity: steam did not offer any *absolute* emancipation in space, whatever that would have looked like, but a *relative* one, real and precious. Given the convergence between supplies of labour power and agglomeration economies on the one hand and supplies of coal and waterways on the other, the spatial liberty afforded by steam was all capital could wish for at this stage in history. Subsequent rounds of relative emancipation lay in store.

A Paradox of Flow and Capital in Space

The immobility of direct-drive waterpower appeared as a problem only under specific historical circumstances. For nearly two millennia, it had been a fact of life, the way things in nature were – neither more nor less – but in the Britain of the second quarter of the nineteenth century, it became insufferable for the vast majority of cotton manufacturers. A traveller does not feel the disadvantage of not knowing a certain language before entering its territory. We have seen that the desire for greater spatial mobility – primarily in order to seek out the most profitable pools of labour power – was a major *cause* of the transition; the more established view casts urban industry as an *effect* of steam. In 1860, factory inspector Alexander Redgraves proclaimed that 'the steam-engine is the parent of the manufacturing towns.'[110] Although not a wholly inaccurate statement, it would probably be more correct to say that *the manufacturing towns were the parents of the steam engine,* not as an invention, but as the main prime mover in the British

cotton industry. Causation was, of course, recursive and dialectical, but there is strong evidence that concentrations of populations trained to industrious habits – as well as markets, workshops and all the other attractive features of the town – made cotton capitalists *turn to steam*.

In stating that supplies of water were still abundant by the second quarter of the nineteenth century, we have referred to total potentials. But the centrifugal dynamic spun outwards from centres of local limits on water: it would be ridiculous to claim that the flow offered limitless room for expansion. The very opposite is true. But that admission cannot be a conclusion, only a starting point for the task of understanding *the nature of the limits and the drive to transcend them*. Localised scarcities determined the spatial advantage of steam – and then there was also the possibility that water could be scarce in another sense: a mill-owner might one day find that he simply needed more power than his waterfall could generate. Confronted with this wall, he essentially faced four options. He could try to utilise the available water more fully and efficiently through some form of technical improvement; he could adopt steam power; he could dismantle the factory and move it to another waterfall with greater capacity; or he could satisfy himself with the existing scale of production in this particular mill and expand further on a greenfield site, on the basis of steam or water. It was in the latter two options that the overall abundance of water came into play, the underutilisation a function of decisions on investment in fresh capacity. In the former two, a situation of 'pure' limitations on water could materialise. There was no equivalent for the stock. 'A steam-engine may be set up any where, and if increase of power is afterwards wanted, other engines can be added; but a water-work has its natural limits,' wrote Farey.[111] Shifting to steam, the capitalist could stay put and avoid being spun away from the centre – just add one more engine.

The very quest for more power cannot be separated from that for automation: it was the diffusion of the self-acting mule and the power loom that pushed power needs beyond the envelopes of rivers at dozens if not hundreds of mill-sites across Britain.[112] Insofar as manufacturers ran into absolute limits on their waterfalls in this period, such localised 'energy gaps' must thus be attributed to *the compulsion to expand production and* – as a concrete form of such expansion – *to replace human labour with machines*. Furthermore, the self-acting mule and the power loom were geared to steam because the alternative would have stripped them of their *social* powers: the centrifugal dynamic of cheap water would have carried capitalists away from workers, markets and centres of technological development, unravelling their control over labour, weakening their competitive positions, divorcing them from the progress of new and improved machines. Automation and transition were two dimensions of a singular historical process, accelerating markedly after 1825, underpinned by the peculiar spatial profile of the stock.

Resting in the exterior – or, rather, the remote interior – of the terrestrial landscape, seams of coal could be reached only through a hole in the ground. At this single spot – the pithead – loads were hauled up from below; the mine itself, its shafts and tunnels, may have sprawled through the underground, but the transfer of coal from the subterraneous deposits to the terrestrial landscape in all its expanse had to pass through this narrow crack. The entry of coal into the world of humans (minus the colliers themselves) was thus *centralised in space,* at points from whence it could be *transported* to consumers and *stored* in warehouses, without the need for further attention, passively awaiting combustion. For the first time in history, the converter and the energy source – the engine and the mine – were dissociated in space, allowing factories to stay closely together. Water flew in rivers. To utilise it, mills would have to form chains rather

than nuclei, spread-eagling instead of clustering around centres.

There is a striking paradox here. The flow was 'in a state of motion by nature,' as Babbage put it; the stock was utterly static. Yet from the standpoint of cotton capital, as it accumulated in space, *the flow was stationary and the stock on the move,* the still and the restless transposed. This can only imply that capitalist property relations of early nineteenth-century Britain had produced *their own form of spatiality,* which, after entering a moment of acute contradiction, had to reorder nature. Neither the crystallisations of labour power, nor the imperatives of factory discipline, nor the need for operatives or markets or machines emanated from nature – the other way around: *they* had to construct and rearrange *nature* out of available materials. Later, we shall follow the implications of this paradox to their theoretical, and political, conclusion. The task before us now is to proceed from space to that other dimension, perhaps as important in conditioning the transition from water to steam: time.

CHAPTER 8

A Force to Count On: Advantages of Steam in Time

Taxing Demands on Britain's Rivers

'The principal objection to water power,' we have heard Thomas Ashworth pronounce, was 'its irregularity'. He, Thom and other advocates of reservoir schemes took up the mission to obviate it, but their stillborn plans left water a captive of the weather. 'It is according as the weather is,' one woollen manufacturer crisply described his energy supply: if a river system, in the words of Louis C. Hunter, 'may be likened to a vast and sprawling engine with many power takeoffs, it was the weather that supplied the dynamic force to set this engine in motion'.[1] But then the engine could come to a stop whenever the weather so decreed. Ice might shut down mills for weeks on end in wintertime, particularly in northeastern Scotland. Dry spells reducing river levels and downpours raising them to the point where the streams would submerge the wheels were of greater concern; both phenomena would slow down or halt the machinery. Some mills were blessed with regular water supplies year-round, but fluctuations were the norm: 'Stream irregular, occasionally a day or day and a half lost by floods. In dry seasons, for some weeks, only three quarters of daily work done,' Samuel Greg sketched conditions at Quarry Bank Mill to the Factories Inquiry. Of the masters and managers of 89 waterpowered cotton mills responding to its questionnaires, 69 percent stated that variations in river levels disrupted their production.[2] The seasonal roller coaster might be so wild as to deprive manufacturers of their energy supplies for weeks on end – but again, this could become a torment only under certain historical circumstances, novel in time.

The weather had written the rules of the game of waterpower since time immemorial. Traditionally, weak streams during dry summers were no more aberrant or maddening than the fact that grain could not be harvested in midwinter or fields ploughed in a thunderstorm. As long as the milling of corn, the fulling of woollen cloth, the making of paper or any other hydropowered activity served neighbouring customers, a stoppage 'was a source of inconvenience but nothing more serious; there were always other tasks to be carried out, few people were employed in any one mill, and most mills had adequate surplus capacity to enable them to complete their quota of work once water levels returned to normal,' in the words of John Shaw. Such indulgence towards erratic rivers persisted even in eighteenth-century Britain, but

the production of commodities for export soon made it impermissible: no longer catering to local needs, but aiming at the maximisation of profits through sale on markets detached from the British calendar, manufacturers could ill afford slowdowns or stoppages.[3] They had to squeeze as much output out of their rivers as possible.

More export-oriented than any other, the cotton industry fostered a novel sensitivity to the ups and downs of water, but this was only one factor raising the bar. When the Gregs complained of 'a few hours lost daily for two or three weeks,' their baseline was at least twelve hours of unceasing production; the drop in the river would force them to temporarily scale back to perhaps ten. This would evidently not have been a bother if the normal working day had ended there – not to speak of a hypothetical day of eight or six hours. Indeed, judging from the shortfalls generally spoken of, a demand of six to ten hours for uninterrupted waterpower would have been rather easy to satisfy, regularly and dependably, around the year. *But working days were not expected to stop there*. Exclusive of meal breaks, the standard in the central cotton districts at the time of the Factories Inquiry was twelve hours per weekday and nine hours on Saturday – a sixty-nine-hour week – although even longer days were still common; at Thom's mill in Rothesay, production commenced at five-thirty in the morning and went on for thirteen and a half hours straight.[4] Simple arithmetic tells us that such long spells were exacting for any given watercourse, compared to what shorter days would have been.

A secular tendency of longer hours pressed on the workers and rivers of late eighteenth- and early nineteenth-century Britain. In the year 1200, an adult male peasant would have worked an estimated 1,620 hours per year; in 1300, a casual labourer some 1,440 hours; in 1600, a farmer or miner 1,980. In 1840, the figure for all British workers stood at 3,105 hours under the assumption of a forty-five-week year and 3,588 under a fifty-two-week year – roughly *double* the amount of labour performed half a millennium earlier, or an additional 1,000 hours over 1750. This lengthening of the annual slog was a function of both extended working days and fewer feast days, the latter having become *more* numerous all the way up to the mid-seventeenth century. Within these broad trends, the factory system whipped workers and rivers into completing an even more strenuous daily pensum than in most other parts of the economy, and together with export orientation, it was this prolongation of the working day that *constituted* irregularity as a trouble of the flow in analogy with its spatial fixity.[5] Another question then arises: why was there such a drive to drag out the working days?

The commissioners of the Factories Inquiry wondered about the same thing and heard answers such as 'profit,' 'a higher rate of profit,' 'an extraordinary desire of increased profits' – the Ashworths' choice of words – 'love of money' and similar variations on the theme. Another closely related factor received more mentions. Machines for cotton production were expensive to install: an hour of rest was an hour of wasted money. Extraordinarily weighty in this line of industry, fixed capital furnished a potent incentive to spread the costs over as many products as possible; keeping the mill in operation for another hour meant more commodities thrown off by the same machinery, building, wheel and engine.[6] Economist Nassau Senior brought the point home by quoting his friend Henry: '"When a labourer", said Mr. Ashworth to me, "lays down his spade, he renders useless, for that period, a capital worth eighteen pence. When one of our people leaves the mill, he renders useless a capital that has cost 100*l*."'[7] Hence Henry Ashworth had every reason to keep his people inside the mill *and the waterwheel in motion* for as long as he could.

Cotton manufacturers strove for maximum profit through the adoption of uniquely advanced

machinery, to whose cry for permanent production the rivers had to answer: automation, it follows, raised the pitch. 'In proportion as manual labour is dispensed with, every diminution in the time of keeping the fixed capital in activity must be attended with an increased effect in raising the cost of production,' factory inspector Leonard Horner reasoned in 1841. Cotton capitalists shared all of these spurs regardless of their prime movers, but there were special incentives bearing on water mills. Insofar as these embodied exceptionally large fixed capital – as would often be the case in colonies – they were *less flexible* than steam mills, whose owners did not stand to lose as much if a few hours were trimmed off the day.[8] Indeed, the two prime movers had opposite cost profiles: waterwheels sunk heavy capital into rivers whose fuels came for free, while the heftiest cost of steam engines was the *circulating* capital – the coal, for which masters had to pay only when the engines were running. A labourer downing his spade would then have been less of an injury in a steam than in a water mill.

This was the standard that the British rivers had to meet. Oscillating water levels would not have become such acute worries were it not for the distant markets, the profit motive, the machines and other forms of fixed capital, all superimposed upon the ancient – comparatively mild – swings of northern British weather. The structural crisis did nothing to ameliorate the pressure: contrariwise, it compelled manufacturers to reach even further for costumers, fight harder for every shilling of profit and fix more machines in place. To make matters worse, it also coincided with some devastating unforeseen events.

The Great Drought of 1826 and Other Extreme Weather Events

It never rains but it pours – or it parches the earth completely. In 1826, as the country reeled under the unprecedented economic crisis, a dreadful drought descended on Britain. Scottish historian Archibald Alison chronicled the year in the fourth volume of his *History of Europe:*

> The year 1826 was long remembered in Great Britain from the excessive drought which everywhere prevailed, and the extraordinary heat with which it was accompanied. The dry weather began early in June, and continued almost without intermission till the end of October, during the greater part of which time the thermometer in the shade was above 80°. It was the climate of the West Indies, without its moisture or sea-breezes. The consequences were remarkable and curious in the extreme; they clearly demonstrated that a long succession of such seasons would change the character, and with it the destinies of the British people.[9]

In the south, grasslands turned a barren brown and harvests withered under the scorching sun; in the north, fires stalked forests and peat mosses, the surfaces of rivers gleaming with dead floating salmons. Robert Thom recorded exceptionally low precipitation on the Isle of Bute. At Deanston, 1826 went down as the year when 'there was no rain from the middle of April to the beginning of August, and the water of the river was insufficient to drive the Machinery' for a period of 100 days. The first half of the year brought a mere sixth of the average annual precipitation to Manchester; in early July, 'the heat in this neighbourhood during the present week has been greater than we remember it at any former period,' said the *Guardian*. John F. Bateman, a collaborator of Thom and leading hydraulic engineer of the high Victorian era, would remember 1826 as 'the driest year in this country, of which we have any record'.[10]

Panic and drought, many a manufacturer was deeply unnerved. How solid a rock would water be for their castles when the next calamity struck? In Yorkshire, whose water mills had been more than twice as many as Lancashire's at the turn of the century, the collapse of the financial

system conspired with the extreme weather to cull firms, cause debts and losses in the tens of thousands of pounds and persuade those who survived to abandon the fickle streams. The combined disaster turned a page in local history, heralding both the conversion from water to steam and the decline of the entire cotton industry, as it relocated to the Lancashire towns while Yorkshire specialised in wool.[11] The same shift in prime movers was documented at Kilmarnock, south of Glasgow:

> Such a drought and scarcity of water has rather been against the manufacturers this season, in not getting yarn spun and dyed so fast as was required. But, in order to remedy this, an enterprising manufacturer … has engaged a steam-mill in order to get yarns forward, *and it is at present going night and day*.[12]

Precipitation could not be dug out of the ground; it continued to vary. In the hot summer of 1842 – coinciding with the general strike: two uncontrollable forces – water levels were precariously low at the Ashworths. 'The unexampled drought to which I alluded in my last Report, and which has prevailed throughout the summer,' one factory inspector noted in September 1844, 'has continued to prove very injurious to the operations of those manufacturers whose machinery is wholly dependent upon the power of water.'[13]

Other extreme weather events compounded the growing distrust of the flow. As wheels required moving and falling water, their buildings had to be positioned in harm's way; instances of mills flushed away by floods are recorded as early as in the 1310s. The young cotton industry had little choice but to seek out the hazard. Shropshire manufacturer Hulbert found his colony deluged in 1805 when the river Severn 'rose to an unusual height,' upwards of two feet inside mansion, mill, warehouse and workers' cottages.[14] In his response to the Factories Inquiry, James Kilgour, proprietor of a sizeable combined factory in Aberdeenshire, recalled the losses during the 1826 drought – and then in 1829, a flood 'seriously damaged' his works, later repaired only 'at a heavy expence'. A violent torrent would not only bring production to a standstill like a drought: it might also destroy some of the most valuable assets of a mill-owner. This happened along the river Etherow on 7 October 1849. Ten days of heavy rain and snow fed into a flood that overtopped a weir and burst into the valley below, snapping fences and bridges, rushing through factories, submerging power looms, washing away piles of cops and pieces of cloth worth a fortune. 'The flood is described as making its appearance between six and seven o'clock in the evening, like a wall of water,' the *Manchester Times* informed its readers; once the wall had passed, 'several of the mills have had to cease running.'[15]

Steam promised both temporal and spatial protection from extreme weather events. Coal was utterly alien to seasons; factories could be placed at a safe distance from riverbanks liable to inundation. In short, *the desire for independence from the vagaries of weather provided one motive to the transition,* which, incidentally, opened the sluice gates to a general change in climate, often experienced as no rain or a wall of water suddenly approaching.

Methods for Smoothing Out Irregularities of the Flow

Less spectacular anomalies were fairly easy to manage. A private reservoir was the primary shield against shortfalls or excesses. If it proved insufficient to equalise the flow, other options were available: a steam engine could be placed on standby, to be switched on when the wheels slackened. The Ashworths had one at Egerton, the Gregs one at Quarry Bank Mill; of the eighty-

nine representatives of waterpower responding to the Inquiry, thirty-eight availed themselves of such auxiliary steam. Fifty-three did not. The practice was more prevalent in Lancashire than in Scotland, with some evidence suggesting it was on the rise. By definition, these engines were kept as deputy prime movers, second choices activated as little as possible. The purchase and maintenance of engines to supplement the wheels made sense only because of the huge gap in fuel costs: it was still cheaper to have *both* prime movers than to rely exclusively on coal consumption, paradoxically attesting to the economic supremacy of water.[16]

Thirdly and finally, there was one cushion ready to hand for all proprietors of water mills, regardless of the extent of their reservoir and auxiliary steam, cheaper than either, easily adjusted to seasonal as well as daily swings. When the elements suspended production, the workers would be sent home. When the flow returned, they would be ordered to work extra hours. Attending to the machines for longer stints, they would make sure that all lost production was recouped and any backlog of orders cleared: 'We sometimes stop as much as three hours at a time,' a bookkeeper at a cotton mill near Bingley described the routines in adverse weather. 'The hands are dismissed, *and recalled by a bell;* they have that time to themselves; they are always paid as working a full day, and expected to make up the time as opportunity may occur.'[17] Of the respondents to the Inquiry, 72 percent said they employed overtime work as a means of smoothing out irregularities while only 19 percent did not (among them Robert Thom). Here was the most popular and widespread method for neutralising the natural variability of river levels: *operatives could always be commanded to work more*.

How much more exactly? At the Ashworths,' the workers usually did one hour overtime each day until they had caught up. When the sap rose again at Deanston after the Hercules had come to an impotent rest, manager Smith might, on his own admission, order the spinners and weavers to continue their work 'during the whole night'.[18] One master declared that 'this, like a good many other mills impelled by water, has no definite hour of commencing work'; the hands were simply informed of the hours as the weather altered; one day they might labour for six, the following three days for fourteen. Naturally, the workers themselves were not always happy with such arrangements. Isabella Key, a twenty-year-old spinner in Dundee, was recorded as saying that 'the hours of working are not regular, and in summer depend on the water, being insufficient,' and 'when they make up time, she has known them to go on from five in the morning till half past nine o'clock in the evening.' That would have been sixteen and a half consecutive hours of labour. With barely concealed resentment, a seasoned cotton worker in the Halifax area related how 'the children were forced to be in activity from four to five o'clock in the morning to nine or ten at night' to compensate for the fits of the flow.[19]

Hence there were, by the nature of the matter, no exact figures on the customary extent of overwork. The commissioners of the Factories Inquiry summed up the practice as spanning 'sometimes half an hour, at other times an hour, and occasionally even as much as two hours daily, until the whole of the lost time be made up,' but even this upper limit appears to have been too low.[20] For a peruser of the thousand-page reports of the Inquiry, however, the main point must have been clear as a factory bell. With their special incentives to long working days, exposure to the weather and strategies to deal with it, water mills were the sites of recurring spells of the most extreme and exhausting toil for adults as well as children. Their proprietors systematically translated the irregularity of water into an irregularity of work time – or flexibility, if one prefers – with the days ranging from six or four or even fewer hours some days and weeks to twelve and a half, fourteen or even more the next. Put differently, proprietors of

water mills absorbed the weather swings by dint of their *unrestrained command over labour power in time*. Robert Hyde Greg declined to give details, merely stating that in weeks of droughts or floods his hands were paid 'the full amount of wages, knowing that *we shall have the power of working up the time* that has been lost'.[21] But that power really could not be taken for granted.

The Factory Movement as the Nemesis of the Water Mills

In the 1810s, spinners in Lancashire formed the first 'short-time committees' and submitted a petition to Parliament calling for the working day to be capped at ten and a half hours, with one and a half hours of rest included. It fell on deaf ears. The campaign smouldered over the following years, but with the repeal of the Combination Laws it sprang to life, the released unions setting up a growing network of committees, mass petitions again tossed off to Parliament. From 1825, the *factory movement,* as it was appropriately called – its programme focused squarely on conditions inside the mills – remained in a state of unbroken activity until 1850: another constitutive feature of the crisis in the relation between capital and labour. By the early 1830s, it had coalesced around the crystal clear demand of ten hours a day and not a minute more.[22]

Meeting in inns and taverns like members of so many other subversive movements of the era, the short-time committees united all sorts of textile workers and combined all sorts of means – petitions and riots, rallies and strikes, letters to newspapers and apocalyptic predictions of revolution – to further their cause. The inflammatory orations of leaders Richard Oastler and Joseph A. Stephen, immensely popular with the toiling masses, seemed to reach new heights every year. On a speaking tour in 1836, Oastler declared that 'the obstinacy and wickedness of the millowners have placed the question in this awful position – *Shall the Law or the Mills be destroyed?';* two years later, in a speech to spinners in Glasgow, Stephens vowed that if the rulers of the nation would not reform the factory system, 'aye, uproot it all, they shall have the revolution they so much dread'; to workers in Saddleworth, 'there was no hope of anything being done for them, unless they resorted to physical force, and the only question was, when should they commence burning and destroying the mills.'[23]

But first they had to try the Parliamentary route. Locked out of the franchise, before as well as after the Reform of 1832, the working-class constituency of the movement had to forge links with sympathetic MPs, such as Michael Sadler of Yorkshire. In the heat of the Reform crisis, on the shoulders of the hitherto largest march and petition, Sadler moved a Ten Hours Bill in the House of Commons, parking the demand at the top of the political agenda for nearly two decades to come. More precisely, he proposed a legal maximum of ten hours' labour for persons under eighteen; since the mills could not operate without such hands, however, such a statute would ipso facto stop production at that point and apply to all workers. A right to overtime to compensate for irregular water was ruled out.[24]

When the commissioners of the Factories Inquiry distributed questionnaires and conducted interviews in 1833, the bill on the table was still the one introduced by Sadler. They found the owners of water mills fretting over their future. In the words of the proprieter of a combined factory at Burley, Yorkshire,

> If this Bill becomes a law the effects would be *to destroy many water-mills entirely* in rural situations in the

> country, and drive the trade into large populous towns … Steam-power is mostly in large towns, and *can be set to work at any moment;* water-mills are subject to many interruptions for want of water, and frequently impeded and totally stopped by floods.

If the Bill were to be enacted, he continued, 'many mills in summer could not run more than from six to eight hours a day,' the customary method for regaining lost time suddenly criminalised. Auxiliary engines were not a viable alternative, since they would burden the owners with 'a great expence of coal'.[25]

The mills of the Gregs were built on the very premise of unrestricted working time, the watercourses leased 'on the understanding that we shall be able to use the whole of the water, *without limitation,* which the stream produces'; no contracts would have been signed, no machines installed 'had we been restricted to ten hours' use'. Under such a short legal day, 'the whole value of the property would be sacrificed'. The only solution remotely acceptable to the waterpowered fraction of cotton capital would be a generous legal exception: 'Very considerable latitude ought to be allowed to mills driven by waterpower to make up lost time,' in the words of James Kilgour, victim of both extreme drought and floods.[26] But no such clause was included in the bill sponsored, and so lengthy testimonies on the existential threat it posed to water mills could be piled up from the Inquiry; of the eighty-nine respondents, *not a single one* could stomach a ten-hour day.

Are these doomsday scenarios to be taken seriously? All sorts of manufacturers who opposed the bill habitually predicted an invasion of foreign competitors, capital flight to other countries, general collapse of the industry, unheard-of destitution. It was not the first nor would it be the last time propertied critics of a proposed interference in the economy foresaw ruin. Perhaps they stood to lose *something* from a ten-hour day and embellished that interest with trumped-up charges and imagined horrors – and if so, we would expect the advocates of the bill to debunk their rhetoric. But in the special case of water, they did not. Commissioner Tufnell interviewed one Manchester spinner who supported the movement:

> Have you considered the effect that the Bill would have on establishments where water-power is used?
>
> – I don't see why they should not be included, as well as those who use steam-power, as their water costs them nothing, and they can spin at less cost than those who have fuel to pay for.
>
> Are you aware that in some factories moved by water-power, it sometimes happens that it is impossible to get the necessary supply of water before a late hour of the day?
>
> – Yes.
>
> Then might not such establishments be sometimes prevented from working more than five or six hours daily?
>
> – I can't say. I think if such is the case they should not have built their mills in such a situation.
>
> Suppose they built their factories many years ago, on the understanding that a Ten Hours' Bill would never have been passed?
>
> – A man ought to have sufficient foresight to have known that it was unnatural to work persons unreasonable hours, and therefore he ought never to have built a mill there. In all cases where such a mill is short of water, he should put down a steam engine to assist.[27]

The goals of the factory movement were a universal reduction in the working day and a complete

end to overexploitation: it did not care for water. Owners of steam mills who opposed the bill likewise conceded the particular vulnerability of their waterpowered competitors.[28] Tufnell drew the conclusion that 'the Bill would prove a sentence of absolute extinction to nine tenths of the water-mills in the country'; deprived of their flexibility, they would be unable to work 'more than eight and a half or nine hours daily,' which, under the laws of this economic life, would spell rigor mortis.[29] It is difficult to resist the impression that Tufnell here blew the threat out of proportion. It is equally hard, however, to discard the evidence that the demand for a ten-hour day did imperil the viability of water mills: river levels did fluctuate, companies did make up lost time; banning them from doing so would cause financial pain. Indeed, not only a prohibition of compensatory overtime but *any* reduction in the working day would be harder to bear for water than for steam mills, since *only the stock could be cut exactly so as to fit a given unit of time*.

Hence the factory movement and the water barons were at daggers drawn, an enmity extraordinaire emerging between them in the 1830s. Henry Ashworth had little reason to chafe at proposed laws before 1833, but in the spring of that year, his own hands wrote a petition to Parliament asking for passage of the Ten Hours Bill. Deeply hurt by the incident, he sat down to pen a pamphlet *On the Cotton Factory Question,* outlining the two most pressing reasons for a master like him to detest all regulations: given the nature of water, any limitation on hours would choke production, and given the scant local population, any proscription of child labour – however children were defined – would exacerbate the problem of recruitment. Rather than focusing on these water-specific concerns, however, he continued with a sweeping condemnation of the very idea of shorter working days, the effect of which would be idle machinery and thus lower profits, starvation, migration, national suicide. With this diatribe, the Ashworths rose to national prominence; by their side, they had, as usual, the Gregs, with Robert Hyde authoring a similar brochure on *The Factory Question*. From the early 1830s, the names of the two families were synonymous with the most stubborn obstructionism coming out of Lancashire. As public spokespersons, heads of deputations to Parliament and organisers of several nationwide lobbying campaigns, they led the fight of the Association of Master Manufacturers – formed in 1828 as a counter-force to the unions, based in the Cottonopolis – to first stave off and then revoke all 'time bills'. Further to the north, Kirkman Finlay starred as the undisputed leader of the Scottish cotton magnates: chief critic of factory legislation, author of his own widely circulated *Letter* on the issue, in which he reiterated the standard scaremongering over impending industrial doom.[30] Thus one of the fronts in a long battle was formed.

From the opposite front, John Doherty, the foremost leader of the Lancashire cotton spinners, took aim at the Ashworths and the Gregs as the most depraved of all masters: Henry, 'I believe, is in favour of a 72 hours per week bill, with a clause to exempt his mill from the operation of it,' while Robert Hyde continued to drive his last batches of apprentices for hours supposedly longer than on West Indian slave plantations.[31] Activists from Manchester pestered Quarry Bank Mill, documented the pernicious practices and forced Robert Hyde to remove 'boards nailed up against the windows for the purpose of excluding the light'; for more than a decade he fought to protect the colony from their unwanted visits. At one point, Doherty led a deputation of activists from Bolton to New Eagley to demonstrate against the Ashworths' opposition to the ten-hour day.[32] The outstanding water mills were under siege.

Now the water barons were anything but alone in resisting the factory movement: they had a whole class behind them. Of 193 masters and managers of steam mills stating their opinions in the Factories Inquiry, 185 were unreservedly against the Ten Hours Bill. One expressed support

for it on what may be termed humanitarian grounds; one said he was prepared to swallow a limitation to eleven and a half hours; three could accept eleven hours; one considered that 'some reduction in the hours of labour would not do much injury to trade.'[33] In spite of the odd sympathiser, this can only be interpreted as a wall of opposition, no less solid than in the water camp. McConnel & Co. gave the typical answer – 'the cost of production is enhanced by a reduction in the hours of labour,' a measure therefore destined 'to ruin the cotton trade, and destroy our property' – and contributed financially to the endeavours of the Association, a cohesive alliance of masters, ecumenical in matters of energy and united in conservatism. Or, in the words of the Inquiry: 'The general tenor of the opinions of the manufacturers is adverse *to any change*'.[34]

So there developed a pointed configuration of general class interests and special concerns of waterpower. Of all cotton capitalists, those dependent on rivers stood to lose *most* from time bills and therefore championed the common cause with particular stridency, assigned the role of mouthpiece by their steaming associates. On the other side of the moat, the factory movement marched on.

The Making of the First Factory Act

Before 1833, no attempts at factory legislation had resulted in much more than ink on paper. The acts of 1802 and 1816 regulating the labour of apprentices barely made a dent in the customs of mill-owners, and the same fate befell two halfhearted laws enacted in 1819 and 1831: stipulating a twelve-hour limit to the workday of those under the age of eighteen, the latter 'has been almost entirely inoperative,' the Inquiry reported after two years.[35] The absence of any mechanisms for actual enforcement or at least credible inspection of the factories – that is, by others than local magistrates in cahoots or identical with the masters – made the statutes utterly ineffectual. This might have been fortunate for proprietors of water mills, who perceived any hint at a limitation of working hours as a special threat to them: a nervousness already prominent in the debates over the 1816 law.[36] One can imagine water capitalists heaving a sigh of relief every time another Parliamentary initiative tampering with factory hours ended in a nullity.

1833 was different. Unlike in 1802, 1816 or even 1831, the factory movement had by now reached industry-wide proportions, pushing for the shortening of the working day with a material force that could no longer be ignored. The cotton spinners manned the barricades as 'invariably the most strenuous' supporters of the Ten Hours Bill, cringed Tufnell, but the greatest achievement of the short-time committees was the breadth of their appeal: here was nothing less than the first movement 'to unite the general interests of labor behind a specific political objective,' in the words of one historian.[37] Excluding 95.3 percent of the population from the right to vote – down from 96.8 percent – the Reform of 1832 had merely fanned the flames of working-class discontent. Throughout the spring and early summer of 1833, the movement tapped into the disillusion, let loose a frenzy of activities, threatened political strikes and assembled up to 150,000 people outside Bradford on 1 July in one of the largest demonstrations in nineteenth-century Britain. The masters had their backs against the wall. 'As the question has been so much agitated, the people will not be satisfied without some reduction,' conceded the owner of a Manchester steam mill to the Inquiry; due to the 'violent appeal to the passions,' one in Leeds expected that 'great evils will be embodied in the proposed bill.' The government

watched events with trepidation, hearing from its informer outside Bradford that it would be unwise to ignore the demands, as it 'would most assuredly sow a whirlwind': 'the meeting on Monday embraced a mighty physical power which may easily be called into adverse exercise.'[38] A realisation spread that *something* had to be done about the factories lest the northern powder keg explode.

Out of this insight grew the Factory Act of 1833 – very far from the Ten Hours Bill, but contrived to take the sting out of the raging agitation. In an astute move, Edwin Chadwick, head of the Inquiry, hit on its weakest spot: the professed care for children, whose exhaustion during the long hours of work took centre stage on the platforms. In his recommendations to Parliament, he proposed that no work should be permitted below the age of nine, while for children between nine and thirteen, hours should be restricted to *eight* per day. 'The great evil of the manufacturing system, as at present conducted,' Chadwick's commission wrote, 'has appeared to us to be, that it entails the necessity of continuing the labour of children to the utmost length of that of the adults.'[39] Claiming to excel Sadler in compassion for these weak creatures – cutting their hours to eight rather than ten – the commission sought to rob the factory movement of its most profitable source of propaganda *and* save the industry from a universal ten-hour day: defending the fundamental health of the factory system by amputating its one rotten leg. The government bought the idea. When it brought the final bill before the House of Commons on 9 August 1833, however, one more crucial clause had been added to soothe popular feeling: 'young persons' – labourers between fourteen and eighteen – should not be allowed to work more than twelve hours a day or perform night work. With that, an actual limit would be placed on the daily hours of production. The bill passed; the factory movement lost the first major engagement and, by autumn, sunk into demoralisation.[40]

When Leonard Horner, soon the most well-known public face of the Factory Act, wrote a manual in 1834 to educate people about it, he recited the most important rules:

> No child can be employed at all before it is 9 years old. No child up to 13 years of age can be made to work more than 8 hours in any one day. No young person under 18 years of age can be made to work more than 12 hours in any one day, and never between half past 8 at night and half past 5 in the morning.

The ordinances covered all mills where products of cotton, wool, flax, tow, hemp or silk were manufactured 'by machinery set in motion by steam-engines or waterwheels; or even windmills, if there be any such. Where the machinery is set in motion by animal power, the Act does not apply.' Explicitly tied to the nature of the prime movers, the Factory Act of 1833 became a new running track for the competition between water and steam, forged by the clash between the classes – or, as Horner himself later justified the pis aller: it had been 'necessary, in order to render the great body of the working classes governable by reason'.[41]

How, then, would the state ensure that this act did not become another dead letter destined to reanimate agitation? By means of public factory inspectors. The United Kingdom would be divided into four districts, each assigned a centrally appointed chief inspector paid by the government, with up to four superintendents residing in the area as his deputies; in a team or on their own, they would ambulate through the mills, the superintendents serving as eyes and ears and writing weekly reports for the inspectors. The latter were given the most far-reaching powers. They had the right to enter factories at any time, examine the age of the workers, see that the children had received the now mandatory levels of education and request any person to give

evidence under oath; penalties could be handed out on the spot if offences were uncovered. Furthermore, the inspectors could issue additional rules and regulations as they found necessary to secure the full execution of the Act without having to seek Parliamentary approval. Combining quasi-legislative with quasi-executive authority, they would order magistrates to open cases against mill-owners, who, if convicted, might have to pay significant fines.[42] This time, the British state was serious. The Factory Act of 1833 would not just become another piece of paper: too much was at stake for that. And indeed, the institution of a special inspectorate marked a qualitative difference from all prior laws; that of 1833 is known to posterity as the first real Factory Act and, moreover, 'the beginning of economic regulation as we know it today'.[43] Becoming for such an event, it immediately influenced the choice of energy sources.

Neither the government nor the inspectors were, however, in any way *bent on* destroying the water mills: ever attuned to the needs of the masters, they saw their plight, heard their protests and concluded that some form of exemptions must be granted. The third paragraph of the Act stated that if time 'be lost in consequence of the Want of a due Supply or of an Excess of Water,' the occupier of the mill would be in his full right to extend the labour of all his hands for an extra three hours per week 'until such lost Time shall have been made good' – but he could never start earlier than five in the morning or go on later than nine in the evening.[44] In a legal praxis developing after 1833, inspectors, superintendents and magistrates interpreted the rule as *half an hour* of permissible overtime per day. Was that enough? Did half an hour constitute the 'very considerable latitude' so many mill-owners had deemed necessary, lest their factories be vanquished by steam? It rather seems to have comprised a minimal space for making up time: half an hour per day was at the very low end of pre-Act practices. A tentative conclusion would thus be that the exemption granted by the 1833 Act gave *some* latitude to water mills, but *far less* than previously enjoyed, amounting to a not negligible *fetter on their production*.

Cracking Down on Water

In 1835, there were slightly more than 200 convictions of mill-owners under the Factory Act. Early next year, the Association rose in a concerted push to have the law rescinded – the Ashworths and Gregs commanding the battalions of cotton capital – provoking the factory movement to rush to its defence in a new round of mass meetings, mass petitions, mass outcries and sinister allusions to sedition if the masters had their way. Even Henry understood that he and his partners were setting the country on fire. 'I find there is much excitement and no little indignation,' he wrote to Chadwick in June 1836, surrendering to a disadvantageous balance of forces: 'The pretended friends of the working classes enjoy their confidence more than we do'; with a repeal 'there is no hope of quietness' and 'in stating this, I am giving an opinion at variance with my interest.' The lobbying campaign backfired. Not only did it give up on modifying the Act, but it reminded the government of the explosive charges in the north and thus induced an *intensification* of enforcement: in the summer of 1836, the Home Office instructed the factory inspectors to bring calm to the country by clamping down hard on offenders.[45]

In 1836, there were more than 800 convictions, a level sustained in 1837 before falling with the business cycle (there being fewer incentives to overwork in times of depression). In those two years – the final stage of the boom – the statistical likelihood of a mill-owner being dragged to court within a given year was one in four, a legal crackdown at the highest intensity; henceforth prosecutions would become progressively rarer, reaching a likelihood of one in forty by 1870.

Guilty verdicts piled up in the courthouses. According to one analysis covering Lancashire and the West Riding of Yorkshire over the period 1834–55, the conviction rate reached more than 70 percent in most years – in other words, the majority of indicted mill-owners were in fact penalised. Fines of only 1 or 2 pounds remained common, but offenders could collect multiple charges and dozens of fines, amounting, in the end, to punitive costs for disobedience.[46]

Where did most offences occur? Already in late 1833, the first inspector of Lancashire and Yorkshire, Robert Rickards, described a source of extensive recidivism:

> The country abounded with mills, situated in, or near, small villages, or on streams of water in still more obscure parts, where all the working hands procurable were … now employed in such mills, and where additional hands, whether of the younger or older age, were not to be had. In these cases, they said, the mill must either be closed altogether, or, as was most probable, worked in open violation of the law, and for longer periods than 12 hours per diem.[47]

When the inspectors and superintendents fanned out into textile districts, they found the statutes governing compensation work particularly difficult to uphold. 'I think it is impossible to check evasions of the law in making up lost time,' Horner, now responsible for Lancashire and much of Yorkshire, summarised his experience in 1840. Two years later the inspector for the Midlands and the East still reported a failure to stamp out illicit overtime: 'I am not without doubt that many water-mills are *always* making up time, which I very much suspect was never lost.' To facilitate detection, Horner found it 'necessary to make some additional regulations'; exercising his quasi-legislative authority, he targeted the water mills head-on with a new statute in 1837. If proprietors wished to compensate for varying river levels, they would henceforth have to 'fix up in a conspicuous part of the mill, accessible to all the workers, a notice stating the date, day and hour when the stoppage took place; the cause of that stoppage, and the amount of time lost'; all overtime performed by workers under eighteen would have to be meticulously recorded in special 'Time Registers'.[48] When an inspector or superintendent visited a factory, he could then cross-check the entries against the public notices and testimonies of the operatives.

In the early years of the Factory Act, night work all but disappeared, child workers under the age of nine became a rarity, and the normal working day approximated twelve hours more closely, fewer mills running into fourteen or fifteen.[49] Neither the notices nor the Time Registers could eradicate illegal overtime, but with their stepped-up surveillance, the inspectors were closing in on the mills: 'Wherever there is the power of making up lost time, it ought to be guarded by every possible check,' Horner emphasised in 1840, pointing out that the effort remained indistinguishable from the implementation of the core of the act: no more than eight hours for children, no more than twelve for young persons. The inspectors were continuously force-fed with zeal to guard these principles by pressure from the factory movement, whose activists resented the very existence of a license to overtime. In a follow-up inquiry in 1840, a spinner from one of Manchester's short-time committees explained what working people thought of it:

> That is the source of grievance to a vast number, both of children and adults. I have heard them frequently say, when lost time is allowed to be worked up, that they would rather lose their wages for the time that was lost than make it up; for after having worked 12 hours, if they have to make it 12½ or 13, it exhausts their strength much. They have expressed themselves strongly on that point; that they would rather lose their wages than work the time up.[50]

The kind of overtime that had recently been comme il faut could now easily cross the threshold to crime. Did the delinquents pay for it? Were water capitalists subject, as one would expect, to more frequent and draconian punishment than those who had banked on steam? In an article in 1977, economist Howard P. Marvel collected data from the parishes of Lancashire and the West Riding of Yorkshire for the years 1834–6, identified the shares of the two prime movers in their cotton factories and set them against all cases brought under the act. He found that water mills 'faced a considerably greater likelihood of court action' – more precisely, that likelihood rose by *one-third* when the energy came from water – as well as more separate charges and stiffer penalties.[51] A similar study of the entire period from 1833 to 1855 later backed up his results: the number of court cases per 100 operatives tended to be considerably higher for the relatively water-dependent parishes under Horner's supervision. In totally steam-dependent Manchester and Preston, there were 0.5 and 0.6 cases respectively in 1838. In Saddleworth, water supplied 21 percent of the horsepower, and there were 2.8 cases; in Whalley, it produced 25 percent, and there were 1.8.[52] To the extent that the Factory Act was a bane for cotton capital, steam appears to have escaped almost unscathed.

The Ashworths were first convicted in August 1836, on three different counts: lacking an obligatory roster of their workers, lacking Time Registers and, worse, 'employing children more than 9 hours per day'.[53] More productive of public spectacle, a second case followed in the summer of 1837. When the local superintendent visited the New Eagley colony, he again found children employed without age certificates, without their names anywhere registered and without any verifiable school attendance; four of them, it turned out, were under thirteen years old while working twelve hours a day. The court at Bolton was packed with mill-owners, managers and notables throughout the six-hour trial. Angry and cocky, Henry put up a show, defending the reputation of his establishment, attacking factory legislation, piling up copies of regulations and asking rhetorically 'if it were possible for any one to attend to all these' and 'at the same time mind his own business': he was found guilty on a total of ten counts.[54]

But Henry Ashworth refused to pay the fines. A warrant of distraint was issued. One Saturday afternoon, officers entered his countinghouse as he sat writing and began to carry away the furniture: the chief officer 'took the chair and the table from me, and I walked off home and left it; and he took other chairs and tables, and went away.' According to Doherty's rendering of the event, Ashworth 'refused to pay the penalty imposed upon him; he wished to be considered a factory martyr, and allowed his goods to be seized.'[55] This was the beginning of a lasting vendetta between the most renowned leader of the opposition to the Act and its executive. Horner and his deputies continued to charge the Ashworths with all sorts of offences, while the brothers carefully cultivated the identity of factory martyrs: the law was impossible to obey if business were to continue.[56] To obstruct inspection, they kept all clocks on their own time and refused to admit any superintendents into the mills, a wilful policy that raised eyebrows in the 1840 inquiry, whose commission asked Henry:

> Did you ever refuse admission to the superintendent before you had been fined?
>
> – Never.
>
> Then in fact you refuse admission to the superintendent lest you should be fined again?
>
> – Yes, to save our money.

> Lest you should be detected to be in the violation of the law.
>
> – Yes … We do not like to be held up before the public as violators of the law.

Ashworth was up in arms over the authority wielded by the inspectors – 'that extraordinary inquisitorial power,' 'this moral police'.[57] His indignation was not unique. In *The Factory Question* – published in 1837, the year when enforcement began to bite for real – Robert Hyde Greg whined that the powers of an inspector were 'greater than were ever before committed to any individual in this country' – indeed, 'what farther power remains to be granted, unless it be that of hanging a mill-owner without trial, and leaving his body to the surgeons for dissection?' Previewing twentieth-century discourses on totalitarianism, he offered an account of intolerable suffering in a fully fledged surveillance society: the masters have

> suffered a total defeat in their opposition to the law, in the first instance, and in their attempt to procure its partial repeal, their characters have been blackened, a limit has been imposed upon the use of their capital, the 'Short Time Committee' has its spies in all their mills, Government has its spies in the inspectors, they again, their inferior spies, in the sub-inspectors, nay, the masters are compelled to be spies upon themselves, and contrary to a well-known principle of English law, to keep *a register of their own offences,*

by which Greg referred to Horner's decree on Time Registers.[58]

Prosecution appears to have been massively disliked everywhere, for the money lost to the fines, for the tarnished reputations and, not the least, for the interference in management as such; overall, certainty of prosecution acted as a strong inducement to comply with the law and adjust production accordingly. Costs of compliance were higher for mills powered by water.[59] The rancour of the Ashworths and the Gregs reflected a real encumbrance of the Act, recapitulated in yet another debate on working hours in the House of Commons in 1847: 'The Legislature had already interfered with regard to the hours of labour of certain classes of operatives – the labourers employed in water power establishments,' one MP pointed out, claiming to know that the result of the meddling 'with the hours of labour in those mills was, that *several of them had been stopped altogether*. They had *pro tanto* crippled the energies of this country.'[60] All of this points towards a general conclusion: the enforcement of the Factory Act did material damage to the waterpowered cotton mills, and the position of steam was correspondingly enhanced.

To that damage must be added the very *fear* of coming laws. Investment decisions were, as ever, based on forecasts: if capitalists expected the introduction of a Ten Hours Act or similar legislation in the near future, and if they perceived it as a mortal threat to waterpower, they would have exercised rational entrepreneurship by hurrying to steam. Sadler's bill might have been defeated in 1833, but – thanks to the revival of the factory movement – it continued to cloud the horizon as a reasonably realistic scenario, in which a total ban on making up lost time would be included. The affair remained distinctly unsettled. Until the very end of the structural crisis, novel bills were introduced in Parliament, campaigns waged, amendments prepared, demands for ten and even eight hours refusing to die down, creating an unstable and unpredictable legal environment that strained the nerves of many a master. Rumours about the content of the next law spread from office to office: in 1842, Horner quoted an anonymous owner of a large mill near Manchester as saying that 'if I recollect right, the (contemplated) new Act prohibits nightwork, or working between certain hours of the evening and morning, and also withdraws the power of making up lost time.'[61] In 1833, Henry Ashworth declared that the

sword of Damocles hanging over him and his peers had subdued his enthusiasm for further investment in the colony, in what reads like a synopsis on the challenges faced by his segment of capital:

> During the past three years the rate of profit has been greatly diminished, and the contentment and good order of the work-people has seriously been disturbed, chiefly by the interference of mischievous agitators; and during most of this period, *the promoters of time bills have threatened still further inroads upon our profits,* by proposing limitations of the time of working; and they have endeavoured, with singular ingenuity and audacity, to fasten upon us, as a body, in the eyes of the public, the most unjust imputations of avarice and cruelty. *We have therefore become indisposed to make any further extension of our works*.[62]

The Gregs claimed, unsurprisingly, to be pushed into the same corner, while the owners of the Stanley colony alleged that a rigid implementation of the Act would make abandonment of their huge investment 'the least of two evils in a pecuniary point of view'.[63] But the shifting sands could also be observed by more detached parties, such as a manufacturer of silk in Manchester, who, referring primarily to the cotton industry, explained a perplexing trend in early 1833:

> Is there a great increase in building going on in Manchester?
>
> – Very great indeed; the increase of factories, too, in the town and neighbourhood, is also very considerable at present; but that may be accounted for from another cause rather than from the increase of demand for goods; *they fear an abridgment of the hours of labour* by the Bill that is now before The House,

or, in other words: capitalists rushed to build steam mills in the Manchester metropolitan area in anticipation of legislation that would squeeze water, even as demand for their products remained weak.[64] When they entered the mid-1830s boom, the business climate would have been loaded with awareness of the aims of the factory movement, insecurity over the new Act, concern over its enforcement. The very *process* of factory legislation constantly in the making altered the incentive structure, and not merely by encroaching upon compensatory overtime. A shortened working day would also put a premium on a prime mover capable of filling out the remaining hours with the maximum amount of work. As the factory movement made its final thrust towards a ten-hour day, this was the capacity on which capital set its eyes.

Ten Hours and a Half, Full Steam Ahead

Having triumphed over the repeal campaign in 1836, the short-time committees retained the momentum and went on the offensive, large crowds again sailing under the Ten Hours banner. But to reach the land of at least some rest and leisure, they might first have to overrun the entire calcified state apparatus. In the following years, the factory movement formed one of the tributaries to Chartism, the great stream of proletarian protest flowing through the manufacturing districts, whose unifying programme promised the fulfilment of the most urgent demands of the class *through* universal (male) suffrage. The general strike of 1842 brought revolution to the doorstep of the kingdom: to choke off the feeder streams, a terrified Parliament reopened the file of factory legislation.[65] In a debate in March 1844, one conservative MP reminded the House of 'what took place in the autumn of 1842'. In those unforgettable weeks,

> the working classes in the manufacturing districts left their masters, and went through Yorkshire and

> Lancashire in masses; for several days, in fact, the whole of those counties was in their possession, and it was not till the military were called out, and blood was spilled, that the majesty of the law was asserted … I am prepared to inform this House from the working classes, that if this House upon this occasion refuse to grant this Measure [the Ten Hours Bill], they will not cease to agitate, and, what is more, those parties who have stuck by them in their agitation throughout the country will not cease to join with them in their renewed agitation.[66]

Close to passing in 1844, the Ten Hours Bill became the law of the land only in May 1847. Steam or water, the masters were as recalcitrant as ever, but in the weeks before the vote, Edmund Ashworth accepted defeat as inevitable: 'Facts and arguments have seemed to avail nothing against the popular cry for a 10 Hours Bill: it is evident the question has now obtained too firm a hold upon the public mind to be staved off.'[67] The Factory Act of 1847 stipulated that the working day for young persons and females of all ages – and ipso facto any remaining hands – be reduced to eleven hours on 1 July 1847 and to ten on 1 May 1848. Replete with loopholes, however, it had to be clarified and amended with another law in 1850: no mills were allowed to open before six in the morning or close later than six in the evening. In between, operatives could work for ten and half hours and must be given one and a half hour for meals. On Saturdays, production must cease at two in the afternoon. Thus the ten hours for which so many had clamoured became ten and half, exclusive of meal breaks, but the British textile industry nevertheless changed forever: henceforth there would be a fixed normal working day with which it was criminal to tinker, every operative being in her full right to walk out at the stroke of the clock. The struggle over working hours in the cotton mills reached a first closure. In spite of some hard-liners protesting the compromises, the factory movement petered out; bended and extended since the days of Arkwright, the working day stabilised behind a limit.[68] Waterpower received its coup de grâce.

If twelve hours of continuous production had been the previous standard, the Acts of 1847 and 1850 took away one-eighth of that time and gave it to the workers to use according to their own discretion. Now, one could expect that such a cut would *improve* the predicament of water mills, since they would no longer have to demand twelve, fourteen or even more hours of uninterrupted flow from their rivers. In another setting, it might indeed have offered some relief, but the logic of capitalist commodity production – the hunt for profit, the burden of fixed capital, the struggle for survival in ultra-competitive markets – operated in somewhat mysterious ways. The remaining hours had to be filled with the maximum amount of labour. In the simplest possible terms, the manufacturer would lose money if his quantity of products also shrunk by one-eighth. He would wish to keep that quantity unchanged. One way to do so was to *produce faster:* the spindles on a self-actor could be made to perform more revolutions per minute, churning out more thread at an increased pace; a power loom could weave more cloth within a given time unit. But the prerequisite for such acceleration was readily available *power,* from a prime mover *whose force could be whipped up by the master* so as to propel the machines with higher speed.

Not all prime movers responded with the same mute obedience. In case of a reduced working day, Leonard Horner reasoned in 1845, a mill-owner might easily recover the losses by raising his productivity: there was room for all sorts of gains in time. 'The work turned off is produced *by the combined effort of the steam-engine and the workman,* and the amount contributed by each varies immensely in different factories'; naturally, a shorter day would spur the mill-owner to drive the workers – hence the machinery, hence the engine – 'at the utmost rate of speed'. The opportunities on the rivers were not as promising. 'In the case of water mills,' the inspector

observed, *'where the intensity of the power in some seasons is continually varying during the day,* the workman cannot bring increased vigilance or attention to bear.'[69] A river might slacken of its own accord. No button could be pushed, no mechanism manipulated to make it run faster. The flow had a temporality of its own, not amenable like the stock to heightened velocity.

During the countdown to the ten (and a half) hours, predictions of speedup as the reflexive reaction to the reform abounded, and may well have been, in one sense, self-fulfilling. A well-informed cotton capitalist mulling over his next investment in the mid-1840s boom would have bet on a prime mover prepared to take his orders. The more working hours were restricted – and the more such restrictions were *anticipated* – the larger the premium on an energy source unperturbed by the rhythm of the weather – or, conversely: the shorter the working day, the greater the power required per hour, the more painful the cost of a wheel slowing or coming to a stop. When the Act finally came into force, the masters knew what to do. In the autumn of 1848, Leonard Horner organised his own poll to explore the effects of the recent legislation: 'The hands must work harder now; but the hours being shorter, they can bear it better. The weavers are now producing quite as much cloth as before in 12 hours. *The engine has been speeded,*' said the manager of one cotton mill. 'They work harder now during the time, and turn off nearly as much work as they did in 12 hours, *the engine having been speeded,*' two spinners told a sub-inspector. 'In the weaving and on the self-acting mules they have made up a little, chiefly by the people working more intensely and sticking closer to their work, and a little by *increasing speed of the machinery,*' stated another manager.[70]

If labour scored a gain in the Acts of 1847 and 1850, capital retaliated by speed through steam. Having dreaded the scenario for nearly two decades, the masters stood ready to reconquer time lost to the relaxation of the operatives by setting them in speedier motion, as Horner continued to observe: 'The speed of the looms,' he wrote in late 1850, 'has been so greatly accelerated in the last few years, that the number of yards of the same fabric which a loom will weave in a given time is now much beyond what it did in 1835'. In 1856, the four inspectors – Horner still their greybeard – reported 'that the steam engine is enabled to drive an increased weight of machinery by economy of force'; 'an increased quantity of work can be turned off by improvements in machinery' as well as 'by increase of speed'.[71] A key concept here was precisely *economy of force,* a trademark of steam power. The Ten Hours Act not only undercut the wheel in its old contest against Watt: it prompted manufacturers to replace one type of engine with another, extracting more force out of the same fuel.

The steam used by Watt was kept at a low pressure, not above that of the atmosphere. In his *Treatise on the Steam-Engine,* John Scott Russell offered a pedagogic explanation: 'When water boils furiously in a kettle or caldron,' the steam comes rushing 'with considerable velocity out of any crevice or pipe which communicates with the open air'. This is low-pressure steam. 'But if we stop up the spout and close the cover with accuracy, so as to confine the steam within the kettle or boiler, the water will become hotter and hotter, and *the steam stronger and stronger*' – it acquires a high pressure, above that of the atmosphere.[72] At an early date, this principle was proposed as an alternative to Watt's: steam could be made to press against the metal, like a bulldog teased to strain the leash. Let loose from the boiler and into the cylinder, it would pound the piston violently only to be abruptly cut off, the rest of the upward push accomplished by its natural expansion. While the Watt engine derived power from low-pressure steam alternately filling out the cylinder and being condensed into a vacuum, this variant acquired its force from the high pressure and expansion of steam, and thus it was either called the *high-pressure* or the

expansive steam engine.

Watt spurned the concept, for several reasons: it rendered his separate condenser superfluous, provided a jerkier motion, increased the risk of exploding boilers. But other inventors pursued the path, notably in the mines of Cornwall, where the performance of the high-pressure engine gradually improved over the 1820s and 1830s until it could generate the same amount of power from a fifth of the coal consumed in a Watt engine. The less steam that had to be transferred to the cylinder – the more of the effect derived from the expansion – the less coal had to be burned; at the same time, the *speed* of the piston could easily be raised by injecting more steam, allowing for a fine-tuning of fuel consumption and velocity of the engine. In terms of 'economy of force,' it was a superior machine. Few disputed this fact, and yet high-pressure models remained few and far between in the manufacturing districts. The costs of scrapping functioning Watt engines, a lingering reputation for fitfulness, fear of boiler explosions – with their potentially devastating effects inside packed factories – and pure inertia inhibited diffusion.[73]

A shock was required for the masters to move. More or less overnight, the Ten Hours Act of 1847 provoked a conversion: in ten and a half hours, the demand for high-velocity power surged – and *now* the mill-owners were willing to risk their property and operatives' lives. Again, social necessity was the mother of adoption. It proved swift; at the end of the 1850s, the engines working on classical Watt principles comprised a tiny fraction in the Manchester area, the swap virtually complete, raising both efficiency and speed: 'From the same weight of steam engine machinery we are now obtaining *at least* 50 per cent. more duty or work,' coal consumption slimmed down to around a forth, James Nasmyth, inventor of the steam hammer, stated in 1852.[74] Slender and long-lashed, here was the perfect whip.

The velocity of the machines in the British cotton mills increased by one-twenty-fourth between 1845 and 1849, according to one estimate; in the judgement of von Tunzelmann, the act kindled the greatest bout of acceleration ever to be registered in the industry.[75] While the quantitative dimensions of the process must remain obscure, some qualitative consequences are more clearly discernible: for water mills, the coming of high-pressure steam was the last nail in the coffin built by factory legislation. There was no widespread advance in waterwheel technology that could match the breakthrough, the wheels continuing to revolve at the stately pace of old as the pulse of the steam mills quickened.

A natural corollary was *a fall in the price of steam:* in the late 1840s, the cost per horsepower in a Manchester cotton mill plummeted. For the first time, the purely economical advantages of water were under stress, though it would take several decades more for steam to erase them.[76] The more frugal consumption of coal in each engine did not, however, translate into lower *total* burning of the fuel – to the very contrary, this was the episode that founded Jevons's paradox: 'It is the very economy of its use which leads to its extensive consumption.' Wasteful, expensive coal consumption had previously *held back* the steam engine, but 'the economy of using high-pressure and super-heated steam' allowed it to radiate from its cotton base towards all fields of manufacturing. Less coal per engine expedited total triumph. In the words of coal historian Neil K. Buxton, the generalised diffusion of high-pressure steam after 1850 'meant that the economy became *increasingly dependent upon a steady expansion in the supply of coal':* another moment in the emergence of the fossil economy.[77]

And another result of a collision between the classes: according to von Tunzelmann, the Ten Hours Act was 'probably the most important determinant' of the rise of high-pressure steam and, by extension, the final victory of the engine in the cotton industry (and beyond). For Allen, the

Act jolted entrepreneurs out of their low-pressure ruts, and, as a consequence, the old-new prime mover 'rapidly displaced water' from the late 1840s: it was here that 'the decisive shift to steam occurred'.[78] But it would be an overstatement to say that the transition from water to steam, flow to stock had its *primary cause* in the Acts of 1847 and 1850. It had been in the making long before; Allen's identification of the 1840s as the critical decade is one too late. Instead, we can discern a dynamic operating with escalating force over the whole period of the structural crisis, encapsulated by the comment of a Manchester cotton manufacturer in 1833: 'It is obvious that the more you diminish the number of hours the more you decrease the value of a water-wheel, in proportion to that of a steam-engine.'[79] As the free disposal of labour power in time was progressively curtailed, cotton manufacturers shifted to a prime mover capable of maximising labour in the time that remained.

The Factory Acts – beginning with that of 1833 and the climate of fear in which it was born – slowly but surely strangled waterpower, first by confiscating the tools used by the masters to manage river fluctuations, then by prodding them to speed up. Steam capitalists were infinitely better equipped to absorb the forward thrusts of the working class and perhaps even *turn them to their own advantage,* as more goods were manufactured per time unit after the mid-century reforms. Time was cut in a size only the stock could fill.

A Paradox of Flow and Capital in Time

'Water,' wrote economist Richard Jones in the 1830s, is 'cheap but uncertain. The steam-engine is costly but powerful, and its action is certain and continuous.' In the *Treatise,* John Farey gave prominence not only to the spatial limitations of waterpower, but also to its variations in time: 'The supply of water is subject to diminution in dry weather, or to total stoppage in frost, and to excessive accumulation in rainy seasons, so as to suspend the works'; moreover, 'the natural currents of wind and water, are limited in the rapidity of their motions, and act most efficaciously on machines with some certain velocities.'[80] These were all natural attributes of an energy source belonging to the flow. Carried by the rhythms of the seasons and the daily weather, riding with the ups and downs of the hydro-logical cycle, water followed its own clock – not that of the factory.

The factory clock took precedence in very peculiar circumstances. When one of Chadwick's commissioners observed that 'the speed of a water-mill can never be regulated with the exact nicety of a steam-engine,' he did so within the context of universal laws of nature *overlaid* by the impending legislation.[81] The temporality of the flow was constituted as problematic only through the conflict between two social forces: the interest of capital in extending production over the maximum amount of daily time and the antithetical interest of labour in securing part of the day for its own needs. Just as in space, then, there is a striking paradox in the dimension of time. The flow was 'in a state of motion by nature,' as Babbage put it; the stock was utterly static. But from the standpoint of cotton capital, as it accumulated in time, *the flow was liable to standstills and the stock fireable at any moment,* the lethargic and the timely transposed. This can only imply that capitalist property relations of early nineteenth-century Britain had produced *their own form of temporality,* which, after entering a moment of acute contradiction, had to reorder nature. Neither the export to distant markets nor the profit motive, the exigencies of fixed capital, the need to regulate the speed of machinery and fill in every hour with maximum labour emanated from nature – the other way around: *they* had to construct and rearrange *nature* out of the

materials at hand. As with space, we shall follow the implications of this paradox to their theoretical conclusion later. But first we need to look closer at steam as a form of power.

CHAPTER 9

‘No Government but Fuel’: The Derivation of Power from Coal in Bourgeois Ideology

Steam Fetishism

A whole ideology was spun around steam in late Georgian and early Victorian Britain. It was an ideology in the minimal sense of a set of ideas, values and beliefs held by a group – in this case a class: the British bourgeoisie – promoting its interests, directing its actions, expressing its experiences and ambitions and assigning it a mission in the world. All of these, and more, were regularly abstracted from the artefact of the steam engine. According to the ‘morphological’ theory advanced by Michael Freeden, an ideology is a configuration of political concepts, clustered in a particular pattern or order – much like a room with furniture arranged in a certain way.[1] On this view, liberalism is a room in which a range of conceptual chairs and tables are assembled around the centrepiece of freedom. In the ideology of steam, following Freeden, the British bourgeoisie gathered its family of cherished ideals – progress, science, mechanical ingenuity, accumulation of wealth, the rights of private property, freedom – around the fireside of the steam engine.

But here we immediately notice an incongruence. The steam engine was not a concept, like liberty or equality or anarchy: it was a thing. It would hardly make sense to speak of ‘steamism’ as analogous to liberalism or socialism, though a reader of a random issue of *Mechanics’ Magazine* in the 1840s or a visitor to the Great Exhibition of 1851 might well have greeted the term with a nod of familiarity. Would it not be more accurate, then, to consider the steam engine a temporary golden calf of liberalism, a necklace worn for a time by a body of ideas and then discarded, a fad within the fold of some generic bourgeois ideology, rather than the source of an ideology sui generis? It was a transient technology. It was also the first great avatar of a fossil economy with staying power. There is a possibility that the room furnished around its flames was the first in a *succession* of ideologies for the fossil economy, undergoing several rearrangements and renovations in later stages, perhaps lasting into the present day. Moreover, students of ideology have long been familiar with symbolic spaces centred not on concepts but on things: the peculiar category of ideological formations known as fetishisms. In the decades of structural

crisis, the British bourgeoisie developed *steam fetishism*.

The Engine Keeps Good Hours, Drinks No Whiskey, and Is Never Tired

Rotative engines were praised for their ability to impel automatic machines, dispensing with the need for unruly labour. The self-acting mule and the power loom were the emblematic gloves for their moving hands, but not the only ones, of course. When writers enthused over steam as a substitute for human hands, they had a whole wardrobe of machines in mind; indeed, the second quarter of the nineteenth century witnessed a drive to automation in many branches other than the spinning and weaving of cotton. Four cases will give an idea of the breadth of the trend.

After the cotton had been spun and woven into calico and bleached into a spotless white, it was time to impress the cloth with colours and figures, often in vivid, delicate patterns stimulating the tastes of fashion: the work of the calico printers. When the cotton industry exploded in the 1780s, the art was still carried out with wooden blocks on which the patterns were engraved; a printer would grab the block by the handle on the back, saturate it with colour, press it firmly against the cloth and strike it with an iron mallet, using only his own bodily power. The procedure would be repeated hundreds of times for every piece of calico. Slow and protracted, it was literally in the hands of the printers, limited in supply by their strength and skill. The printers acquired a bargaining position similar to that of the spinners, to the extent that, in the first two decades of the century, their illegal combinations appear to have controlled most aspects of production in the printworks – quantity of output, kinds of patterns, choice of tools, employment of apprentices, hours of production – demoting the masters to feeble deliverers of capital.[2]

Meanwhile, the destroyer of the printers bided its time. In connection with a strike in 1785, a master near Preston patented a machine for printing calico: a copper cylinder engraved with patterns and imbued with colour, then rolled over the cloth by the force of an external prime mover. The imperfect device was slowly put to use, but in the early nineteenth century new models appeared – for, as one manufacturer explained to *The Tradesmen,* the trouble the printers 'gave their masters, inclined many to make great improvements in machinery, by means of which great quantities of goods were printed, independent of the journeymen'. As late as in 1835, there were still complaints of the powerful unions and high wages of the blockprinters, but in these critical years, their militancy only served to hasten automation: sharing the fate of the handloom weavers, they were inexorably put out of business, their occupation extinguished by the self-acting printer, one more collective of headstrong workers consigned to history. For Ure, the machine was a chariot of redemption from the tyranny of the operatives on a par with the Iron Man, the automatic printing establishment a wonder equal to the combined factory.[3] The engine calmly operated its marionettes on this stage as well.

Outside cotton, the same sequence – disorderly workers, new machines, steam and tranquillity – was repeated in the worsted sector, where the tangled and snarled fibres of the wool first had to be straightened out: the traditional work of the wool combers. A comb in each hand, the initial stage of production on their knees, they would simply comb the wool until it was ready for spinning. 'Since the commencement of this century,' we read in John James's voluminous *History of the Worsted Manufacture in England* from 1857, 'the wool-combers had become a powerful, organised body, who frequently by their commotions, strikes and insubordinate conduct, occasioned much difficulty with the masters' – they 'seem to have been the dictators to

their employers'. Two months after the repeal of the Combination Laws, they united in an association in the worsted districts of the West Riding of Yorkshire, leading to 'the bitterest strike of Bradford's history' in the words of E. P. Thompson, some 20,000 wool combers and weavers downing tools for half a year.[4] Attention now turned to the idea of a combing machine. In 1827, inventors Platt and Collier duly patented the first practical model, and the masters in Bradford, capital of worsted, immediately took it into their hearts:

> To free themselves from the intolerable conduct of the combers and weavers, combing machines and power-looms were speedily brought into the service of the trade. Platt and Collier's newly invented combing machine being found eligible for working up long and coarse wool, were set up in the town,

alongside power looms in the branch of weaving.[5]

Turmoil and boom in the early and mid-1830s precipitated further automation, and in the same moment of compressed change, 'in the small interval between the years 1833 and 1838,' James related, 'there had been a most rapid and remarkable increase in the steam power,' particularly in Bradford, where horsepower from steam outdid that from water by a proportion of 23 to 1 in 1841. The coalfield of West Riding supplied the requisite fuel. When James published his history, all seemed well in the worsted industry: strikes had subsided, self-acting machines were in place, steam puffed, coal burned; the improvident wool combers 'are fast dwindling into insignificance, and are threatened with extinction'.[6]

But who would manufacture all these machines? When mechanisation spread to other sectors than cotton, demand for the work of the machine-makers naturally rose. Proud artisans, they trusted to eye and hand when boring a cylinder, building a carriage or operating a lathe, drill or screw – tools they often owned. The usual instability in hierarchies followed. 'The men were masters,' Fairbairn wrote echoing the sentiment of the latter; the whole kingdom had to rely on these secretive craftsmen for the provision of machinery; making the most of the situation, their unions pushed up wages and prices.[7] 'The enormous expense which was incurred,' wrote James Nasmyth, proved 'a formidable barrier' to the delivery of machines: 'The necessity of more trustworthy and productive agents rendered some change in the system imperative.' Such agents could, of course, only be *other* machines, or 'machine-tools,' the basic principle of which was a self-acting instrument for cutting or shaping an object, with power from a non-human prime mover and precision from within the instrument itself. Nasmyth, most famous for his steam hammer – a huge hammer raised by the pressure of steam that descended with a precisely regulated blow – recalled how Lancashire's mechanics enjoyed a sellers' market in the boom of the mid-1830s: the greater the need for their skills, the more they struck, drank, loitered in the early weeks and came and went as they wished:

> The irregularity and carelessness of the workmen naturally proved very annoying to the employers. But it gave an increased stimulus to the demand for self-acting machine tools, by which the untrustworthy efforts of hand labour might be avoided. The machines never got drunk; their hands never shook from excess; they were never absent from work; they did not strike for wages; they were unfailing in their accuracy and regularity, while producing the most delicate or ponderous portions of mechanical structures.[8]

Commencing in the mid-1830s, the transformation of machine production had been all but completed by 1850. In this period of a decade and a half, British industry experienced the most concentrated spike in machine demand of the century; at its end, little of the old order in the

workshops remained. Machines would no longer be made by artisans but by machine tools – the slide rest, the planing machine, the boring machine; machines for grooving, slotting, paring, drilling, polishing – easily operated by low-waged lads since they 'required very little exertion of muscular force, but only observant attention. In this way the tool did all the working (for the thinking had before been embodied in it), and it turned out all manner of geometrical forms with the utmost correctness.' A master like Nasmyth would now derive his fortunes and authority from the one unfaltering prime mover: '*The factory engine supplies the labour or the element of Force.*'[9]

Thus the steam-powered machine saved the steam-powered machine for a new era. Indeed, the mechanisation of machine production was vitally important for ending the structural crisis: without it, expanding capital accumulation on the basis of machinery simply would not have been possible. Only with the multiplied productivity and certainty of the machine tools could the self-acting mule, the power loom, the cylinder printing machine, the combing machine and, not the least, the steam engine itself be spread over the surface of the British economy. The years after the panic saw *the first general push* to substitute machines for human labour – particularly skilled, adult and male – but why not on the basis of water? Everything indicates that capitalists in the branches mentioned here chose steam for broadly the same reasons as in the spinning and weaving of cotton, with some variations in emphasis. Machine shops were not covered by the Factory Acts; instead, they were more dependent on the spatial concentration of technological know-how than any other establishments. Most of them went straight from animate power to stock, skipping the intermediate station of the flow. In the mid-1810s, Fairbairn employed 'a muscular Irishman' to turn lathes in his Manchester workshop; in 1823, the Irishman was replaced by an engine.[10]

Tufnell highlighted another fascinating case of such a shortcut, taken from the construction sector proper. In the early 1830s, strikes by hodmen, bricklayers and builders in Lancashire spurred the masters to entrust some of their work to steam engines that mixed lime and sand, made mortar and hoisted materials to upper floors without the need for human hands. What exactly was the great benefit of this arrangement? Tufnell inserted a letter by one of the building masters: 'We send up indiscriminately bricks, stone, iron or timber; *the engine is much more tractable and civil than the hod-men, easier managed, keeps good hours, drinks no whiskey, and is never tired.*'[11] This would become a truly fetishised quality of steam in Victorian ideology.

Once capitalist property relations were established in commodity production, capital and labour were locked in combat, inducing the former to unleash wave after wave of machines to subdue the latter – and never more forcefully than in the first structural crisis. Here was the context in which bourgeois ideas on energy in general and steam in particular developed. They were profoundly shaped by the intense and persistent experience of workers who resisted management, shirked hard labour, drank whiskey and became tired – and of engines that did not.

The Magical Power of Machinery

Fascination with automata has a long pedigree in Western culture. As Minsoo Kang documents in *Sublime Dreams of Living Machines: The Automaton in the European Imagination,* Hero of Alexandria – the ancient architect of steam toys – inaugurated a tradition of experimentation with marvellous self-moving contraptions. In the late tenth century, the Byzantine emperor adorned his throne chamber with models of lions and birds automatically roaring and chirping when

people approached; in the sixteenth and seventeenth centuries, royalties and nobles of France and Italy were fond of filling their gardens with moving and water-spouting statues, often in the shape of classical gods or monsters, astonishing visitors with their stunts. In the late 1730s, Jacques de Vaucanson became the most famous European automaton-maker with his 'defecating duck,' a mechanical imitation of a duck that could flap its wings, drink water, swallow grain and even excrete small pellets all by itself. Spectators flocked to the amazing wonders; word of the apparitions travelled far.

All of these devices were automata, under Kang's basic definition: machines that mimic living beings, with an apparently innate capacity for motion. In pre-industrial Europe, their main function was to awe, surprise, intimidate, amuse – in short, impress. They were almost exclusively the property of extremely rich individuals, who used them to display grandeur. Magic and sorcery were often imputed to the objects. The automata of early nineteenth-century Britain – the machines that more or less exactly imitated living spinners, weavers, printers, combers, turners, and so on – were offspring of the same imagination, but fulfilled a radically different function: actively partaking in the production of commodities. If the automata of pre-industrial Europe had the main purpose of *flaunting* wealth, those of industrialising Britain were meant to further its *accumulation*.[12] Only after this shift can we speak appropriately of what political ecologist Alf Hornborg calls 'machine fetishism'.

The word 'fetish' derives from the Latin verb for 'make' or 'manufacture'; as is well known, its current use originates in the encounters between Portuguese merchants and West African belief systems in the fifteenth and sixteenth centuries: the natives were seen as worshipping manufactured objects in a most primitive form of delusion. Since then, 'fetish' and 'fetishism' have, of course, drifted into a range of different significations, from the sphere of religion to art, sex, economics and ideology, but some common denominators bind (most of) them together. A fetish is a thing supposedly endowed with its own autonomous force. It is treated as though divinity, beauty, excitement, virtue, growth or some other vital potency inheres in it, as a property of the object itself. It is inanimate, material, most often manufactured by people, but perceived to embody the qualities of a living subject. It is the concrete appearance of a meaning. It possesses some sort of power.[13]

In critical studies of capitalist societies, certain objects – notably money and commodities – have long been recognised as modern fetishes, operating as though they had agency of their own, placed on a pedestal above ordinary mortals and venerated; like 'primitive' fetishes, they conceal within themselves their true origins. Social power is imparted to the objects, so that relations between human beings appear in the guise of things, to the detriment of some and the gain of others. Now, to this body of theory Hornborg has made the signal contribution of attending to *the machine,* which, he claims, is nothing less than 'the most central fetish of industrial capitalism'. 'Machine fetishism,' then, is the attribution of generative capacity and independent productivity to the machine, ostensibly the greatest agent of progress, a cornucopia and latter-day idol, whose real foundations are obscured.[14] It occupies a liminal zone imbricating fantasy and actuality, the two moments reflecting and reinforcing each other.

The automata of early nineteenth-century Britain were adored as archetypal fetishes. 'It is in a cotton-mill,' Ure wrote, 'that the perfection of automatic industry is to be seen; it is there that the elemental powers have been made to animate millions of complex organs, *infusing into forms of wood, iron, and brass an intelligent agency*'. The self-acting mule and the power loom were conceived as quasi-persons, artificial objects behaving as if they were alive – a perception we

have already encountered in the sobriquet 'Iron Man'. In the worsted sector, Ure regarded the wool-combing machine as another wondrous instance of *'embodying handicraft dexterity and intelligence in a machine,* and thereby' – the very rationale for the device – 'substituting cheap and docile labour for what is dear, and sometimes refractory.'[15] This was the nub of his vision: the deliverance of industry from contumacious hands by means of self-acting machines, to which all skills were to be transferred.

If automation in the mills constituted a hands-on fetishism, bourgeois language held up a magnifying mirror to it. Speaking to the British Association for the Advancement of Science in 1861, Fairbairn extolled the machine tool as having *'within itself, almost a creative power;* in fact, so great are its powers of adaptation, that there is no operation of the human hand that it does not imitate.' Nasmyth deployed an image of fabulous metamorphosis: from within the tools, he and his peers could cut and drill and shape metal pieces with 'a degree of accuracy as if we had the power of transforming ourselves into pigmy workmen'.[16] A more common and telling metaphor for machinery was that of slaves. In a remarkable passage in his 1844 novel *Coningsby,* the Conservative MP and prolific author Benjamin Disraeli resorted to oriental mythology when describing his protagonist's visit to the factories of Manchester:

> He entered chambers vaster than are told of in Arabian fable, and peopled with habitants more wondrous than Afrite [an underground *jinn* in Arabic folklore] or Peri [a descendant from a fallen angel in Persian legend]. For there he beheld, in long-continued ranks, those mysterious forms full of existence without life, that perform with facility and in an instant, what man can fulfil only with difficulty and in days. *A machine is a slave* that neither brings nor bears degradation: it is *a being endowed with the greatest degree of energy* and acting under the greatest degree of excitement, yet free at the same time from all passion and emotion. It is therefore not only a slave, but *a supernatural slave*.[17]

Such mysticism was everything but rare in accolades to the machine: in his treatise on the power loom, master weaver William Radcliffe spoke of '*the magical power of machinery,* which subjects wool, linen, silk and cotton to illimitable production by mechanical agency that consumes no bread'. The boundary between technology and magic, Hornborg remarks, has always been difficult to draw.[18] In late Georgian and early Victorian Britain, the mechanical idiom was irresistibly pulled back towards the beliefs and perceptions of pre-industrial times, visits to the cotton mills eliciting the same emotions as strolls in the garden of a Florentine aristocrat or exhibitions of de Vaucanson. Even in an age that prided itself on its consummate rationality – even in speeches to scientific audiences – the magical tropes were never far away; we shall see how far this apparent retrogression went.

Located in a different economic galaxy, however, bourgeois amazement at the machine – slightly more sober, more pragmatic: greedier – was infused with the scent of finally approaching victory over workers, the fetish worshipped for its ability to vanquish human labour. While the automata of earlier ages had been empty masks, hiding merely the mechanisms of a speculative gimmick, those of nineteenth-century Britain were filled with actual capacity for commodity production transposed to them from living hands. Machine fetishism was born out of the hand-to-hand combat against 'refractory' hands, as a fantastic mist rising from the battlefields of mills and workshops; endowed 'with automatic movements and superhuman force,' the machine now represented *a physical embodiment of power,* stealing away the one asset of the operatives – their indispensible labour – and transplanting it to its own mute body.[19] The old sublimity of mechanical dreams touched ground.

As with all forms of fetishism, however, this one had its many moments of concealment, two of which we shall mention here. In the writings of a Ure or a Babbage, the automated productive apparatus became an ontological category in itself, peopled only by inanimate beings, the subjectivity of the workers literally effaced from the shop floor. While this corresponded to actual endeavours, the mirage of perfect automation was always one step ahead of inventors and capitalists, always leaving a need for some human labour, however far it proceeded. This was obscured. Every now and then, it appeared in the form of a blatant but symptomatic inconsistency:

> It is, in fact, the constant aim and tendency of every improvement in machinery to supersede the human labour altogether, or to diminish its cost, by substituting the industry of women and children for that of men; or that of ordinary labourers, for trained artisans,

in the words of Ure.[20] Even Ure's automatic utopia was inhabited by a workforce, still necessary to keep production going but liable to invisibility – largely, of course, for reasons of gender and age. In fact, the point of machinery rather was to extract *more labour* out of hands old and new: the very opposite of rendering labour entirely superfluous.[21]

To prop up the vision of machinery as self-acting, bourgeois ideologues had to hide the presence of new, more intensely sweated generations of workers, but it was rarely done with any consistency. Here was a tension within British machine fetishism: machinery was said to fully obliterate *and* better subordinate human labour. To some degree, this ambiguity expressed the realities of a *process* of automation, whereby one form of human labour – male, adult, refractory – would be replaced by another, supposedly more docile, by means of machines. It was an ongoing process, permanently unstable and unfinished. Even young women might rebel. Paradoxically, then, machine fetishism was undermined and stimulated at the same time, every remaining collective of operatives – at least if displaying some propensity for unruliness – both giving the lie to it and providing the incentive for another thrust.

But never did the machine truly become its own self-sufficient source of productivity. The automata of bourgeois Britain were, in fact, anything but autonomous, for they required, among other things, constant attachment to a prime mover without whose energy their lifelessness would be instantly revealed. This antinomy was handled in a more productive way: by moving the fetishism one floor down the factory building, to the engine room.

How All the World Is Governed by Me

One week after the repeal of the Combination Laws, on 18 June 1824, the cream of Britain's bourgeois crop convened in the capital, in the Freemason's Hall on a square between Holborn and Covent Garden, for a very special purpose: to demand the erection of a monument to James Watt. He deserved a statue at the seat of national power. A committee was selected, counting among its members the Earl of Liverpool – prime minister and chairman of the meeting – James Watt Jr, Charles Babbage, two dozen MPs, a couple of reverends and several of the most illustrious manufacturers Britain could muster: wool magnate Benjamin Gott, pottery baron Josiah Wedgwood, Peter Ewart, John Kennedy and, not the least noteworthy, some of the most successful proprietors of waterpowered cotton mills: Kirkman Finlay, Robert Peel, William Strutt, Richard Arkwright Jr. One speaker delighted in seeing on this occasion 'many of that

enlightened, ingenious, independent, and upright class of men, the manufacturers of England,' and Peel joined the chorus: 'I feel the class of society from which I derive my origin exalted and honoured, by possessing such a man [Watt] among its ranks.'[22] A class had come to pay homage to one of its greatest benefactors. In the Freemason's Hall, steam power was ritually consecrated as *a class project*.

One of the many functions of ideology can be to unify a class, close its ranks, weld it into a force fit for social combat, confident of a high calling and probable victory.[23] The meeting at the Freemason's Hall expressed an extraordinary consensus, encompassing even those capitalists who remained convinced of the practical advantages of waterpower in their own mills: a sign of the sway steam already held over the bourgeois mind. No antagonism pitted a Peel or a Finlay against a Kennedy and a Ewart; they were all equally aware of the services Watt had given to their lot – indeed, Peel himself took the occasion to praise the inestimable value of steam in drawing factories to centres of population. On the other side of the crisis, in 1849, Henry Ashworth would likewise laud 'the social reforms which proceed from the use of the steam-engine'.[24] What makes the campaign for a monument to Watt particularly interesting, however, is that it occurred *before the shift from water to steam had come near completion*.

Following the meeting, busts and statues of Watt popped up across Britain. When a larger-than-life monument was proposed, the local elite of a town would congregate for the purpose, give speeches in Watt's honour, assert the indispensability of such an edifice and encourage all monied persons to subscribe. In Manchester, the meeting was held, somewhat tellingly, in a room in the main police office. Presenting the case for a Watt statue, an MP and owner of a cotton mill in Salford first acknowledged that monuments to his genius were already present on every street in the city: the Cottonopolis was built upon this great alternative to waterpower, chained to which manufacturers would have had to scatter. But if Watt was the guardian angel of the city, he ought to be sculptured as such. In Edinburgh, Leonard Horner was among the initiators; in Glasgow, Andrew Ure gave the public lecture as the monument was unveiled; in Birmingham, one of the promoters reminded a distinguished audience in the Royal Hotel that steam 'is a national blessing; and, in fact, it has brought upon the surface of the globe, millions and millions of money.'[25]

Why was it so important to build monuments to the creator of the rotative engine? It 'would tend to perpetuate and hold up to admiration the memory of Mr Watt,' argued one activist in Edinburgh; more precisely, a monument ought to be raised in a central location so that *'it might be seen by the poorest mechanic,* while he was walking the streets in his ordinary dress, and with the implements of his calling'.[26] The local bourgeoisie coming together to build a giant Watt staring down on the workers: here was a scheme unintelligible outside of the context of virulent popular opposition to steam-powered machinery (the subject of the next chapter). But the consumers of Watt images and artefacts appear mainly to have been other members of the bourgeoisie. Here was, above all, a class speaking and showing off to itself, carving an article of faith for the coming decades, cutting its values and aspirations in marble. The exceptionally expensive London statue did not appear until 1834, under the glorious roof of Westminster Abbey, but the mania for Watt monuments raged between the years 1824 and 1826, on the very threshold of the structural crisis: a ceremonial inauguration of steam fetishism. Not coincidentally, *The Oxford Dictionary* gives 1826 as the first year that 'steam' began to be used figuratively to imply 'go,' 'energy,' 'speed' as in still-used idioms such as 'full steam ahead,' 'picking up steam,' 'blowing off steam,' 'under your own steam'.[27] First constructed in the mid-

1820s, the ideology of steam was powerful enough to fossilise in the English language.

In steam fetishism, the fundamental dependency – indeed, the ontological non-autonomy – of automatic machines could be explicitly recognised. No self-acting capacities were in fact self-generated, Russell pointed out in his *Treatise on the Steam-Engine:* 'a machine has no power, either of consuming or creating motive power'; 'it can only transmit it,' only 'modify it to suit particular purposes. In terms of power, the machine was but a passive medium, a mere conduit for the force of the prime mover. While one current of bourgeois thought mystified this relation, it was joyfully embraced in steam fetishism, in whose order of things the engine was the mother of all machines. Authors of manuals were wont to dub it the most important device ever made. In the eyes of Fairbairn, it had 'effected more revolutions and greater changes in the social system than probably all the victories and all the conquests that have been achieved since the first dawn of science upon civilized life': rather an extreme, but commonplace, hyperbole, echoing in another inflection today.[28]

Conceived as a class project, the engine was simultaneously – a slide typical for ideology – imagined to be a blessing for humanity. 'It might be said to have given a new power to the human race,' said a monument champion in Edinburgh; it 'has accomplished more than any other machine for the promotion of the comfort, convenience, and well-being of mankind,' claimed the Society for Promoting Christian Knowledge; it was more than a mechanical piece – 'it may be said to be a great moral power. It will lead to important changes in the moral structure of society,' maintained manual author Hugo Reid; it was the apotheosis of civilisation.[29] In such excited prose, the interests and endeavours of the Freemason crowd – the actual bearers and owners of steam power – were obviously conflated with those of the human species as a whole.

Here the engine was appreciated for much more than its power to drive machinery. This might have been its principal task, but steam was eulogised for its incredible versatility, extending, of course, to navigation on the oceans and locomotion on land, to pumping mines and draining fens, to working on countless fields where humans had previously toiled and strained: a universal mechanical fetish, as it were. In the engine, 'the iron and brass became instinct with motion, and endowed with active power' able 'to work, to forge, and spin, and weave, to fly, and lift, and dig'.[30] The fetishistic transferal of human capabilities to the rotative engine had no limits, precisely because it could impart mechanical energy to practically any object that moved. In January 1834, the *Manchester Guardian* carried a piece on a newly invented steam-driven pot for brewing coffee, beginning with a line pinpointing the perceived essence of the new era:

> *What business of life is there in which steam will not have a part?* Besides working our cotton mills [obviously the paramount duty], propelling our boats and carriages, printing our books, and labouring for us in a thousand other ways, behold it now upon our breakfast tables, making our coffee! *Nothing is too great or too small for its potent and subtle agency*.[31]

It was but a short leap from such admiration of the all-round engine to a vision of it as omnipotent. Steam could do anything; therefore it would soon rule the world, or already did so. M. A. Alderson opened *An Essay on the Nature and Application of Steam,* published in 1834 and selected as the prize essay by the London Mechanics' Institution, with an almost liturgical invocation: 'STEAM! all powerful steam!' But the theme was best embellished through poetry. A subgenre of steam poems emerged in the decades of the crisis, often exceeding all bounds of decent literature and vying for the most extreme bombast, as in T. Baker's *The Steam-Engine; Or, the Powers of Flame: An Original Poem in Ten Cantons*. Here steam appears as a speaking

spirit: 'I am the Genius of aerial flame / By Heaven's command, omnipotence I claim!'[32] A similar image was deployed in 'A vision of steam,' printed in *The Times* in December 1829 and reprinted in the *Manchester Guardian,* in which the protagonist is awakened from a century of sleep among ruins and dirt by the sudden touch of a spirit:

> But the silence broke, and the stranger spoke, –
> I heard him in my dream:
> 'Fear not,' he said, 'but come and see
> How all the world is governed by me,
> The mighty Spirit of Steam.'

Then the spirit takes the newly awakened man on a chariot ride through Britain in 1830, where streets are swept, books written, even criminals hanged by the agency of steam.[33]

As much as this was a phantasmagoria, it is important to note that the theme of steam-as-omnipotence grew out of and fed into the emerging realities of the fossil economy, *constituted precisely by the protean nature of the rotative engine*. Neither the combustion of coal in stoves nor Newcomen's pumping engine aroused visions of all economic activities – every 'business of life' – permeated by this particular form of energy. In their eras, the powers of the flame were still materially limited; only when Watt's engine had proved its utility in the propulsion of machinery could an ideology of steam burst into unrestrained fantasy. Time and again, the engine was described as being alive, a subject acting and performing and doing all sorts of things ex proprio vigore, even an organism with all the hallmarks of metabolism and vitality:

> And why should one say that the machine does not live? It breathes, *for its breath forms the atmosphere of some towns*. It moves with more regularity than man. And has it not a voice. Does not the spindle sing like a merry girl at her work, and the steam-engine roar in jolly chorus like a strong artisan handling his lusty tools?,

in the words of Disraeli.[34]

Situated in England in the years before the panic, *John Halifax, Gentleman,* an enormously popular rags-to-riches novel by Dina Mulock Craik, climaxes when the eponymous mill-owner and hero replaces his wheel with an engine. The scene of the installation radiates with private potency and solemn, centralised authority: the workers 'only stood and gaped at the mass of iron, and the curiously-shaped brickwork, and wondered what on earth the "master" was about?' Utterly impassive, the 'simple mill-people' watch as the engine begins to rotate – and all 'of a sudden, a soul had been put into that wonderful creature of man's making, that inert mass of wood and metal, mysteriously combined. The monster was alive.' A better précis of fetishism would be hard to find. Next moment, Halifax declares his mission accomplished: 'Steam power once obtained, I can apply it *in any way I choose.*'[35]

In *Our Coal and Our Coal-Pits; the People in them and the Scenes Around athem,* an important work to which we shall soon return, the steam engine was said to cast a spell on the spectator unlike any other machine, with a mesmerising charisma absent in the loom and the hammer: it 'stands *as if it had life and breath in it,* working of itself, earnestly, steadily, and manfully'.[36] Was this how British people actually saw the engines: as living beings coming towards them, manoeuvring in front of them, gesturing and talking to them? No semi-structured interviews can be made, but the extant literature makes it rather clear that bourgeois fetishism did indeed reach a new level in the face of the glowing engine, harking back ever closer to the

imagery of lions and birds, the classical gods and monsters of old.

Steam was showered in mystical allegories and analogies, to the extent that it (or its inventor) became virtually deified. 'Watt! and his million-feeding engineer! / Steam-miracles of demi-deity!,' exclaimed free-trade poet Ebenezer Elliot, while Baker in his book-length ode called the engine 'god-like' over and over again. It sprung from that primordial province of mysterious existence: the underworld:

> A BEING rose of supernatural might:
> With pond'rous rod he brought the foaming waves,
> *As if by magic, from earth's deepest caves;*
> Varied his task his wond'rours powers to prove;
> Swift o'er the plain he bid the chariot move,

et cetera.[37] Perhaps it was no coincidence that Disraeli likened the steam-powered machinery of Manchester to the underground jinn of Afrite. In a sense, the combustion of fossil fuels *is* material necromancy: the conjuring up of dead organisms, reawakening their vital forces to steer the actions of the living. In any case, the steam engine lent itself to such mysticism by the defining trick of *transforming the most utterly inert matter into the most dynamic motion,* something no other prime mover had ever done before. The spatiotemporal profile of the stock determined the practical advantages of steam *and* its supernatural aura in bourgeois society, for masters as well as for minstrels.

The engine was 'miraculous and Herculean,' 'like the rod of the Israelitish Prophet,' or simply a creation of the Christian God, but a more conspicuously common reference was Arabic mythology.[38] Farey, author of the most technically exact and supposedly clearheaded manual, trumpeted that the steam engine 'has been made to realize some of the Oriental fables of those beneficent and laborious genii, who, at the request of some favored mortal, would raise populous cities in the midst of deserts, excavate subterraneous palaces,' and all the rest. In *North and South,* Elizabeth Gaskell compared Nasmyth's steam hammer – a machine tool with an inbuilt engine – to one of the 'subservient genii in the Arabian Nights,' while Walter Scott referred to Watt as 'this potent commander of the elements, – this abridger of time and space, – this *magician*'. In perhaps the most turgid panegyric of the Victorian era, *The Silent Revolution: Or, the Future Effects of Steam and Electricity upon the Condition of Mankind,* Michael Angelo Garvey blended Christian with Arabic imagery: steam 'has descended to earth. It mingles with men … It defies the tempests … The talismans of Arabian fable never endowed their possessors with such power as that which science has bestowed upon mankind.'[39]

How shall we assess the prevalence of these transcendental tropes? Two interpretations are possible. Either writers on steam used myth as a foil to rationality, in order merely to underscore that true marvels belonged to the sphere of modern engineering – not to stupid saga – or they invested the engine with mythical power because they seriously believed, on some level, in its miracles. In the first interpretation, statements on spirits and genii and Israelitish rods were stylistic ploys of no import; in the second, they operated on a cultural register of at least residual irrationalism, not to be discounted from the ideas that mattered in practice. Perhaps the statements drifted between the two usages. The sheer frequency of metaphysical language does suggest, however, that something more was taking place than a trivial play on words. So do the fundamentally fetishistic structure of the steam ideology, the extensive lineages of quasi-mythological receptions of novel automata in European history and, from another angle, the fact

that the era scarcely distinguished itself for its great sense of irony. Even if Farey did not sincerely mean that Oriental fables had now become realised, he and his bourgeois peers seem to have developed a veneration of the engine deeply resonant with mythical archetypes. Asa Briggs, distinguished historian of the era, has written of the ideology as 'the gospel of steam'; in *Engineering Empires: A Cultural History of Technology in Nineteenth-Century Britain,* Ben Marsden and Crosbie Smith label it a 'worship of power'; yet another suggestion is 'Wattolatry'.[40] It would hardly qualify as a full-blown religion – though the idolised Watt came close to the role of a prophet, his career to national epiphany, the monuments to temples – but perhaps a half-secular, half-spiritual creed: one of the classical connotations, of course, of the concept of 'fetishism'.

Indeed, pre-scientific chimeras appear to have made a resounding comeback in early and mid-nineteenth-century Britain. In *Sublime Dreams of Living Machines,* Kang traces the twists and turns of European ideas about the automaton, from the profound enchantment of the Middle Ages to the scientific revolution of the seventeenth century, when mechanical objects were suddenly desacralised and disenchanted. In the time of Descartes, the Western intelligentsia insisted on purely naturalistic explanations of self-moving apparatuses: they all operated on the basis of laws of nature, just like the clock, the emblematic artefact of the era.[41] The machines were purged of their magic. By the time of the structural crisis, however, the British bourgeoisie had long since shaken off the grip of feudal religion. It could allow itself to resurrect the spirits, to the paradoxical effect that a period that wore scientific rationality as its finest badge of honour constantly relapsed to romanticism, or even mechanical obscurantism.

This might have had practical consequences. Waterpower evoked no commensurate ideology. The basic technology of the wheel had been known since antiquity; it represented an inheritance from the past, not a window to the future; the most gigantic installations attracted and impressed tourists, to be sure, but they were in no way comparable to the nimbus of steam: there were no *mysteries* about them. Unlike the stock, the flow was perceptible in motion, fully transparent, familiar to everyone from personal experience; the wheel just transmitted the current of the river, presenting no ghostly mien like the engine, whose arms were linked to yet cut off from a distant nether region. The wheel did not travel back and forth between the realms of the living and the dead.

Self-acting mules, power looms, wool-combing machines could easily be installed in water mills, but machine fetishism never really hooked onto water. There were no campaigns for monuments honouring famous wheel inventors – if there had been, Thom might have thought himself a candidate – no hydro-idioms introduced to the English language, no talk of water as 'a great moral power' or a metabolising organism or a fable come true, no steam capitalists coming to pay homage to the other side in Freemason's Hall. When Robert Thom sought a broad explanation for the – in his view – irrational negligence of waterpower, this was the direction in which he groped:

> Perhaps the brilliant success of the steam-engine has had no small share in it. *The halo that encircled the brow of Watt seems to have attracted almost all the aspiring mechanical genius* of the age to the steam engine; and *the more natural, but less attractive,* power of water were of consequence thrown into the shade.[42]

How significant might this factor have been? It is unlikely that capitalists chose steam over water if it gave them no particular profit, only losses, just because they wished to spend time with phantoms from the Arabian Nights. Yet it cannot be ruled out that steam fetishism exerted a real

influence on the minds of manufacturers and mechanics, blinding them to the considerable potentials of waterpower technology. Wheels inspired no comparable fervour or bewitchment, lent no similar ambience of *mission civilisatrice* to their owners, fired no enthusiasm in the heart of bourgeois culture. Just like any other human beings, capitalists are more – or less – than exclusively rational creatures, and ideology can arouse passions, orient actions, egg on its adherents in their practical life, including in the sphere of commodity production. It cannot be ruled out that the masters fell under the spell. Its relative efficacy is well-nigh impossible to gauge, but it is certainly noteworthy that Watt was glorified and steam power fetishised *before* the critical years of the mid-1830s; ideal images of the transition, they might have played a part in *motivating* cotton capitalists and others to see it through. On the other hand, there is a danger in isolating fetishistic ideas as a causal factor in themselves, somehow elevated above the context of day-to-day struggles on the ground floors of the economy. In fact, the former never quite left their moorings in the latter, however lofty they were – rather to the contrary, steam gained its halo from battle.

Like Thine Own Arm, Subservient to Thy Will

The sequence of that battle was eloquently rendered by Peter Gaskell. A surgeon by profession and a liberal by persuasion, he wrote one great work, *Artisans and Machinery,* a few dozen pages into which he praised steam as the redeemer of Britain:

> Human power is urged beyond a certain point with great difficulty; and, what is still worse, when great numbers of individuals are in exclusive possession of one particular occupation, it is a power difficult to manage, and still more difficult to be depended upon … [The masters] had indeed but little alternative, and it is quite certain that a crisis was rapidly approaching which would have checked the progress of manufactures, when steam, and its applications to machinery, at once turned the current against the men, and has been since steadily, but securely sweeping their opposition to the dust.[43]

The central scene of this wave movement was the cotton industry. It would have been stunted, burdened with ‘expensive details’ – a reference to the colonies – and finally destroyed by the growing combinations ‘but for the application of steam’. Indeed, insubordination provided manufacturers with the one overarching reason to introduce steam power, whose promise it was to free them from the yoke of ‘utterly unmanageable’ workmen; Gaskell urged the capitalists onwards, sighting the complete annihilation of proletarian influence in the mills by means of the ‘tractable and gigantic servant the steam-engine’.[44] Gaskell here assumed the role of spokesperson for strategic management of the crisis: rolling in the engines to roll back the workers. All the fetishised properties of the automatic machine, inferred from their use-value in the class struggle, were transposed straight onto the engine, and this move was indeed symptomatic. In steam fetishism, the themes of machine fetishism were generalised and amplified as *functions of the prime mover,* the universal self-actor, the father of all minor iron men, or, as Baines would have it, the heart of the factory impelling innumerable ‘arms, hands, and fingers’.[45]

What, then, were the ideological pathways that made machine fetishism pass by water and run into steam? (This is but another way of posing the question of the transition.) *The very same bourgeois values incorporated in automatic machines were found in engines* but not in wheels. When discussing the ‘theory of the motion of rivers’ in his *System of Mechanical Philosophy* in

1822, Watt's confidant John Robison claimed that the engineers still had not learned to master the force of water. It refused to bend to their wills. 'Nature,' he contended, *'shows her independence* with respect to our notions, and always faithful to the laws which are enjoined, and of which we are ignorant, *she never fails to thwart our views, to disconcert our projects, and render useless all our efforts*'.[46] A startling view of nature in general and water in particular, with a revealing gendered language, this statement made it perfectly clear why the British bourgeoisie could not stand the flow in the end: it possessed an *autonomous mechanical power,* conforming to the laws written by her own sovereign nature, over which the masters could exert no stable control. The parallelism with human labour is striking.

Workers might go on strike and water freeze; workers might depart in a restless and migratory spirit and water run faster in faraway hills; workers might refuse orders and water dry out; workers could embezzle materials and water flood premises. All vexations of human labour were mirrored in the flow. Conversely, *all virtues of the automatic machine echoed in the stock,* primarily, and in sum, the absolute absence of any autonomy. In 1848, Nassau Senior lectured on this essential advantage of steam at Oxford University:

> What distinguishes it from all others is its manageability. Wind power must be taken as it is given by nature. It can neither be moderated nor augmented. Water power is rather more under control. It can always be diminished and a little may sometimes be done to increase it. *The power of steam is just what we choose to make it*.

Even more damning to their energy credentials, human beings and horses were endowed with their own wills. Senior chose an illustration from the latter creatures, but it was clearly meant to extend to the former: 'Brutes are governed by *instincts and passions which we cannot always foresee or control,* since they are perhaps never precisely the same – I doubt whether there are two horses with precisely the same moral and intellectual qualities.' By contrast, 'the action of two steam engines made on the same model is precisely the same. They act therefore according to laws all of which can be known and all of which can be provided for' – laws in the hands of masters and mechanics, making the engines incapable of erraticism, domesticised once and for all.[47] The engine possessed a unique combination of potency and manageability. Having guided the reader through the world under his rule, the genius of the aerial flame said it himself in Baker's poem:

> Like thine own arm, subservient to thy will.
> I've shown thee much at this eventful hour,
> Which appertains to this RESISTLESS POWER.[48]

The figure was ubiquitous: Babbage admired steam for being 'obedient to the hand which called into action its resistless powers,' Ure 'the gentle docility of this moving force,' Fairbairn 'powers so great and so energetic as to astonish us at their immensity, while they are at the same time perfectly docile'. Inside the Manchester police station, master Philips revered steam for its 'controlled and governed, and regulated' nature, while Robert Stuart, author of an 1824 *Descriptive History of the Steam Engine,* lauded not merely its 'prodigious powers,' but just as much 'the ease and precision and ductility with which they can be varied, distributed, and applied'.[49]

We may call this *powerless power* – a cardinal doctrine of steam fetishism. Its attractiveness

was a function of the glaring lack of submissiveness *among workers and in watercourses,* the former the social, the latter the natural contrast to steam. Not the least frequently, the engine would be held up as the antithesis of rowdy humans. In the first major biography of Watt published in English, François Arago, a French scientist and associate of the Royal Society of London, declared him 'the creator of six or eight millions of labourers, of assiduous and indefatigable labourers, *among whom the law will never have to suppress either combination or rioting;* of labourers working at wages of five centimes per diem', presumably the cost of coal. Calculations of how many acres of woodland the engines replaced were rare in the literature, for obvious reasons, but those of how many *workers* they equalled were all the more common. One study suggested that the total horsepower capacity of Britain's stationary engines in 1826 represented that of precisely 6,400,000 men (compared to 480,000 in France).[50] The diffusion of steam, Babbage remarked, 'has already added to the population of this small island, millions of hands'. Gaskell estimated the standing force to be 'equivalent to the entire adult labour of the kingdom,' while a hagiography of James Watt published in *The Times* in 1859 revised the number radically upwards, reporting that total steam power of Britain was now *'equivalent to the manual labour of 400,000,000 of men, or more than double the number of males supposed to inhabit the globe*. Such *power* did Watt confer upon this nation.'[51] Accurate or not, the figures conveyed a certain perception of steam: not as a terrain of ghost acreages, but – an altogether more fetishistic quality – as a kind of *ghost population,* first replacing human labourers and then outgrowing them, marching onwards in the factories, ever growing in numbers.

Here the slave trope of machine fetishism appeared afresh. The engine was a mega-slave, passive *and* energetic, or in the words of Farey: Watt and his fellow inventors 'rendered it capable of very rapid movements, and put its powers so completely under control, that it is now *the most tractable, as well as the most active, laborer we can employ*'. In principle, Farey argued, all labour performed by steam could be done by human bodies, but with certain attendant difficulties; suppose, for instance, that an engine draining a coal mine was exchanged for 3,500 men. First, their discipline would have to be ascertained – no easy matter. Second, they would be exhausted from the exertion, requiring several relays of men. 'Thus we have' in steam, Farey concluded, 'a laborious and indefatigable servant, doing as much work as 3500 men could do, and *so docile, that it requires no other government* or assistance than that of two men to attend and *feed it occasionally with fuel*'.[52] A perfectly docile and ductile labourer – no government but fuel: a sublime dream of crisis-ridden capitalists.

Steam was perceived as the ultimate substitute for labour, because it was everything that labour was not. All its virtues were negations of working-class vices: here was a mechanical mega-worker and *anti*-worker. All its merits were also negations of the minuses of other energy sources, primarily water. Steam was valued for having no ways of its own, no external laws, no residual existence outside that brought forth by its owners; it was absolutely, indeed *ontologically* subservient to those who possessed it. 'It is called into existence by the will of man,' wrote Hugo Reid.[53] The purpose of self-acting machinery – to reconsolidate power over labour – necessitated a prime mover *over which capital could exercise absolute power* while at the same time *offering capital all the power it needed*. In the formula of powerless power, the British bourgeoisie found an ideal basis for automation, as well as an ideological doctrine summing up the concrete benefits of steam: divisibility under individual capitalists, mobility in space, reliability in time, all aspects of a fundamental called-into-existence ontology. In a period in which the disobedience of flowing nature became uncannily analogous to that of a foaming

people, the response from the steam genie – picture a trapped capitalist – must have been irresistible: *Master, I will obey you. Have you any other commands?*

There is a slight deviation here from 'normal' fetishism, if such a thing exists. A fetish is a material object treated as though it had a life of its own, but steam was fetishised precisely for *not* having one. It was worshipped for its utter lack of volition. There was never any need to appease it, supplicate or please it; steam had no autonomous agency, only relaying that of the masters; it needed not be submitted to, and therefore it could be deployed so efficiently to subject others. To the extent that it was deified, it was a strange deity, one without the ability to influence its followers – or, with Reid, steam was 'so completely under our control, and possessed of a self-regulating property to such an extraordinary extent, that it almost realises the fable of Prometheus, and may fitly be compared to *an intelligent being devoted to our services*'.[54] If steam had life, it was a lifeless life, a ghastly population created by capital in its own image, pushing against the boundaries of the phenomenon of fetishism and towards something rather more sinister.

Mechanical power and social power were here fully at one. In steam fetishism, slippages between the poles were constant, to the extent that they can only be pulled apart by retroactive violence. One of the most oft-repeated anecdotes from the company of Boulton & Watt revealed the former to consciously play on the dual meaning of the English word:

> When Matthew Boulton entered into partnership with James Watt, he gave up the ormolu business in which he had before been principally engaged. He had been accustomed to supply George III [king of Britain 1760–1820] with articles of this manufacture, but ceased to wait upon the King for orders after embarking in his new enterprise. Some time after, he appeared at the Royal Levee and was at once recognised by the King. 'Ha! Boulton,' said he, 'it is long since we have seen you at Court. Pray what business are you now engaged in?' 'I am engaged, your Majesty, in the production of a commodity which is the desire of kings.' 'And what is that? what is that?,' asked the King. 'POWER, your Majesty,' replied Boulton, who proceeded to give a description of the great uses to which the steam-engine was capable of being applied.[55]

The story circulated in several different versions, many of which had Boulton telling a visitor with radiating pride: 'I sell here, Sir, what all the world desires to have – POWER' – a statement today circulating on the British fifty-pound note. But even if the king was exchanged for the world, the allusion to a centralisation of power in the hands of a few was integral to the story. Retelling it once more, a hagiography in *The Times* interpreted it as proof that 'a new era had dawned when *power* could be sold upon this scale, and its creators and vendors might deem themselves princes and kings of *powerless* men.'[56]

Omnipotent agent, ghost population, the power always at hand: in all its multiple fetish guises, steam was perceived as a mechanical-cum-social power – and thus by definition *central,* not equally distributed over the surface of humanity: in the hands of some, to be wielded against others. The full context of these ideas cannot be grasped on anything but a world scale. Steam power might have rendered its most valuable services on the waves, as the British Empire expanded from sea to shining sea. But inside the mills, the engines were, of course, installed in the power relations between masters and hands. We have seen Ure describe how the engine 'summons around him his myriads of willing menials,' imposing his will as the 'central power' of the factory – a notion connoting the duality of the phenomenon, incomprehensible if either of the two aspects is subtracted. In another colourful phrasing, Ure stated that 'the steam-engine is, in fact, the *controller-general* and main-spring of British industry, which urges it onwards at a steady rate, and never suffers it to lag or loiter, till its appointed task be done': it *embodied* the

power, dictating to the hands the rhythm and length of their work as a stand-in for the manufacturer, his commander-in-chief or the metallic carrier of his subjectivity. Nasmyth chose another military metaphor: 'We all know the influence of a quick merry air, played by fife and drum, upon the step and marching of a regiment of soldiers. It is the same with the quick movements of a steam-engine upon the activity of the workmen.'[57] Such talk laid aside all pretensions at transcending the need for human labour and blazed abroad the intention to extract all the more of it.

Here the steam engine resembled a peculiar form of fetish, today existing in the Western imagination rather than in any actual religious practices of Afro-Caribbean communities, but once common in ancient Mediterranean cultures and, it seems, in medieval France: the voodoo doll. Archaeological findings of such artefacts in Italy suggest that they were pierced with nails for the purpose of "nailing down" opponents and making them immobile,' drawing them into the orbit and submitting them to the will of the performer of the rite.[58] The likes of Ure and Nasmyth perceived the engine as something similar: an object through which antagonists could be manipulated by remote control. In this regard, it was perhaps not so different from other modern fetishes – notably money – but it seems to have lacked the capacity, in ideology as well as in reality, to *turn on its creators,* establish an emergent mastery over its authors, constrain their actions or demand their sacrifices. Steam was advanced as *the materialised power of the bourgeoisie*. The domination of this class at the point of production no longer required Combination Laws or similar legal, extra-economic interferences to the same extent as before: now the government resided in the prime mover. All it demanded, in ever-growing quantities, was fuel.

Coal Is All-Powerful

Some steam fetishism replicated the illusions of machine fetishism by rendering the engine literally self-moving. 'It feeds itself,' Alderson wrote disingenuously, 'and draws from its own labours all that is necessary to its own subsistence,' as though it were in fact a closed system. Garvey suggested that the real 'prime mover and director' of steam was 'the mind itself' – the sheer intelligence of Britain's engineers – while others remembered that little detail: here was 'an Automaton; / Destined from man no trouble to require, / Save now and then to prime his heart of fire'.[59] Others still sought to bring steam fetishism fully down to earth:

> It is common to depict the advantages introduced by the steam-engine, and to say that it weaves, it spins, it pumps, it prints, it winds, it draws, it stamps; and, in fact, does all that steam-moved machinery can do. But what enables the steam-engine to do all this? – *coal*. All the skill of Watt would have been in vain without supplies of mineral fuel,

remonstrated John R. Leifchild.[60] A government commissioner into the conditions of mining labour in the early 1840s, explorer of the coal districts and leading Victorian writer on carboniferous matters, he hid under the pseudonym 'A traveller underground' when authoring *Our Coal and Our Coal-Pits; the People in them, and the Scenes Around them*. The gist of his work was the exposition of the subterranean foundations of all the miracles of steam. Leifchild was not, of course, alone with the insight – 'without an abundant supply of coals, the use of steam-engines, and the practice of the modern system of manufactures, would be very limited,'

wrote Farey – but he went one step further by actually descending into the mines, putting their content on display before the bourgeois reader, bidding him to discover the cellar supporting his existence.[61]

Leifchild offered himself as cicerone to the landscapes of the stock. Hardly anyone ever went there unless involved in excavation, but Leifchild claimed uniquely extensive experience from the coal mines of northern Britain. Approaching them, a visitor would first notice their swarthy canvas: 'You begin to see tall engine-houses, and vastly tall chimneys, breathing into the sky long black clouds of smoke.' Next he would hear the 'unearthly' sounds – the groaning engines, whistling pulleys, wailing railways – and then, coming closer, pass by the chimneys hoisting into the sky their 'slanting column of turbid smoke': always the omnipresent smoke. It was a landscape artificially constructed for the shovelling out of the earth's intestines, or the transposition of underground and surface. The coalfields as described by Leifchild increasingly resembled the depths of the mines – black, sooty, gaseous, crammed – as a consequence of turning the downside up; along his route, 'every thing is sacrificed to the coal.'[62]

Informing the exploration was an acute awareness of the principles of the fossil economy. Leifchild began *Our Coal* by comparing gold and coal, the two most valuable minerals in the world: one 'bright and dazzling, the other black and forbidding'; one stored up in banks, the other hidden in seams; one 'the apparent representative of the country's wealth, the other its real representative' – the true digging for diamonds took place not on distant shores, but right under the feet of the British. If all their deposits were to be turned into pure gold in an instant, the loss would be catastrophic. Without coal, 'our steam-engines would rust unused, for lack of suitable fuel; our factories would be closed; our railroads would be untraversed; our steam-vessels would be dismantled, and decaying in the dock; and all our processes of manufacture would be deteriorated' – or, in short, growth would come to a grinding halt.[63]

During the structural crisis and the decades after it, other treatises on the fuel expressed the same, slightly vertiginous realisation: *the kind of economy Britain had now developed turned utterly on coal*. It had become the basis for 'the employment of capital and labour – the advancement of general commerce – the improvement of land – the appropriation of the wonderful power of the steam engine,' standing 'pre-eminent as the cause of our national wealth'. It had become 'the mainspring of modern civilization,' with Jevons: upon Britain had dawned 'the Age of Coal. Coal in truth stands not beside but *entirely above all other commodities*. It is the material energy of the country – the universal aid – the factor in everything we do.' Jevons's pronouncement is sometimes quoted as an inscription over the gateway to addictive fossil fuel use; eloquent as it is, it only articulated a wider zeitgeist. In the literature of the time, the identification of coal as the bedrock of the economy and the attribution of British manufacturing supremacy to the abundant reserves became another refrain repeated ad infinitum. To take but one more example: 'Coal, as the great source of the moving power of manufacturing production is the principal of these original, peculiar, and comparatively exclusive sources of wealth,' in the words of *Circular to Bankers*.[64]

Material omnipotence may thus have been located one level below the enginehouse. Jevons marvelled at the 'almost incredible' amount of power 'bottled up in the earth' and corrected the famous Boulton anecdote: 'In coal we pre-eminently have,' as the partner of Watt said, 'what all the world wants – POWER.' Taking the tropes of steam fetishism to their ulterior home, he announced that 'as the source especially of steam and iron, *coal is all powerful.*'[65] Leifchild resorted to stanza:

> Let foes but steal our cash, and then
> They leave us what we were – brave men.
> But could they filch our mines of coal,
> They'd steal our bodies, selves, and soul.
> 'Tis COAL that makes our Britain great,
> Upholds our commerce and our state.[66]

Alchemical, 'the *true Philosopher's Stone,*' surpassing all the miracles of saints, coal was 'a heaven-born gift to man' – or just 'a power unremitting in its labours'.[67]

At this point, steam fetishism appears to have boiled down to *coal fetishism,* passing the properties of the derivations onto the fuel itself, as though coal by its own force exerted power, maintained the state or spread miracles. While reaching the material substratum of the higher floors, bourgeois ideology here lapsed into other acts of concealment. One of them concerned the workers in the mines: coal did not eject itself from the dark chambers. Of this, however, Leifchild was well aware. He portrayed the colliers with a mix of anxious hostility – particularly to their trade unions and strikes – and pity, as creatures inhabiting the lowest step on the ladder of the fossil economy. They were unenviable 'poor carbonized-looking men,' 'blackened, queer, begrimed beings,' more and more assuming the appearance of their work material for every year underground. At the same time, the hewers were the 'equivalents of the crocodile, the ibis, or the bull in the Egyptian temple'.[68] Lower than them, farther into the chambers of the earth, no one could go.

The Structure of Steam Fetishism

There is an ambiguity at the heart of theories of fetishism in modern societies: money, the commodity, the machine are all said to be objects of illusory beliefs about their innate power, while they also *do* exercise material power over people. The sway a religious artefact holds over the believer is solely a figment of the imagination. Money is likewise adored, but it has *real* command over resources in the sphere of exchange, since relations between human beings have been objectified, congealed, embodied in the coin or note; the flow of goods and services *is* mediated by money, and so faith in its supremacy is not entirely delusional, but rather reflects a peculiar social order. The same goes for the commodity and the machine. 'Fetishized objects are in an important sense constitutive – not just misrepresentations – of accumulation and power,' with Hornborg. It follows, with theologian Roland Boer, that 'the one who made the idol in the first place was right in some respect, for the object does have power, *but a pernicious and destructive power*' – a proposition that could have been designed for the steam engine.[69] Yet it would be nonsensical – and a surrender to fetishism – to claim that the engine exerted any power *in itself,* as an artefact moving around on its own, installing its body in mills, tying shafts, ordering coal, calling up workers, and so on. Like money, its functions could only be fulfilled by humans who *operated through it,* delegating their domination to the object, deploying it as a medium: power was *in* the engine, but only insofar as it was used by some against others.

In the ideological formation we have called steam fetishism, steam did indeed stand at the centre. The machine was, figuratively speaking, located above it; coal lay below; each level of fetishisation fed into a corresponding level of material reality, and vice versa. But this particular current of power – extracted from the caves, transmitted by the engines, aimed at labour in the

mills – did not exhaust the utility of its foundations. Above steam, apart from automatic machines, a whole range of objects traversed the economy; the valorisation of the versatility of the prime mover arose from other sources than class struggle. Outlined here is only *one* route from stock to domination – but a strategic one. The struggle against labour called for machinery, which called for steam power, which called for coal, thereby coupled to the growth of manufacturing. Steam stood precisely in the middle, between the lower and upper levels, as the apparatus mobilising the netherworld at the behest of capital.

The reflective – and formative – ideology represented a class in combat. No one would have called himself a 'steam fetishist' as he could have brandished the label 'liberal' or 'socialist,' an anomaly this particular ideological formation shared with money, commodity and machine fetishisms. Unlike these, however, steam fetishism did not just grow spontaneously out of the material (and semiotic) fabric of society: it came into being by bourgeois intellectuals *articulating it openly* as others did liberalism or socialism – but as an integral aspect of an emerging reality, namely the rise of steam power and the birth of the fossil economy. Steam fetishism was a militant, utopian project *as well as* a structure of reification in the making, the worldview of a class subject *and* a reflection of the society it governed, imagined and tangible in its effects. Similarly, the attribution of omnipotence and spiritual influence to steam was only partly false. Hornborg sums up this antinomy of fetishistic ideology in an inimitable formulation: 'Magic and power share the same hybrid position between scam and efficacy'.[70] What sort of magic? Black, in the eyes of many subjects of steam.

CHAPTER 10

‘Go and Stop the Smoke!’: The Moment of Resistance against Steam

Steam Demonology

A shadow of resistance followed virtually every new machine rolled out in the Industrial Revolution, and the steam engine was no exception. One morning in March 1791, the Albion Mill – the first ever to be powered solely by steam – went up in smoke after incendiaries set it alight in several places. ‘The satisfaction of the populace was afterwards expressed by songs in the streets of London,’ recorded Farey; up in Birmingham, Boulton & Watt responded by arming staff at the Soho works against attackers. The incident provided a key incentive for the development of fireproof buildings as a form of insurance against plebeian rage.[1] Following the Luddite revolt and, more particularly, the rising of the Lancashire handloom weavers in 1826, when more than one thousand power looms were smashed, the British state promulgated a new law to protect machinery. In the fifth paragraph of the Act from 1827, we read: ‘If any Person shall unlawfully and maliciously set fire to any Mine of Coal or Canal Coal, every such Offender shall be guilty of Felony, and, being convicted thereof, shall suffer Death’– and the same punishment would be meted out to anyone who tried to ‘pull down or destroy, or damage with Intent to destroy or render useless, any Steam Engine’.[2] At the Lancaster Assizes of March 1831, the judge reminded the audience of the nub of the Act, clearly articulating the priorities of the state:

> It is declared, that if any persons riotously or tumultuously assemble together for the purpose of destroying any steam engine, or any machinery, fixed or moveable, in any manufactory or mine, or any bridge or waggon way, they are deemed to be guilty of a capital felony.[3]

In other words, the critical years of the transition to steam were enclosed behind a law that made wilful damage to a coal mine or an engine *punishable by death*.

These were not mere words. In November 1831, bedlam broke out in Coventry as a mob rushed into a mill equipped with power looms for weaving silk ribbons, destroyed them, set the building on fire and smashed the steam engine with a sledgehammer. Three men were sentenced to death by hanging for the crime. Another way of upholding the Act of 1827 was to acquit

defenders of a factory whose bullets had killed besieging rioters, if intention to damage machinery could be established: this happened in Oldham in April 1834. Yet in spite of the draconian law, workers continued to target steam engines. In a strike in Preston in 1831, spinners extinguished the fires under the boilers in several mills, thereby bringing production to a halt, and, in one case, deliberately drove up the speed of the engine until it broke apart.[4]

What did workers think of steam engines? There are no referendums or opinion polls to consult, but some pieces of evidence allow us to peer into an undergrowth of dissent. Frederick Marryat – seafarer, Royal Navy officer, novelist and editor of *The Metropolitan Magazine* – wrote a piece on steam as seen by Belgian and British workers and, of course, himself. Before the countenance of the engine, Marryat was rattled:

> I never can divest myself of the idea that it is possessed of *vitality* – that it is a living as well as a moving being – and that idea, joined with its immense power, conjures up in my mind that it is some spitting, fizzling, terrific demon, ready and happy to drag us by thousands to destruction. And will this powerful invention prove to mankind a *blessing* or a *curse?* – like the fire which Prometheus stole from Heaven to vivify his statue, may it not be followed by the evils of Pandora's fatal casket?[5]

Here fetishism was inverted into *steam demonology:* the engine as a force of its own, not for good but for evil. Moving its limbs with inherent vigour, a formidable current of energy hidden within its body, the engine appeared to be possessed with an uncanny, almost diabolic power.

To Marryat, the dragging to destruction was already well underway. Workers who feared that 'it would take away their bread' had reached an 'instinctive and prophetic truth' about steam power. An anonymous English gentleman, with whom the writer shared the unpleasant experience of travelling onboard a steamboat, spelled it out: 'It is a melancholy discovery, sir, this steam' – not only to seafarers, but a 'melancholy to those on shore, sir; the engines work while man looks on and starves. Country ruined, sir – people miserable – thrown out of employment.' All the talk of blessings covered up an undiluted curse, and 'there is no chance of a return to our former prosperity; unless we can set fire to our coal mines.' The gentleman perceived Britain as a country turned upside down, shattered to its core, disturbed even in its weather:

> I ask you whether even the seasons have not changed in our unhappy country; have we not summer with unusual, unexampled heat, and winters without cold; when shall we ever see the mercury down below sixty degrees again? never sir. What is summer but a season of alarm and dread?[6]

In these pregnant paragraphs, Marryat connected three prominent sub-tropes of steam demonology: the engine as an agent of *despotism* (it works 'while man looks on and starves'), of *degradation* (the 'country ruined, sir') and ultimately of *doom* (here in the guise of 'unusual, unexampled heat'). The triad also appeared, of course, in the writings of workers. The decades of the crisis witnessed the emergence of an independent proletarian press, with newspapers such the Owenite *New Moral World,* widely read by union activists in the mid-1830s. Originally published in its pages, 'The Factory Child,' a short story by Douglas Jerrold, painted the grim life of the protagonist with the brush of steam demonology: 'The engine, like a thing of life, a monstrous something that awakens in the imagination the might and vastness of the pre-Adamite animals; *that* as though instinct with vitality, works without pause unerringly on, an iron monster with a pulse of steam.' In a pathetic tone, Jerrold wrote of the working girl as 'united – fast married – to the giant steam,' forced to supply her 'infant bones and sinews for the Moloch

engine,' her 'fragile limbs opposed by metal valves – the piston against the human heart!'[7] The despot in action, shackling the hands and expending their force: some confirmation of the bourgeois view of steam-as-power, but seen from the opposite camp.

Demonological sentiments were regularly expressed in the pages of *The New Moral World* and, so it seems, shared by significant segments of the working class. Baines decried 'the common prejudice' that the steam engine 'is a tyrant power, and a curse to those who work in conjunction with it,' while *The London and Westminster Review* cited the view of another group on the brink of downfall: '"But," say the working mechanics, "*steam is our enemy;* it is the servant of the rich man, and does nothing to serve us, but, on the contrary, throws us out of work by giving its labor at a cheaper rate." This,' the *Review* added, 'we believe is the common argument of the uninstructed' – of the workers who, under the influence of malicious agitation, had developed erroneous views of steam and turned blind to its gifts.[8] At a critical juncture in the crisis, such beliefs were translated into direct action.

Towards the Summer of Discontent

In terms of numbers involved, geographical extension, duration, sheer insurrectionary fervour and near-revolutionary dynamics, the general strike of 1842 was the greatest revolt of the British working class in the nineteenth century. It was also the first general strike in the history of any capitalist country. Around half a million workers turned out in the manufacturing districts and strikes hit no fewer than thirty-two counties, albeit with Lancashire, Cheshire, the West Riding of Yorkshire and Lanarkshire as the unmistakable centres: here, the bulk of production was suspended for between one week and two months, beginning in mid-July and ending in mid-September.[9]

To the Victorians, however, the general strike would be better known under another name: 'the Plug Plot,' 'the Plug Riots,' 'the rising of the plug-drawers' and other, similar variations. The plug in question was affixed to the boiler of the steam engine. When marching through the manufacturing districts, the strikers systematically pulled the plugs out or pushed them into the boilers, sending the water onto the floor and the steam into the air and bringing the revolutions of the engines to an instant stop. In the perceptions of contemporaries, this was the mode of striking, the practical act around which the uprising revolved, the weapon used by the riotous hands to impose their will on the hapless nation – but modern historians have chosen to ignore it. In the only book-length study, *The General Strike of 1842,* Mick Jenkins is quick to disparage plug drawing as 'an incidental feature of the strike' and then pays no more attention to it, other than depicting it as a slightly embarrassing detail in an otherwise heroic rebellion.[10]

In the summer of 1842, Chartism had been on the march for four years, demanding a complete overhaul of the British political system along the lines of the six-point 'People's Charter': the right to vote for all men (not women), secret ballot, annual elections, constituencies of equal size to guarantee equal representation, no property qualification for MPs, but payment of salaries so that poor men could stand for election. Universal suffrage was the bottom line of the movement. It was, however, conceived as a vessel brimful with social substance, strictly speaking a means to an end: the rectification of all evils plaguing the workers of Britain. If only they – the vast majority – were allowed to vote, their representatives would take hold of Parliament, depose the capitalists and make all the right decisions on working conditions, hours, wages, taxes, relief and a range of other issues – including, as we shall see, machinery. Captivated by this simple and

straightforward strategy, the whole family of working-class currents – radical reform associations, trade unions, the factory movement, the anti–poor law movement – rallied to the Chartist banner. Here was, at last, a panacea for the proletariat.[11]

Chartism had its main base in the textile industry. Factory operatives swelled the ranks, most prevalent among them the cotton spinners, who brought their hostility to self-acting machinery, bitterness over disappearing jobs and desperation in the wake of declining unions to the cause. But weavers of various stripes were the most numerous constituencies. Handloom weavers of cotton, completely fed up with the state after innumerable petitions had been turned down, hurried to the movement as their final chance to turn the tide against the power loom, as did the handloom weavers of worsted in the Bradford area; by their side, the new generations of power loom weavers became particularly staunch supporters. Blockprinters, wool combers and mechanics all had their own pressing reasons for joining. In the depressed years of the late 1830s, there began to spread a conviction that the plight of the workers could only be ameliorated if the capitalist monopoly on state power were dissolved, and so all the contradictions began to 'converge towards a single point. This point was the vote,' in the words of E. P. Thompson.[12] But in the summer of 1842, the convergence point was of a different nature: less elusive, more concrete and material.

The colliers of North Staffordshire were the first to turn out. Notified of wage reductions in early July, they responded by striking for pay raises, a working day of nine hours and, notably, the Charter as the sole guarantee for both. Bands of colliers roamed the mines and ensured their closure by raking out the fires under the boilers or pulling out the plugs. During the following fortnight, columns moved westwards and northwards into the neighbouring counties with the aim of shutting down all production: in Shropshire, they 'led the starving, but misguided men from pit to pit, and encouraged them to destroy the machinery, and prevent the colliers from working at the present low rate of wages'; ropes leading down pitholes were cut, engines disabled.[13] Before long, the Staffordshire potteries – national centre of ceramic production – were crippled by fuel shortages, just as the colliers had intended. The template for the general strike had been developed: crowds of workers marching from site to site, suspending production by sabotaging steam engines and, along some frontiers, deliberately withdrawing coal from the market.

The turnouts first ricocheted up to other mining districts in Britain. In early August, colliers in Lanarkshire reacted to wage cuts by shutting down 200 pits and plundering potato fields; similar disputes erupted in other Scottish regions and Wales as well as in the Black Country, from which the workshops and factories of Birmingham drew their fuel. Establishing contacts across the kingdom, the striking coal workers began to ponder the formation of a nationwide union as a force for defending wages *and* a shock troop for the wider Chartist cause. In the first week of August, 800 delegates from various districts assembled at Halifax. 'It was only a preparatory meeting, in order to secure a general organization, previous to an universal strike,' reported *Leeds Times,* and *'the power which was in the hands of the colliers of stopping all mills, factories, railways & c*. was insisted upon by many, as making the colliers a very important political body.'[14] The strikers had sensed their leverage. In the new type of economy that Britain had developed, coal was the lifeblood of all manufacturing: cut the arteries and the body would cease to move. But the strike of 1842 was elevated into a general one only when the cotton operatives entered the fray.

Pulling the Plugs

On the pretext of tumbling profits, some manufacturers in Stalybridge and Ashton – old hotbeds of spinner resistance – announced wage reductions of up to 25 percent, days after the price of wheat had risen to a seasonal peak. On the Sunday morning of 7 August, thousands of operatives assembled on a moor between the towns. Speakers vowed to proceed from factory to factory and close them all, and 'when we are out, we will remain out, until the Charter which is the only guarantee you have for your wages, becomes the law of the land.' As in the coalfields, wage disputes with individual employers spontaneously flowed into the national struggle of the Chartist movement, which did not *plot* the general strike as much as it reflected the mood and expressed the strategic determination of the class: in the summer of 1842, the step from demanding better pay to calling for the Charter was short to nonexistent.[15]

The morning after the mass meeting on the moor, several thousands congregated again as agreed 'and did not go to work, but proceeded to Stalybridge, accompanied by spinners, weavers, colliers, labourers, and work people of all descriptions from Ashton and its vicinity, and insisted on the steam-engines being stopped,' as recorded by *The Observer*. In the afternoon, the crowd swelled to nearly 15,000 people, splitting into one column heading for Hyde and another for Oldham: both methodically pulled the plugs in the factories en route. Open-air strike meetings repeated the formula of 'a fair day's wage for a fair day's work' – often specified as a return to the wage levels of 1840 and a ten-hour working day – plus, or through, the Charter. Carrying a black flag with a red cap in the front, the first contingents showed up inside Oldham; all production ceased in an instant.[16] Manchester would be their next stop. At yet another mass assembly on Tuesday 9 August, this time with upwards of 30,000 present, one speaker urged the audience to march on the Cottonopolis, even if soldiers tried to block their path:

> It were much better for them to die on the highway, under the pure sun and pure atmosphere of heaven, than to die while pent up in a factory, and attending to the revolutions of machinery. It were better to die on the street than to die surrounded by the rattle-box, and thundering and clattering of the machinery of the capitalist.

But the crowds did not encounter any resistance, and so 'considerable damage was done at some of the factories' along the way to Manchester.[17] Upon reaching the outskirts, they incited local workers to join the action, which many of them apparently did with gusto.

There ensued a sweep of attacks on mills. The next day, hundreds of strikers 'seized a boat, which they put across the canal to Beckton's Mill,' a major cotton factory in the centre of the town, 'and nearly destroyed a new engine of 300 horse power, with some other machinery'. The sawing machine of a timber yard was 'completely destroyed'. In the Ancoats area, a procession mostly consisting of female power loom weavers moved from mill to mill, demanding shutdown of the engines under threat of break-in; at one, the manager initially refused, but after a few windows had been smashed he complied, and 'the engine was stopped amidst the cheers of the mob.' Most mills in Manchester and Salford were turned out in this way: by workers from the inside or the outside stopping the engines, or by the managers doing it themselves 'under the influence of fear'.[18]

Manchester in chaos, rioters successfully entered a police station and threw its furniture out of the windows. Several bakeries and shops were plundered. During the night between Wednesday and Thursday,

> the premises of a joiner and builder, named Mouncey, who has recently erected some steam saw mills, and probably by doing so has made himself obnoxious to the people, were discovered to be on fire. The conflagration was cheered and laughed at, and the whole of the premises were destroyed, notwithstanding the exertions of the firemen.[19]

With negligible exceptions, the industrial establishments of Manchester were still and silent by Thursday 11 August, the operatives in all major branches having downed tools. In these early days, the armed forces were overwhelmed by the masses shooting through streets and factory floors. 'I have but a very inadequate force in this town,' whimpered a major-general from Manchester, conceding defeat to 'the state of organisation amongst the working classes'; the mayor saw the Cottonopolis slip out of his control, into the hands of another power, 'which both in its extent & for its efficiency is of a character not contemplated by any, and which every day appears more formidable'.[20]

The change of scene extended to all cotton towns of Lancashire. Ashton and Stalybridge continued to function as command centres, dispatching delegations and organising marches; from Manchester, processions fanned out to spread the strike further, although mere word of it often sufficed to touch off the discontent. At Stockport, between 6,000 and 8,000 strikers arrived on Thursday 11 August, walking eight or ten abreast, brandishing large sticks in the air, setting to work with local reinforcements:

> In several instances, where any hesitation was evinced in stopping the mills, portions of the mob entered the premises, and pulled the fires from under the boilers, which shortly caused the moving power to a stand still. *Every steam-engine in the borough was shortly stopped:* and the hatters, moulders, calico-printers, tailors, and every other trade were soon idle.[21]

In one of the many strike meetings during the following days, Chartist orators condemned 'the improvements in machinery as being a great cause of so many people being out of employ,' particularly spinners. For a couple of weeks, the local 'Chartist council' was so powerful as to oblige the magistrates of Stockport to work under its command. No engines moved.[22]

Early in the morning on Friday 12 August, power loom weavers from one of the Preston mills met to discuss an internal wage dispute: the gathering rapidly snowballed into the typical roaming turnout for higher wages and the Charter. At factories where the hands were not immediately discharged, besieging crowds threatened to wreck the premises, smashed gates and broke windows until all work was terminated. The next morning, however, some resumed production. 'This being perceived by the mob,' the *Preston Chronicle* reported, 'they gave a loud shout, and said they would "go and stop the smoke", meaning that they would stop the mills, by raking out the fire from under the engine boilers.' The cry 'Stop the smoke!' was chanted rhythmically as the strikers moved through the industrial zones and burst into engine rooms, sometimes beating up men standing in their way. Alarmed by the furore, the magistrates of Preston called for a military detachment to waylay the mob. So it did, on a street along the main canal, with live ammunition fired into the crowd.[23] Five people were killed in the Preston incident, one of the bloodiest of the general strike. Among them was George Sowerbutts, a nineteen-year-old power loom weaver who had been raking the fire from under the boilers in one factory, throwing water on the coal and punching the overlooker, according to the latter's testimony at the inquest. The bullets were intended to end all such activities and shield the engines of Preston.[24]

In Bury, insurgents drew the plugs in all factories; according to one of the many correspondents serving the government with daily updates from the field, a mob on the outskirts of the town was also in the process of 'breaking machinery and had nearly pulled down one Mill'. From Burnley, word came that 'almost every Mill and workshop in the Town where steam is employed was in the course of a few hours effectually stopped.'[25] Similar events transpired in Bacup where the local population joined a touring crowd, together slaking 'the fire and steam power' in all mills and workshops within one hour. 'Shaking their deadly weapons over their heads, and bidding defiance to all law and authority,' a brigade of more than 10,000 strikers marched on Wigan, closed all mines along the route – at one pit, both plug and engineer were carried away – and so intimidated the commander guarding the entrance to the town that they were allowed to enter and pull the plugs; they then continued to tour various mills and foundries in the countryside unobstructed. Boilers were emptied in Bolton, whose mayor also reported 'some of the machinery destroyed'.[26] In a mass meeting on 15 August, the cotton spinners of the town and its vicinity declared that 'a great deal of the distress in the Manufacturing districts is owing to the improvements of Machinery' and demanded a ten-hour day with the restriction placed on the moving power: no engine or wheel should be allowed to revolve for more than that. In Macclesfield, 'immense crowds' succeeded in stopping every factory by 'putting out the engine fires,' according to the humiliated mayor; in Accrington, they closed 'all the power by letting off the steam,' in one case even emptying the water reservoir; Bingley and Chorley, Colne and Clitheroe and Haslingden were likewise shut down in their entirety, the plugs sometimes drawn even after the turnout had manifested to ensure that it would last.[27]

By the end of the second week of August, practically all production in Lancashire had been discontinued. Nearly a quarter of a million workers were out. Only on Tuesday 16 August, when the uprising was a fait accompli, did the sixty delegates of the executive of the National Charter Association congregate in Manchester, endorse the general strike and call for its extension to the entire kingdom; in a proclamation distributed in the cotton towns, they applauded the fact that 'within fifty miles of Manchester, every engine is at rest, and all is still, save the Miller's useful wheels and the friendly sickle in the fields.'[28] The interlaced cadres of Chartists and unionists had implemented the turnout on the ground, plugs being pulled like falling dominoes, the wave having swept far to the east.

On the weekend before the Association congregated, thousands of workers swarmed through the green valleys of Saddleworth, towards the woollen and worsted districts of the West Riding of Yorkshire. In every mill studding their way, they drew the plugs of the boilers, earning them the name 'Plug Dragoons' in the *Bradford Observer*. Meanwhile, local Chartists launched a campaign of agitation to seize the moment, plastering Bradford with bills and calling for a mass meeting on a moor outside the town on Sunday 14 August. Among the nearly 10,000 participants, the *Observer* noticed that 'the question of machinery seems to be a prominent topic: nothing more common in the assembled groups than the remark, that machinery has compelled the man to wander in idleness, and has harnessed the woman and the child to incessant labour.' Breaking up from the moor, the workers marched off towards Halifax, where they crossed paths with the 'dragoons' coming in from Lancashire. Several people – the exact casualty figure remains unknown – were killed in clashes around steam mills, prodding even the *Observer* to condemn the army for its 'unnecessary cruelty'.[29] Bradford and Huddersfield experienced similar commotion, as did Leeds, where intruding workers took off their hats and hurrahed when the engines fell silent. In the countryside of the West Riding, enormous processions of up to 20,000

workers passed through the mills, visiting the engine rooms according to the script and then moving on, establishing a coverage as extensive – if briefer – than in Lancashire. On 15 August, a speaker whipped up a crowd of thousands near Todmorden: '"And now I ax ye, *will ye pull the plugs out?*" "Aye, we'l do't for 'em", was shouted from all parts of the meeting, amidst tremendous cheering', in what *Leeds Times* called a proclamation of 'the plug doctrine'.[30]

At this point, it should be clear that 'plug drawing' – shorthand for a repertoire of acts of sabotage against steam engines – was not incidental but *constitutive* of the general strike. How many instances were there exactly? There is no way to know for sure. Neither newspapers nor government informers enumerated all individual actions, but rather lumped them together, recounting that 'the plugs were drawn,' or something to that effect, in this or that locality. Often they would merely report that 'the mills were stopped' without mentioning – it being obvious – that the engines had been immobilised. But a few figures give a hint of the numbers involved. In the relatively small town of Dewsbury, dominated by the wool industry, thirty-eight factories had their plugs drawn. A rioter in Leeds boasted of having knocked out thirteen plugs in a single morning.[31] Given the reports of 'all' or 'most' steam-powered factories having their engines disabled in towns such as Stockport, Bury, Burnley, Bacup, Bingley, Chorley, Macclesfield – to name but a few – and given the seemingly uniform course of action in the manufacturing districts, it seems reasonable to infer that the instances of plug drawing must have counted in the many hundreds if not thousands.

The Spigot Opened by Force

Meanwhile in the mines, original homes of the revolt, stillness reigned. The many ironworks of Birmingham were paralysed, the price of coal rising into 'a severe and oppressive tax on the middle classes'. The colliers – few workers turned out in the city itself – sought to detain all provisions: 'Two boats of coal have been sunk in the canal, and fresh destruction of coal is expected,' the *Morning Chronicle* reported from nearby West Bromwich.[32] Some miles further to the west, in Stourbridge, rich in glassworks and blast furnaces, most fires had been raked – 'There is little smoke by day or flame by night to be seen.' On 1 September, the Birmingham Chamber of Commerce sent a resolution to the government declaring that it 'views with alarm, and dismay, the prospect which is upon the Manufacturing interests in consequence of the rapidly diminishing supply of Coal'. In Scotland, the coalfields likewise remained the main theatres of the strikes, whose effects, however, by the nature of things, rippled into other sectors, particularly iron. Reversely, roving strikers in the textile district attacked coal mines where the workers had still not turned out: around Manchester, Bolton and Leeds, colliers were drowned in shouts from the approaching mobs, plugs drawn and pits filled with water.[33]

Rather than being centrally orchestrated, these attempts to pursue the strategy of the Halifax meeting – forcing the ruling class to surrender by depriving the economy of fuel – were scattered and impulsive, the idea percolating through segments of the working class as spontaneously as the tactic of plug drawing had gained popularity. But this was the first of its kind. At the pitheads and in the mills, the general strike of 1842 invented a formula for a new era: *the working class could impose its will on capital by closing the spigots of the fossil economy*. Two weeks into August, idle engines and inactive mines were seals of proletarian power, and the strike movement reached proto-revolutionary dimensions: an economy frozen, local authorities collapsing, seeds of parallel government structures, talk of a final march to London. 'For several

days past, the working classes have had everything according to their wish,' moaned the editorial of the *Manchester Guardian* on 17 August. Their doings amounted to 'an insane movement,' an 'epidemic,' a 'disease'; 'a giant torrent, which, tearing and bursting its furious and misguided way among our northern depots of commerce, has swept down the barriers of citizenship and order, converted the labourer into an anarchist, and assumed all the alarming features of systematic insurrection,' from the vantage point of the *Illustrated London News*.[34]

But at the end of the day, the insurrection could not stand up to the one supreme strength of its adversary: military power. The manufacturers of the north sat out the first wild weeks waiting for it to come. Starting around Sunday 14 August, the government finally got its act together and inundated the manufacturing districts with troops, dispatched from the capital or summoned from other parts of the kingdom; in Manchester, thousands of soldiers arrived by train and marched ostentatiously through the streets with heavy artillery. By their side, they had freshly sworn-in special constables – 9,000 only for the Cottonopolis – watch-and-ward-men, yeomanry cavalry and hastily assembled volunteer patrols of respectable citizens on horseback.[35] In Leeds, soldiers were sent out for the purpose of 'displaying their numbers, and overawing the inhabitants by demonstrations of military strength' as though 'in hourly expectation of an invasion from some formidable foreign foe,' noted the staunchly pro-business *Leeds Times*.[36] Public meetings were banned, local strike leaders and Chartist agitators nabbed in batches.

Behind this raised wall of physical force, some mill-owners could reinsert plugs and set their machinery in motion. As they mobilised reserve armies of 'knobsticks,' as hunger broke the ranks of the strikers and induced some to cave, as the national leadership found itself divided or behind bars, the general strike collapsed in early September. Then came the predictable aftermath: more barracks, effusive thanks to the troops and constables from mill-owners, mass trials against suspected rioters. By October 1842, 1,500 arrests had been made; a year later, the number had increased tenfold. The juries appear to have been obsessed with punishing the crime of plug drawing, summarily doling out sentences – ranging from imprisonment for two months to transportation (that is, deportation to a colony) for a decade – to anyone who could be tied to the deed. The total amount of convictions after the general strike is not known, but the repression was clearly the harshest and most extensive in the history of Chartism, transportations alone numbering some 200.[37] It deflated the movement in the manufacturing districts. Indeed, the defeat of 1842 and the ensuing militarisation effectively ended the revolutionary ferment among the industrial working class and, by extension, the collective actions against the engine. Never again would steam power be deliberately taken down – if only for a few weeks – on this scale, in Britain or anywhere else in the world.

In his classical essay 'The Machine Breakers,' Hobsbawm introduced the famous concept of 'collective bargaining by riot': early industrial workers damaging or destroying machinery as a way of wringing concessions from their masters.[38] Such vandalism represented a crude but effective form of trade unionism avant la lettre. The plug drawing of 1842 obviously falls into this category: it prevented manufacturers from keeping their operatives at work. It could shut down entire towns in a matter of hours. The strike could move as fast as the crowds, across wide swaths of territory, by the force of the human hand – hard to placate when it struck with a pike or hammer. Taking collective bargaining by riot into a new era, however, the strikers of 1842 did not disable any machines they came across but aimed straight for the enginehouses and pitheads: this was collective bargaining by *rioting against the fossil economy*. As the general strike unfolded, it became clear that the interests of the bourgeoisie could only be advanced through a

full reignition of the fires, and those of the working class by extending the temporary cessation of coal combustion, in a contest ultimately decided by extra-economic force. Though steam would never again occupy the centre of such contests, the general formula would resurface in the most varied settings: subalterns rising up by denying their rulers access to the energies of the stock.[39] *In itself attesting to the power relations of the fossil economy,* extending into the present day, this lineage of resistance first appeared in the British mill-towns and coalfields of 1842.

But was there something more going on that summer? Did the plug drawers only seek to hit their counterparts where it hurt the most, or did they also demonstrate animus towards a certain prime mover? How are we to interpret – to all intents and purposes, the term is warranted – the Plug Plot Riots? There is clearly a danger of reading too much into them. By no stretch of the imagination can they be regarded as a revolt against steam power: this was an uprising for decent living standards and political power – 'a fair day's wage for a fair day's work,' plus the Charter – in which the fossil economy figured as the *material terrain* of the struggle, one party rolling forth its ragged brigades to seize and close it, the other its uniformed soldiers to retake and open it. So far, however, historians have succumbed to the opposite danger of not reading *anything* into the Plug Plot Riots, even when the signs are there to see.

At a minimum, the pandemic of plug drawing proved that the tenets of steam fetishism had not trickled down to the working class: knocking out a plug or raking out a fire was not a means of showing reverence for steam. What other message did it send? We would want to know more about what the plug drawers actually thought about steam power. Apart from extant documentation of some speech acts from the frenzy of the moment, we have, fortunately, a shortcut to their hearts and minds: the prolific movement of Chartism itself. In the words of Malcolm Chase, currently the leading scholar in the field, 'Chartist arguments and perceptions of labour's situation informed the actions of trade unionists, strikers and rioters alike' in the years around 1842 and provided them with 'a tool "to think with"'.[40] So we should seek to learn more about *Chartist thinking on steam*.

In Heated Atmosphere of Smoke and Fire

A month after the defeat, on 22 October 1842, the *Northern Star* published a long article entitled 'Man versus machine'. Signed by the pseudonym 'Hungry Handless,' it positively oozed with exasperation. Britain was a country boasting of civilisation and science, but filled with hungry operatives,

> a land rich with all the choicest gifts of creation, but from which the working man has been debarred by a forced competition with the Mammon-made machine; that with its eternal thump, thump, thump, has been reducing, under the piston of the steam-engine, the poor to powder, and like the giant of whom we have read in our nursery tales, has been crying out –
>
> Foe, fau, fum –
> I smell the blood of the working man;
> Be he alive, or be half dead,
> I'll grind his bones to make my bread.

Getting off to such a demonological start, the piece continued as a recollection – the author must have been fairly old – of encounters with a critic of machinery in the Lancashire cotton industry

in the early 1810s, variously referred to as 'the seer' and 'the prophet'. Upon hearing of the Luddites, this teller of truths proclaimed that 'they were knocking the right nail on the head,' for 'the effect of machinery, will be to make the poor poorer, and the rich richer.' In the view of Hungry Handless, the prophecies had been resoundingly vindicated. 'In the insolence of presumed power, the millowners told the working men to bow down to the steam idol or starve,' but they ended up having to do both; subjected to 'the almighty steam-engine' – the totem of the masters, with 'arms of iron but breath of steam' – they were offered starvation wages and diminished in stature, turned adrift and forced to play a losing game against ever-improving machines.[41]

Northern Star was the lifeblood of Chartism. Conveying information on the latest activities of local Chartists and unionists, reporting on the news of the day, agitating for the cause and elaborating on a broader worldview, the paper proved critical for the coalescence of the – spatially, occupationally, politically – disparate components of the movement. National in coverage, it reached a peak of 50,000 copies per week in 1839, dropping to around 10,000 in the following years. But such figures capture a fraction of the readership: *Northern Star* would be read aloud in workshops and homes, during lunch breaks and at meetings; passed between friends, available in sympathetic taverns and coffeehouses, eagerly awaited every week by entire communities. The number of actual readers and hearers per sold copy probably ranged from ten to eighty. Almost exclusively proletarians, they actively shaped the content and language of the *Star,* often submerging the editors in pieces and poems, declarations and correspondence, a pulse of working-class life running through the pages.[42]

Machinery in general and steam in particular were salient topics in the years around the general strike. In early 1841, Numa, another nom de plume, wrote a severe indictment of the state of British society in a series of open letters to the queen: the transition from water to steam, read one complaint, had sunk the workers into penury and woe. At its commencement, factory labour was 'carried on by means of water power, on the banks of the various streams of Yorkshire and Lancashire, which having for ages rolled in undisturbed repose, became agitated by the whisk and noise of water-mills,' a new system 'in which vast profits were realised'. Yet 'feelingless' capital was not satisfied: it craved larger gains, and so 'the water wheel, which could not be kept perpetually in motion, was almost universally made to give place to the steam engine,' by which shift three things were effected. First, vast amounts of human labour were displaced. Second, 'the insatiable monster, avarice' trampled down the value of labour and replaced adults with children. Third, the new demand for coal produced a population of miners, many of them young and female, 'who are compelled to work hundreds of feet below the surface of the earth, in postures which must be injurious to the constitution'.[43]

Steam stood at the centre of the Chartist analysis of class rule: in a lead article entitled 'Steam aristocracy,' the *Star* claimed that progressing machinery had propelled a new class of tyrants to the summit of the nation. The jealous possessors of state power, whose fortress the Chartists sought to overrun, were none other than the proprietors of steam. 'Already do we find our army, our navy, our pulpits, our offices, and our senate house filled with scions of the steam aristocracy.' For the workers, the regime of the 'steamocracy' – as the words were often fused to form a common derogatory term for the bourgeoisie – meant an end to merriment and rejoicing, and 'nought remains, but work, work, work, for the slave, and money, money, money for his master.' In a long fictive dialogue, operative Robin provoked his employer Quill by denying that queen Victoria ruled the country: 'Its *King* still, Master Quill … I mean, that *the Steam-Engine is*

KING *now*!'[44]

Sometimes the paper would enter into direct polemics against steam fetishism. After printing excerpts from a paean to James Watt from *The Illuminated Magazine,* it tagged certain blind spots of the writer: 'So far from the discovery of Watt being an unmixed good, it has been to millions an unmixed evil.' Fetishism was a truth for a tiny class only: 'To the *few,*' the *Star* emphasised, the engine 'has been a more powerful talisman than ever Eastern geni was fabled to command; but to the *many* it has been the heaviest curse that ever lighted on this earth.'[45] In the months before the general strike, the paper repeatedly attributed the rampant poverty in the manufacturing districts to all the self-acting machines for spinning, weaving, drawing, boring, printing, engraving: sawing timber.[46]

Chartism developed a whole cluster of smaller newspapers, none of which compared in circulation to the central *Star,* several of which preached the same anti-steam gospel.[47] Of particular note, *The Odd Fellow* reprinted a fictive story plainly headlined 'Steam' by the minor writer William Cox, who combined several genres – pastoral, Swiftian satire, sci-fi dystopia – into a resounding condemnation of the steam-powered world. Apparently written as a rejoinder to the fetishistic reveries regularly published in the bourgeois press, it must have been deemed of value and interest to a Chartist audience. True to form, Cox began by recalling the unspoiled, idyllic landscapes of his childhood village, where a river meandered through a wild common, 'the very trees possessed an individuality' and 'the balmy air was laden with the hum of unseen insects.' Then came the fall:

> I looked upon the surrounding country, if country it could be called, where vegetable nature had ceased to exist … Houses and factories, and turnpikes and railroads, were scattered all around; and along the latter, as if propelled by some unseen infernal power, monstrous machines flew with inconceivable swiftness … Animal life appeared to be extinct … Nature was out of fashion, and the world seemed to get on tolerably well without her.

Cox had entered the world of steam, populated by a race of what we would today call robots, eerily similar to the hands of old, whose tasks they had all appropriated. Living proprietors and 'locomotive' men now made up the two main classes. Nagging anxiety in his throat, the author looked for the alehouse of his old village as a refuge from this disturbing new world, only to discover that a railroad hotel had been built on the spot: 'Here also it was steam, steam, nothing but steam!' The rooms were heated by steam, the beds made by steam, the meat roasted by steam, the books on the tables 'filled with strange new phrases, all more or less relating to steam'. Cox 'took up a volume of poems, but the similes and metaphors were all steam; all their ideas of strength, and power, and swiftness, referred to steam only,' while an encyclopaedia listed things now only vaguely remembered from a world gone by: horses, trees, tranquillity. Walking back into town nauseated, the author ran into a staging of Hamlet by steam-powered automata, performing as vividly as if they were living actors – until one of them exploded. Now he neared the end of his visit and, depicting the streets of the city, drove the vision to its climax:

> It was the hour for stopping and starting the several carriages, and no language can describe the state of the atmosphere. Steam was generating and evaporating on all sides – the bright sun was obscured – the people looked parboiled, and the neighbouring fisherman's lobsters changed colour on the instant; even the steam inhabitants [i.e. the robots] appeared uncomfortably hot. I could scarcely breathe – there was a blowing, a roaring, a hissing, a fizzing, a whizzing going on all around – fires were blazing, water was bubbling, boilers were bursting – when lo! I suddenly awoke. It was a dream![48]

Next in the column followed an address from the London Working Men's Association on the progress of the struggle for the People's Charter.

But the genre that resonated most powerfully with the Chartist rank and file was probably poetry. As Mike Sanders has recently shown in *The Poetry of Chartism: Aesthetics, Politics, History,* the activities of reading, writing, publishing and reciting poetry were surprisingly central to the culture of the movement. Poems expressed a collective identity, debated tactics, laid down a proletarian morality, instilled a sense of confidence and widened horizons; under the influence of the poetry columns of the *Northern Star* – sometimes several in a single issue – Chartists learnt to appreciate the beauty of a finely crafted stanza and compose verses of their own in the thousands. During its lifetime between 1838 and 1852, the *Star* published 1,500 poems and rejected hundreds more, its editors occasionally wading through unsolicited contributions from amateur bards.[49]

Steam loomed large here as well. Half a year after the general strike, the *Star* featured a poem called 'The steam king' by Edward P. Mead, a Chartist activist in Birmingham:

> There is a King, and a ruthless King,
> Not a King of the poet's dream;
> But a tyrant fell, white slaves know well,
> And that ruthless King is Steam.
>
> …
>
> Like the ancient Moloch grim, his sire
> In Himmon's vale [i.e. Gehenna, or hell] that stood,
> His bowels are of living fire,
> And children are his food.
>
> His priesthood are a hungry band,
> Blood-thirsty, proud, and bold;
> 'Tis they direct his giant hand,
> In turning blood to gold.
>
> …
>
> Then down with the King, the Moloch King,
> Ye working millions all;
> O chain his hand, or our native land
> Is destin'd by him to fall.[50]

A silver-tongued work of steam demonology, all the major tropes – steam as agent of despotism, degradation, doom – are here brought together in the image of one mechanical evil.

Ernest Jones, commonly regarded as the foremost Chartist poet, elaborated on the degradation of the environment. Prefiguring 'A Fable for Tomorrow,' the opening chapter of Rachel Carson's *Silent Spring* widely considered the beginning of modern environmentalism, one of his poems opens with an invocation of 'merry old England' where the breezes flowed, people walked slow, 'summer fields rolled – Their long billows of gold.' Then some evil spell settled on the community. Everywhere was a shadow of death. A cloud of plague rolled over the land, darkening the sun:

> Say! *whence* comes the change? – *Whence* the curse has been sent?

…

What wheels revolve in dungeons hot and black,
Of modern tyranny the modern rack!
What horrid birth from that unnatural womb?
The demon god of FACTORY *and* LOOM!

…

The very sun shines pale on a dark earth,
Where quivering engines groan their horrid mirth,
And black smoke-offerings, crime and curses, swell
From furnace-altars of incarnate hell![51]

In the same vein, a poem by a contributor from Manchester bewailed the fate of the power loom weaver: 'Contending hard against mechanic power, / From early morn till midnight's latest hour, / *In heated atmosphere of smoke and fire,* / He slaves for life to gain a scanty hire.'[52]

To make sense of Chartist poetry, Sanders borrows Raymond Williams's concept of 'structure of feeling'. The rhymers of the movement articulated a structure of feeling deeply embedded in the lives of the working class, their verses printed as distillates, or, with Williams, as 'social experiences *in solution*'. If this is a reasonable characterisation – and so it seems – and if, as another Chartist scholar has put it, the *Northern Star* was 'always an accurate reflector of the labour movement's trends,' then we can hardly escape the conclusion that plenty of steam demonology swirled in the minds of British workers in the 1840s, both before and after the general strike.[53]

How about their leaders? Towering high above all others, Feargus O'Connor held an incomparable sway over the masses of the manufacturing districts: in him 'the English people see themselves. O'Connor is the people summed up in one man,' noticed a German journalist residing in Bradford in the early 1840s.[54] Fresh out of prison, O'Connor's propaganda against steam-powered machinery reached a climax in the months leading up to the Plug Plot Riots. 'Your complaint is MACHINERY, and the remedy is the CHARTER. Steam, the Poor Law Amendment Act, and a Rural Police, constitute a trinity of villainy, complete and indivisible,' he thundered from his pulpit in the *Star* in April 1842. Around this time, O'Connor began – another exercise in revelatory metonymy – to refer to the enemy as the 'smokeocracy'. 'You are mere attendants upon your steam-producing master,' he would lecture the workers: 'slumber until time shall have nurtured and matured for us a whole generation of steam vipers, and then arrest their progress and destroy their influence who can?'[55]

But perhaps the most stirring statement of steam demonology and trenchant exposition of the fossil economy appeared on an anonymous placard right in the midst of the Plug Plot Riots:

> To the Colliers of
> England and Wales,
> Strike! Colliers! Strike for the Charter!
>
> In your hands is reposed such a power as the tyrant few, who oppress and grind the faces of the poor, cannot withstand. Without *coal* the lordly aristocrat cannot cook his luxurious meal. Without coal the *Steam Engine* whose iron arm has beggared so many of your poor fellow-countrymen, willing to work – murdered thousands of *innocent children* in our Cotton Mills yearly – reduced thousands of tender mothers to a worse state than brute beasts, and hung their pale limbs with filthy rags – without coal this giant monster, the Steam Engine,

> cannot work. Your labour, my honest friends, supplies it with strength, for without Coal it is powerless. *Stop getting Coal, for Coal supports the money-mongering Capitalists*.[56]

All of this evidence points to a conclusion, which, if so amply supported, could hardly have been missed by contemporary observers. And it was not. 1842 saw 'alarming chartist riots, plug-drawers, and outrages, the like of which had not been hereabouts witnessed since the days of Luddism,' wrote the West Riding chronicler John James, his analogy selected with choice: 'The distress which prevailed, reached its height in the month of August, and the deluded workpeople *being induced to believe that their privations arose from the use of machinery, determined to draw the plugs of the steam engines,* and thus stop all the factories.'[57] All the Chartist censure of steam power infused workers with and reflected their rage against the engines. The plug drawers perceived them as an incarnation of distress and thus rife for attack: of all accumulated wrath erupting in the heated summer weeks of 1842, some *was* directed against steam. Moreover, rather than registering the Plug Plot Riots as a faint echo of the Luddite legacy – which standard interpretations of the event would not even allow – we might well regard it as the universalised, glowing, evanescent *culmination* of that tradition taking aim at the new prime mover, a target that made far more sense at the tail end of the transition than it would have done in, say, 1812 or 1826.

The rise of steam power coincided with the moment of the fiercest resistance, the engine contested in word and deed by masses of people unhappy about it. The general strike of 1842 was the most dramatic episode, but far from the only one; much like the water reservoirs, there is a current of unsuccessful opposition to steam running all the way from the Albion Mill to the late nineteenth century, waiting to be uncovered.[58] Perhaps most tantalisingly, there appears to have been what we might call a *proto-environmentalist* component of the critique of steam: the persistent imagery of belching smoke and consuming fire, noxious atmosphere and receding nature, extinct vegetation and unbearable heat – 'the people looked parboiled.' But could this have been more than an accidental fit of the imagination?

The Climate of the Factories

A defining property of the steam engine was the production of heat. A wheel derived mechanical energy from the gravity or impact of descending water or both, an engine from a burning fire: little wonder, then, that workers came to associate the rise of steam with the rise of temperatures. Excessive heat in steam-powered cotton mills attracted attention as soon as the conditions of factory children became a national issue. 'It is an unquestionable truth,' remarked a magistrate responsible for the Bolton area in 1819,

> that Children employed in Cotton Factories that have fallen under my Observation are generally puny and squalid, especially those who work in Mills where Steam Engines are used; but in Establishments where the Machinery be worked by Water Wheels, the Climate of the Rooms is more wholesome, and the Appearance of the Children better.[59]

Suffering from stifling heat became yet another gloomy refrain of the Factories Inquiry. The temperature was said to pass 100 degrees Fahrenheit, or 38 degrees Celsius, inside one Glasgow factory, other workers complaining of a normal range of 84 to 94 degrees.[60] A former piecer at McConnel & Kennedy fumbled for words to describe the climate to commissioner Tufnell, who

then asked: 'As hot as it was the day before yesterday? – Yes; I have known it to be hotter in the mills than the hottest day I have ever been in in London.'[61] Bodies were widely believed to become languid, muscles eroded, minds depressed, respiratory and nervous systems impaired by confinement in these 'hot-houses,' particularly when contrasted to the cold of the northern British winter, into which the workers would abruptly step after twelve hours or more.[62]

The heat appeared in an impoverished atmosphere. Wrote surgeon Gaskell: 'When great numbers of individuals are congregated together, that portion of the atmosphere which is essential to life is rapidly removed' and replaced by another gas, namely 'carbonic acid gas – a gas destructive to life'. Hands inhaled 'a slow poison,' gradually sapping their energies and draining their faces of colour. Such injuries from increased local CO_2 concentrations were well-known at the time of the transition – 'the greater the quantity of carbonic acid gas in a given volume of air, the greater would be the insalubrity of that air,' Partington laid down as a rule in his manual – as were, in rudimentary principle, the chemical relations between coal combustion and CO_2 production.[63] If the CO_2 concentration of the open atmosphere was around 280 ppm by this time, it might well have been an order of magnitude higher in the most congested factory rooms, and modern research has indeed confirmed that such indoor spikes are deleterious to health. But not everyone was exposed to the harms. In his impassionate pamphlet *Observations on the Sanitary Arrangements of Factories,* Edinburgh engineer Robert Ritchie inveighed against the injustice: 'One would think that giving *supplies of heat* without *supplies of fresh air,* to apartments occupied by human beings, was the most preposterous of all absurdities,' but such were now the daily realities of hundreds of thousands of operatives.[64]

Their climate was not of their own making. 'In manufactories,' Ritchie pointed out, 'both temperature and atmosphere are under the control of the overseer, not the workmen.' Then what could be done about these ills? Perhaps influenced by his Scottish origins, the engineer proposed, among other remedies, a return to waterpower: 'There is surely, however, nothing in the present times to prevent manufactories, of almost every kind, from being *erected in open and airy situations,*' at some distance from each other, where free air would be in abundance and the wind sooth the operatives from all sides. But we know what interests such a reform would have threatened. Gaskell, too, was aware of the logic: carbonic acid poisoning and related ailments were ultimately due to steam power, which 'of necessity crowds men [sic] into limited spaces, a circumstance ever unfavourable to health'.[65] The centripetal dynamic of the fossil economy and the combustion of the stock conspired to create local climates of elevated heat and carbon dioxide.

Inside the steam-based towns, residents were bedeviled by omnipresent smoke. In *The Chimney of the World,* Stephen Mosley charts the vitiation of the air in Manchester and other cotton towns of Lancashire consequent upon the shift to steam: in the Cottonopolis, the number of mill chimneys stood at 1 in the 1780s and 500 by the early 1840s, prodding Charles Napier, commander of the government troops in the restive northern district, to coin the phrase 'chimney of the world' as a pun on the workshop.[66] Its skyline and grime became proverbial. All the smoke, the acid rain, the sulphurous fog literally killed off flora and fauna, sights of trees and birds and even the sun itself denied those forced to live within the town. But 'the merchants and manufacturers have detached villas, situated in the midst of gardens and parks in the country,' observed Faucher in 1844: 'The rich man spreads his couch amidst the beauties of the surrounding country, and abandons the town to the operatives.' Life enveloped in smoke was

reserved for the workers, the negation of nature – the areas where 'Nature was as strongly bricked out as killing airs and gases were bricked in,' with Dickens – dumped on them.[67]

The bourgeoisie adopted an apologetic attitude to the problem. From the 1840s, when the level of smoke in Manchester had become positively poisonous, mill-owners and their political representatives unremittingly and successfully opposed any idea of government interference: 'Suppression [of smoke] might materially injure important branches of our national industry,' the House of Commons concluded in 1846. Manufacturers argued that the quantity of smoke was rather a barometer of prosperity – and, besides, any negative effects on the health of the population were unproven.[68] A similar situation prevailed in another zone of great and rising danger for workers: the steam boilers. They had a tendency to explode, particularly if operated on the high-pressure principle. In the journal *The Engineer and Mechanist,* Fairbairn described an incident in the year 1845, when a boiler in a Bolton cotton mill blew up 'in an oblique direction, carrying the floors, walls, and every other obstruction before it; ultimately it lodged itself across the railway at some distance from the building,' having killed between sixteen and eighteen people on its way through the mill.[69]

The hazard was trifling in the first three decades of the century, grew in the 1830s and exploded in the wake of the Ten Hours Act. According to government figures from 1870, the number of fatalities from boiler blasts per decade rose from 52 in the 1810s to 209 in the 1840s and to 486 in the 1850s, but other sources indicate a far worse plague.[70] *The Engineer and Mechanist* claimed, in the same 1851 issue in which Fairbairn related the Bolton case, that 'within the last three years no less than *sixteen hundred* individuals have been sacrificed by the explosion of boilers; thus giving a loss of life, from this cause alone, on the average, of more than one per day.' Regardless of which figures were closest to the truth, it is evident that the capitalist countermeasure to the Ten Hours Act – speeding up the engines by means of higher pressure – took quite a dreadful toll on the operatives, who comprised, naturally, the overwhelming majority of the dead and injured. By the 1860s, far more people lost their lives in boiler explosions than in railway accidents, making them some of the most common and murderous calamities of the Victorian era. But no legal protection was forthcoming.[71]

All of these inconveniences and dangers were vastly amplified within their ulterior source: the coal mines. Temperatures above 100 degrees Fahrenheit, remorseless destruction of lungs by coal dust, suffocating inhalation of the concentrated gas known as 'choke-damp' (primarily carbon dioxide) and sudden ignition of 'fire-damp' (primarily methane), falling roofs, fires and, of course, explosions of epic magnitudes, with hundreds of victims in single cases, made the collieries exceptionally dangerous places of work. Dwelling in the exterior interior of the landscapes, the colliers were by definition shut out from tropospheric nature, to their peril: 'The choke-damp angel slaughters all – he spares no living soul. / He smites them with a sulphurous brand – he blackens them like coal,' went 'The miner's doom,' a poem by a local Tyneside bard from the early 1840s.[72]

A considerable segment of the British working class would then have experienced the coming of the fossil economy as a palpable deterioration of the immediate environment, in the form of, among other symptoms, excessive heat, heightened concentration of carbon dioxide, air pollution by smoke and the risk of sudden explosive disasters. All were products of the synergies between the social and biophysical determinants of that economy – in short, the *concentration of wage labourers in certain places where coal was burnt or extracted*. Some afflictions could be counted in fatalities and disease rates, but one component was less tangible: the very *perception* that

nature decayed and receded from the lives of working people. In the debates over the development of living standards in the Industrial Revolution, this factor has proven the most difficult to gauge, because – unlike earnings, life expectancy, marriage rates, physiology – there are no quantitative benchmarks for it. Qualitative sources indicate, however, that the perception was there.[73] It provides some backcloth to apocalyptic fantasies of working-class steam demonology: not to mention the gas, whose frequent explosions threaten one day to blow up Babylon itself.

CHAPTER 11

A Long Trail of Smoke: The Fossil Economy Consummated

By 1800, most of the smoke from British coal combustion still left fairly small chimneys. The best estimates put the share of household consumption at between half and two-thirds. A few rapidly developing industries already looked upon coal as a key input, but even the most important among them – iron – still accounted for no more than 10 to 15 percent of total demand; the dynamos of economic growth – cotton above all – used other sources.[1] Combustion had yet to be decoupled from population, and so Britain could not be said to have constituted a fossil economy proper. By 1850, all of that had changed. The turning point occurred somewhere around the year 1830. One way of measuring it is to look at the average annual growth rates for coal production in Britain. The rate sped up somewhat between 1800 and 1815, only to – interestingly – slow down in the following fifteen years, the great acceleration taking place *after the panic,* with an apex in the years 1847–54. The span 1830–54 saw *by far the highest rate of growth in coal production ever experienced between 1700 and 1900.*[2] British capital, both numbers and words tell us, wrested itself out of the crisis through an unprecedented mobilisation of energy from the stock.

More significantly for our definition of a fossil economy, domestic heating had lost its dominance by 1830. In 1816, it swallowed 53 percent of all coal produced in the nation; in 1830, the share stood below the critical mark at 45 percent, shrinking to 34 percent in 1840, 23.5 percent in 1855 and 14 percent in 1903. This secular reduction in the portion going to domestic heating – not the absolute volumes, of course – had begun already in the last two decades of the eighteenth century, but the sector accounted for more than half of all coal extracted in Britain up to some point between 1816 and 1830; by the latter date, it still constituted the single largest source of demand, a position it did not lose until after 1840. Between 1844 and 1855, another source ascended that throne: 'general manufacturing'. In 1855, this sector took 28 percent of all coal produced, compared to 23.5 percent for domestic heating and 24.5 percent for iron and steel (if exported coal is excluded, the figures were 31 percent, 25 percent and 26 percent respectively). With manufacturers thus presiding over the largest share of combustion, followed by proprietors of iron- and steelworks, Britain had consummated the fossil economy. The structural crisis bequeathed a novel formation. By 1870, three times more coal was burnt in general manufacturing, iron and steel than in the hearths and homes of Britain, the fires

decoupled from population growth and linked to self-sustaining *economic* growth.[4]

Figure 11.1. Annual compounded rate of growth of coal production in the UK, 1700–1900 (percentage).[3]

Turning from coal to steam, we find a lasting predominance of textile, cotton in particular. In 1870, textile factories accounted for 52 percent of all horsepower generated from steam in British industry, cotton mills alone taking 31 percent – more than blast furnaces and iron mills, upwards of three times more than the chemical, leather, construction, food and paper industries combined. The growth of steam power capacity in cotton proceeded at its fastest clip in the 1830s and 1840s, slowing down one notch in the 1850s and another after 1870. Clearly, the crisis decades marked a make-or-break moment: in the shadow of the better-known colonies, small waterpowered factories collapsed in droves under the combined pressures of the mid-1830s boom and the subsequent depression. The water mills remaining in existence were remnants of a bygone age; most had disappeared by the 1860s, the incentives to invest in water virtually extinct after the mid-century.[5] Fairbairn's assessment in 1864 was not inaccurate: 'It is only of late years that in this country the steam engine has nearly superseded the use of air and water as a prime mover. Until recently steam has been auxiliary to water; it is now the principal source of power, and waterfalls are of comparatively small value except in certain districts.'[6]

Then a question naturally arises: how much of all the coal raised in Britain was directly gobbled up by its engines? For 1800, the estimate has been put at *one-tenth;* for 1830, at *one-sixth;* for 1870, at *one-third*.[7] The growing relative voracity of Britain's steam engines secured the ascent of general manufacturing, even though this category also included the use of coal for heating in breweries, bakeries, brickkilns and a host of other miscellaneous businesses. In other

words, when general manufacturing eclipsed all other sectors by mid-century, it did so *primarily due to the express diffusion of steam* over the previous decades – a trend centred on cotton. However, the cotton–steam nexus never directly accounted for anything like the bulk of coal consumption. It might have been the strategic, beating heart of the emerging fossil economy, but by its side, it had wholly new applications of steam – to railways and ships – as well as the use of coal in gas manufacture, though these were comparatively weak accelerators; more important were the rapid strides of iron.[8] A total history of birth of the fossil economy would obviously have to deal with them as well.

The influence – both direct and indirect – of the transition from water to steam in cotton was most clearly visible not on a sectoral, but on a regional level. Of all coalfields in Britain, those in Lancashire exhibited the fastest output growth in the first half of the nineteenth century. In the final decade of the eighteenth, some 8 percent of British coal came from the Lancashire and Cheshire mines, leaving them behind those of Scotland and Yorkshire and equal to those of South Wales; standing at 15.3 percent in 1854, the region had surpassed them all, now second only to the classic northeastern district. Other coal-producing regions such as the East Midlands dropped behind precisely because they lacked an insatiable textile industry impelled by steam. Lancashire was the most powerful motor of the escalating coal extraction, and the motor of the Lancashire economy was, of course, the cotton industry: mines opened to feed mills. Discounting any multiplier effects, by 1870 the cotton factories of this single county directly burnt more coal than the entire output of southern and eastern Europe.[9]

In Lancashire and the nation as a whole, the coal industry itself was a rather passive agent, responding to signals from the wider economy. The turning point around 1830 did not follow from anything that happened inside the pits, a scientific breakthrough in excavation methods or an aggressive marketing campaign from mineowners; rather, output expansion was determined by increasing *demand*. All the collieries had to do was to raise larger volumes as consumers craved more of the fuel, without pushing up prices in the process – and this was, indeed, the greatest achievement of the sector in the eighteenth and nineteenth centuries. 'There is,' in the words of one study, 'little sign of a technological revolution in coalmining. English coal reserves, known and exploited since Roman times, simply found a much larger market in Industrial Revolution England.'[11] The very cutting of coal remained an extreme form of drudgery, powered by human bodies equipped only with simple instruments such as picks, wedges and hammers, with some assistance from gunpowder; new technologies of importance did not appear before 1890; prices of coal were, as we have seen, stable in the critical decades.[12] The fossil economy was consummated aboveground.

Naturally, it left an immediate imprint on the atmosphere. The levels of annual CO_2 emissions from Britain follow a curve in full conformity with the historical dynamics outlined above (figure 11.2). Four stages can be discerned: a protracted, almost imperceptibly slow growth in emissions during the proto-fossil stage; a rise to slightly higher levels around the turn of the century, towards the end of that stage; a marked climb in the years 1825–40 leading to a radically different trajectory; a new escalation and extrapolation after the crisis. Thus business-as-usual, as we know it today, became a material reality. It was the unique creation of Britain. While research in economic history has lately tended to downplay the exceptionalism of this country, there can be no doubt about it on this count, and the more coming generations are forced to upgrade the significance of matters of carbon, the more sharply will the British exception stand out and its history attract interest – not to honour the name of the kingdom, but rather to smear it in the soot

it has bequeathed to humanity. Choosing 1850 as a date for comparison, and using the few countries for which data are available, we find a quite startling aberration (figure 11.3). In 1850, Britain emitted nearly twice as much carbon dioxide as the US, France, Germany and Belgium combined. It emitted a thousand times more than Russia and two thousand times more than Canada. If global warming has a historical homeland, there can indeed be no doubt about its identity.

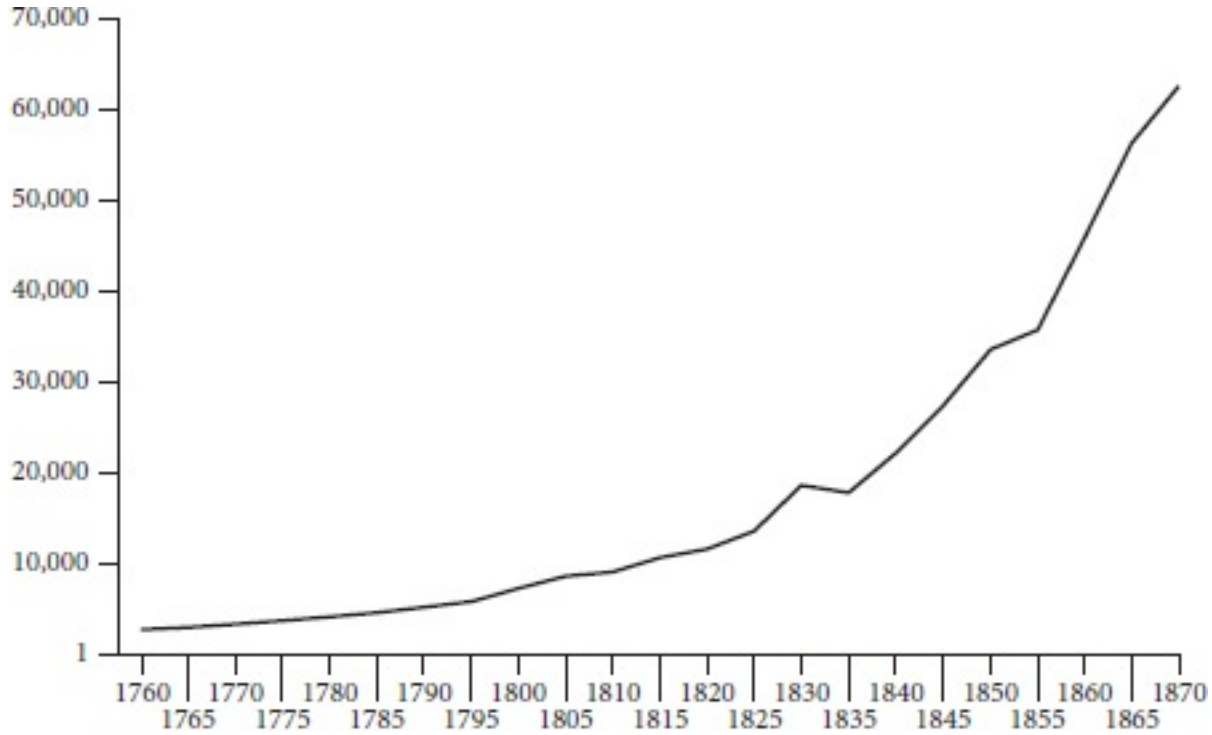

Figure 11.2. CO_2 emissions in the United Kingdom, 1760–1870. Emissions in metric tons of carbon, in thousands.[10]

Figure 11.3. CO_2 emissions of selected countries in 1850. Emissions in metric tons of carbon, in thousands.[13]

CHAPTER 12

The Myth of the Human Enterprise: Towards a Different Theory

Missing Steam

The rise of steam power in the British cotton industry presents, it should now be clear, established theoretical frameworks with a serious anomaly. Let us begin with the Ricardian-Malthusian paradigm. Contrary to its expectations, the transition trumpets from every corner an enduring surfeit and low cost of water: the defining argument of the paradigm contravened by some of the most conspicuous facets of the historical process. All talk of good sites being 'few' or 'no longer available,' the spread of steam 'ecologically favoured,' is pure paradigmatic prejudice punctured by the record. Do the Ricardian-Malthusians have a line of defence to fall back on?

Wrigley makes an attempt to apply the law of diminishing returns to what we have called the centrifugal dynamic of waterpower: here was a source of energy 'subject to rising marginal cost of provision since the better sites were naturally developed first, leaving smaller or less conveniently situated falls for later exploitation'.[1] Though this might sound like a good match for the Ricardian model, it does in fact diverge from it in crucial respects, betrayed by the two words 'less conveniently'. Ricardo spoke of 'land of an inferior quality,' less fertile 'by the laws of nature, *which have limited the productive powers of the land*' – think of sandy soil or steep slopes. But there is no evidence that the waterfalls at the outer rims were 'smaller' or poorer in any such absolute sense; to the contrary, they tended to be *more* powerful up in the hills than in town centres. The disadvantage of distant watercourses did not stem from their deficient capacity to generate mechanical energy. Rather, it took the form of an 'inconvenience' – a trouble constituted not by the physical properties of the land, as in the theories of Ricardo and Wrigley, but *by the incongruity between these properties and certain social relations,* which necessitated, inter alia, access to centralised stores of labour power. Manufacturers were not pushed into the steamy towns by natural limits to the land; attractors more powerful than cheap energy pulled them in.

The paradigm might have worked better had the cotton manufacturers discarded some source of energy drawn from present photosynthesis: wood, animals, people. All would have required larger amounts of land than waterwheels to produce the same amount of power. Riverine water is

spread out in space but compressed, flowing in a channel delineated by two beds; it does not cover vast expanses of territory, like forests and fields of clover or wheat. A shift from any of these sources to coal *could* have relieved the land from stifling pressure – which leaves us with the possibility that the Ricardian model holds the key to other moments in the history of the fossil or proto-fossil economy, notably the Elizabethan leap, with its substitution of coal for wood. We shall revisit it below. Prior to steam, animals and humans rarely served as prime movers, but the latter powered handlooms in homes, until the engines and machines usurped their labour. Did the growth of the army of handloom weavers contribute to the cultivation of inferior soils, translating into higher food prices and wages, thereby giving manufacturers the incentive to shift to steam looms? There is absolutely no sign of any such causation. Wages plunged.

As for the Malthusian component, steam for mills exploded all previous ecologies because it *dissociated* coal burning from population growth: as long as domestic heating accounted for the bulk of consumption, the fires were kept in check by the sluggish rhythm of procreation. 'Since it was over 110 years before the British population doubled its 1700 level, the growth of demand from this source was unlikely to provide much stimulus,' in the words of B. R. Mitchell, maven of historical statistics: only a *structural divorce* from couples making babies could kindle a fossil economy.[2] Between 1800 and 1870, the British population increased by slightly less than 150 percent, while coal output jumped by 720 percent. Historical reality turning Wilkinson's model on its head, the spiral set off at the moment when the fetters of fertility were burst – that is, when population *ceased to determine the pattern of coal consumption*. Nor does it seem any more plausible to impute the late eighteenth-century cotton miracle to that ancient form of growth, whose levels at the time happened to be similar across northern Europe, Britain no outlier in *this* regard.[3] The Arkwrights, the Gregs, the Finlays did not build their mills in a desperate attempt to satisfy the needs of multiplying denizens – entirely different dynamics were at work – and neither did the McConnels and other steam capitalists. When Pomeranz and Kander and their colleagues claim that waterwheels were cast aside because they could not keep pace with the breeding of Brits, they are dreaming things up.

How much weight, then, should be attached to this anomaly? How threatening is the rise of steam to the durability of the Ricardian-Malthusian paradigm as a whole? We have argued throughout – and so has, ironically, Wrigley himself – that the shift to the stock as a source of mechanical energy for commodity production represented the critical moment in the inception of the fossil economy. A paradigm capable of mustering only little if any explanatory power when it comes to this watershed deserves to be questioned. Damning in itself, however, that failure might be symptomatic of deeper analytical problems, the anomaly a peephole into hollows stretching beyond steam, coal, cotton, Britain.

Universalising Business-As-Usual

We want to know why self-sustaining growth was first welded to the combustion of fossil fuels: why the agents of economic expansion turned to the stock and made it the indispensible foundation for further rounds. In the mature fossil economy, they no longer *chose* between flow and stock. The choice had already been made. The dying out of water mills in the British cotton industry signified a necessity to employ steam for manufacturers who wished to stay in the game; no more an optional prime mover, the engine had become imperative for commercial survival. A

law of motion subsequently spurred the fossil economy onwards: grow by burning *or die* – not only in cotton, of course, but in all major branches of industry, in all advanced economies, the spiral whirling through the various departments of labour. The moment of *transition,* then, marks the passage from an economy in which the stock was one possibility among several to one in which it reigned supreme.

What is the Ricardian-Malthusian explanation for this? Abstracted from any particular line of business, it assumes a general form: there is a hunger to consume more energy in all human societies, and in the eighteenth and nineteenth centuries, *Britain finally managed to satisfy it*. Presenting such an account of the fossil economy – or the 'inorganic' or 'mineral-based' economy, to use Wrigley's imprecise terms – requires the invocation of a transhistorical factor, some urge shared by all formations in history, which, by the time of the Industrial Revolution, found its wanted object. In Wrigley, it is simply the impulse to growth. 'The move away from an exclusively organic economy was a *sine qua non* of achieving a capacity for exponential growth,' he writes, or: 'The land surface of the earth was a fixed quantity and formed a barrier to indefinite growth,' or: 'The energy bottleneck which set limits to growth in organic economies was widened progressively as fossil fuels replaced organic [sic] fuels.' Similar formulae are repeated ad infinitum in his writings. Sometimes myth is used to carry the message: 'No matter how assiduously Icarus may strive, human flight is not possible if the energy employed in the attempt is muscular' – presuming, as a matter of course, that preindustrial societies *strove to fly like Icarus,* yearning to master the sky of growth, failing and falling until they forged fossil wings.[4]

For Wilkinson, a more passionate Malthusian, the transhistorical factor is the biological urge to breed, shared not only by all societies but by all animal populations. Fired up by recurring population crashes, a unilinear 'growth of need' forced man 'to involve himself in more and more complicated processing and production techniques' over the ages; when all other options had been exhausted, he had to pick up fossil fuels.[5] We have seen Pomeranz distil the essence of these arguments: Britain deviated from all others not because it developed some novel system or peculiar disposition, but because it broke through the constraints 'that had previously limited *everyone's* horizons' – doing what all humanity had vainly dreamed of, Icarus-like.

This brand of analysis has not, of course, emerged from a theoretical vacuum. Impregnated with classical bourgeois economics, it simply brings the trinity of Ricardo–Malthus–Smith to bear on energy – a coloration the proponents of the paradigm do nothing to hide. Hence it is vulnerable to the same critique that has been levelled against Ricardian, Malthusian, Smithian and associated theories of economic development, most effectively by Ellen Meiksins Wood and Robert Brenner in debates over the origins of capitalism.[6] In fossil energy as in capital, bourgeois theorists see human proclivities – Icarus, Robinson – realised at last; on both issues, they can be charged with substituting myth for that vexing, unsettling vector of human life: change over time.

Ricardian-Malthusians assume the dynamics of the fossil economy to have existed latently, in trapped form, long before its actual appearance. A tendency to expansion was permanently present in pre-fossil economies, bottled up throughout history, waiting for the right opportunity to break loose: a primal hunger at last hitting upon the meal. The emergence of the fossil economy took the form of a *lifting of constraints,* allowing humans to behave as they – from the Yangzi to the Thames – had always wanted to. Here the motivations characteristic of the agents of expansion in a fossil economy are ascribed to pre-fossil actors, whose economy was not of a

different kind, but contained within itself all the elements subsequently given free reign. Much like bourgeois thinkers regard capitalism as the fulfilment or extrapolation of a human nature present since time immemorial – the propensity to truck, barter and exchange; the age-old practice of buying cheap and selling dear; the rationality of market actors; sheer acquisitiveness – Wrigley and his fellow historians presuppose a yearning for fossil energy. Committing the fallacy of *petitio principii,* they beg the question of *what is special with the fossil economy*.

The transition, then, is reduced to a moment of *scarcity*. The long thread of the human enterprise approaches the eye of a needle, is saved by fossil fuels, passes and extends on the other side. Since that which requires explanation is postulated as biding its time, the transition itself becomes a mere formality, provoked by a *quantitative gap* between demand for and supply of energy. The fossil revolution is not a rupture separating two distinct orders from each other; the problem of how one type of economy mutated into another is assumed away and restated as a gradual, incremental process – exponential once scarcity had been overcome. In Wrigley, the workings of the fossil economy are understood in terms of the 'organic' predecessor and its limitations; in Wilkinson, through the lens of eternal superfecundity. Having no distinct laws of motion, business-as-usual is here rendered so usual as to be timeless.

At a closer look, furthermore, the Ricardian-Malthusian explanation turns out to be circular: the shift to fossil fuels is explained by the impossibility of self-sustaining growth without them, the onset of self-sustaining growth by the shift to fossil fuels. In the middle of the circle sits a refusal to consider novel power relations as the mainspring of either component. 'Capitalism,' according to Wrigley, 'is an elusive concept' unworthy of application; the capitalist era is simply one of 'rationality' and 'progressive modernisation'. In his zeal to move beyond eurocentrism, Pomeranz likewise jettisons the category of capitalism in favour of something called 'the developmentalist project,' an endeavour 'to "tame" or "conquer" nature' common to all continents, whose most successful practitioner happened to reside in the West.[7] Conceiving of growth as an eternal, universal pursuit, the Ricardian-Malthusians cannot avoid a tautological account of the transition: it happened because humans act that way.

If the paradigm fails to illuminate the birth of the fossil economy, it seems equally unable to shed light on its *continued growth*. The liberation from the land constraint – the spark on which the whole paradigm is centred – can only be a one-off driver at best, unrelated to the further adding of fuel to the conflagration. This becomes clear if we revisit the mathematical conversions from fossil energy to acres of woodland so highly regarded as explanatory exercises by Wrigley and his followers.[8] When he calculates that all coal in 1800 equalled 35 percent of the British land surface, rising to 150 percent in 1850, this is obviously a hypothetical, counterfactual thought experiment. Can it tell us anything about why coal consumption rose in the period? For that to be the case, Wrigley would have to present evidence that land scarcity pushed up prices for traditional fuels, that the rising costs of these fuels impelled British consumers to shift to coal, and that such cost-motivated consumption made up the bulk of all coal-burning in the first half of the nineteenth century. He does not provide anything of the sort, and it would indeed be difficult to do so. Then can the exercise tell us anything about the causal forces operating later in the history of the fossil economy?

Consider Malanima's conclusion that a Europe bereft of fossil fuels would have needed 2.7 times its continental surface in 1900 and more than 20 times a century later: can it elucidate the drivers of this tremendous blaze? Logically it cannot, for if the land constraint had been lifted from Europe – even before the onset of the twentieth century – it could no longer have operated

as a causal factor. The supposed breaking of the Ricardian curse evaporates as soon as it transpires: once land scarcity vanishes as a pressing concern, some other impetus has to take over. A baby cannot develop any further inside the womb and so exits, but in the same moment, that lifting of constraints ceases to determine the further growth of the child. When the girl is five or ten years old, anyone explaining the biological dynamics of her growing body by saying that she could not stay inside her mother's belly – it would have required twenty wombs by now – would be deemed somewhat off the track. Once a bottleneck is shattered, it is gone.

The problem may be viewed from another angle through some purely imaginary conversions. Let us suppose that if all the plastic bags in the world as of the year 2000 had been replaced by cotton bags, the switch would have required X tonnes of cotton, demanding Z acres of land for cultivation, equalling – an arbitrary number – 40 percent of the total land surface in the world, impossible to set aside for the purpose. Would we then possess an explanation for *why the production of plastic bags had become so enormous?* Evidently not. The same would go for the mathematical conversion of e-book readers into biomass, all machines into human bodies, or – more to the point – current worldwide resource withdrawal into more than one planet Earth. Such exercises can serve pedagogical purposes, illustrate predicaments and underpin calls for a corrected course, but they cannot identify processes of causation. If all oxygen in the earth's atmosphere were to be exchanged for carbon dioxide, all life would suffocate as on Venus, but this fact says nothing about how oxygen once filled the atmosphere and is continuously replenished.

In the lap of Malthus, Wilkinson runs into even deeper problems. If technologies are developed when – and only when – people plunge into poverty because procreation has run riot on a narrow resource base, if the Industrial Revolution was a response to such a crisis and coal struck upon as the solution, then *technological development should have petered out thereafter,* the use of fossil fuels stagnating at the new 'ecological equilibrium'. Now, having to admit that 'industrial development did not cease once subsistence needs had been catered for,' Wilkinson makes a bold attempt to save his model by arguing that, as a matter of fact, later technologies have arisen out of squalor and overcrowding: look at 'modern systems of waste and sewage disposal'.[9] Too many people wade around in misery – that is why innovations spread. We need not detain ourselves in an inquiry into the ability of this model to account for two centuries of perpetual technological change under capitalism – a quick glance at the nearest laptop or car should suffice – only note that if sewage disposal were representative of such change, and if ecological disequilibrium and poverty were its motors, as Wilkinson does assert, then the invention and diffusion of technologies that *destroy ecosystems, deplete resources and create poverty* would be inexplicable. The model posits them as cures to – not causes of – such maladies.

If this is how the Malthusian member of the dyad tries to stay relevant for the rest of the history of the fossil economy, its Ricardian partner simply falls back on the axiom of growth as an eternal-universal pursuit. Further expansion would then be propelled by forces several millennia old, in accordance with an ahistorical view of the transition: nothing new emerged; the old was merely realised. Now the Ricardian-Malthusians might object that the astounding growth of the global economy and population witnessed over the past two centuries *would not have been possible without fossil fuels* – and in this they are, of course, correct. Wrigley can hardly be contradicted when writing that pre-fossil economies

> had to work within an energy budget which made many of the activities and processes which became basic to

> economic life in later centuries physically impossible. It would be impossible, for example, within the constraints of an organic economy to produce iron and steel on a scale sufficient to construct a modern rail network or an oil tanker, still less the tens of millions of cars which are manufactured every year.[10]

True, surely – but is this a statement on the causes of the fossil economy or on its *effects?* It seems concerned not with deciphering the dynamics of spiralling combustion, but rather with indicating *what it can achieve*.

Perhaps Wrigley and his peers are not so interested, after all, in the mechanisms of business-as-usual. Perhaps their purpose is rather 'to find adequate explanations for change or lack of change in the economic fortunes of a community,' for the fulfilled promises of growth, the tens of millions of cars every year: another explanandum.[11] But how about a functionalist account? One could imagine the proposition that fossil fuels were resorted to *because* they made twenty times the European continent available, or *because* they lifted Britain to the throne of the world, or *because* they allowed for endless growth of GDP or populations. Such an explanatory form might be plausible: an institution (the fossil economy) may have some beneficial consequences (for growth), which serve to expand and consolidate it, the selection (of fuels) confirmed again and again. But no functionalism can explain *why an institution came into existence in the first place,* since that would violate 'one of the few simple and self-evident rules of causality: if event *E* happened before event *C,* it cannot have happened because of it.'[12] The original transition to fossil fuels cannot possibly have been caused by the subsequent function of opening up a subterranean continent twenty times the size of Europe. Saying so would be to indulge in teleology.

But surely the watercourses available on the British Isles could not have powered all their industries in, say, 1979? Granted, but any such hypothesised later scarcity cannot, again, explain the turn to steam, any more than the causes of the Second World War can be found after 1945. In this case, moreover, the scarcity of water not only postdated the transition but *in fact never eventuated*. The same mysterious status is shared by several other counterfactual crises of scarcity invoked in the Ricardian-Malthusian literature: 'In the absence of coal as an energy source, Ricardian pressures would have become acute,' writes Wrigley – but if the pressures did not materialise, they could not have compelled anyone to do anything. Environmental historian Edmund Burke III invents the same argument for steam power:

> If British factories had been dependent on wood (or more likely, charcoal) for fuel, there would not have been enough wood in all of Britain to fuel the boilers of the 'dark Satanic Mills.' The consequences of what Vaclav Smil calls the 'Great Transition' from wood to coal was *therefore* momentous.[13]

But the British factories *never were dependent on wood or charcoal for fuel*. If they had been, a Ricardian world might have existed, but historical theories are not vindicated by fantasies about possible worlds different from the real one.

Beyond the empirical anomaly of steam, the Ricardian-Malthusian paradigm really does seem flawed to the core. It is unable to make sense of the origins of the fossil economy and can only, on the most charitable reading, explain its further development through a functionalist account deduced from the growth axiom. Some contours of an alternative framework for understanding our peculiar business-as-usual – its birth, life and possible death – are then readily apparent. It would, first of all, view self-sustaining growth as an *emergent property* of capitalist property relations rather than as an attribute of the human species present since dawn. Since that kind of

growth had been set off prior to the full turn to fossil fuels, it would need to explain *why it latched onto them* in a certain conjuncture. The transition would be taken seriously, as a monumental transfiguration of one order, with a specific set of rules for how to engage with people and the rest of nature, into another, in which fossil fuel combustion became *an imperative* – not a longed-for opportunity. To speak with Ellen Meiksins Wood, that imperative would be seen as rooted 'in historically specific social relations, constituted by human agency and *subject to change,*' the latter a particularly welcome corollary under a carbonising sky.[14]

But, one may ask, could any account of the transition avoid singling out a one-off event? We have emphasised steam-powered machinery as a substitute for human labour, not wood: can this sort of substitution continue any longer after the first swap? Is combative labour a more lasting stimulus to the expansion of the fossil economy than the land constraint? One of the great paradoxes of mechanisation is that it *always produces new dependencies on human labour,* virtually by definition. Someone has to produce the machines, extract the fuels required to drive them, carry the goods spewed out by them, and so on: for every unit of labour capital displaces, another (not necessarily of equal quantity) becomes essential. There is no similar logic to the shift from wood to coal. It does not *in itself* renew the dependency on wood, which has been dispensed with in favour of another material. But labour is the universal input of capitalist production. Its replacement by fossil-fuelled machinery can continue *if novel contradictions between labour and capital arise and call for such a resolution:* possibly a part of subsequent waves of fossil development. But these are merely contours of a theory, waiting to be filled in.

Mistaking Capitalists for Humans

The ability to manipulate fire was a necessary condition for the commencement of large-scale fossil fuel combustion in Britain. Was it also the cause of it? The birth of Adolf Hitler in 1889 was a necessary condition for his rise to power in 1933, but no one would propose the former as the cause – or the 'trigger' or 'catalyst' – of the latter; a closer analogue to the Anthropocene narrative, however, would be the proposition that Nazism was the result of the genesis of the Germanic peoples, perhaps dated to the tribal migrations of the first century BCE. But not all Germanic peoples developed Nazism. Neither did all fire-manipulating humans create a fossil economy – not even if they had immediate access to coal deposits and knew how to use them.

The Northern Song should be enough to break the putatively straight line. No less conversant with fire than the British, no less richly endowed with coal, the Chinese still did not tie self-sustaining growth to fossil fuels. For those who wish to portray the economic laws of China as identical to those of Britain, the only explanation for the nonfeasance is some chance circumstance: hence Pomeranz's claim that China's coal reserves were too far away from the Yangzi delta to be profitably exploited.[15] But that claim flies in the face of plenty of evidence of coal mining in the lower Yangzi area and southern China, deposits being known and scratched as far south as Guangdong. Even if we accept his assumption that the delta was the only possible site for a fossil-fuelled Chinese industry, mines were in fact within easy reach of it, as evident in the early twentieth century when soaring demand triggered a massive expansion of coal output. 'China's (or the Yangzi delta's) delayed industrialization, in other words, cannot be explained by the lack of availability of coal as Pomeranz asserts; rather, it is *the lack of industrial demand* that explains the non-development of China's coal industry' – a lack of demand obviously not stemming from ignorance of fire.[16] Everyone knows where gunpowder was invented.

The Chinese and the British knew how to burn stuff and extended this knowledge to coal in the Northern Song and the Elizabethan leap respectively, and yet neither episode had any 'appreciable impact on the atmospheric concentration of CO_2,' as noted by Steffen, Crutzen and colleagues.[17] Not even *the ability to manipulate coal fires* precipitated a fossil economy, much less the existence of the 'fire-ape, *Homo pyrophilis*'. If the genus *Homo* learned to control fire 1.6 million years ago, it continued to earn a living from gathering, hunting and fishing for more than 99 percent of its ensuing history, burning its way here and there, at long last cultivating soil and herding cattle and grinding flour in water mills – fire always near at hand – only developing the fossil economy in the blip of the *last two centuries*. For that step, combustion control was indeed a necessary faculty, as were tool use, language, cooperative labour, knowledge of how to build a spade and excavate the earth's crust and whatnot, but none of these things could eo ipso bring about business-as-usual.

The error here is amply covered in historiographical textbooks. 'However necessary they may be, the most constant and general antecedents remain merely implicit,' writes March Bloch in *The Historian's Craft:* 'What military historian would dream of ranking among the causes of a victory that gravitation which accounts for the trajectory of the shells, or the physiological organization of the human body without which the projectiles would have no fatal consequences?'[18] Such factors are simply too ubiquitous to merit special attention. Fire manipulation has *always* been present in human history as a necessary condition for the emergence of pre- and proto-fossil as well as fossil economies and so does not deserve a special niche in the genealogy of the latter. It is a *trivial* condition, lacking correlation with the outcome of interest.

But perhaps the pyro-theorists have only done the honourable job of tracing the problem to its very deepest root? Such endeavours are, John Lewis Gaddis argues in *The Landscape of History: How Historians Map the Past,* subject to 'a *principle of diminishing relevance':* the greater the time that separates a cause from an effect, the less weight should be attached to it.[19] Deriving the fossil economy from the command over fire is like explaining the rise of drone warfare with the evolution of binocular vision and opposable thumbs, the mass demonstrations in Tahrir Square in 2011 with the appearance of towns in the Neolithic revolution, the systematic torture in Bashar al-Assad's prisons with the invention of bricks and mortar or any other number of inane exercises. We would expect the dots to connect rather more directly. Moreover, to propose ultra-remote causes of such recent events is to *obfuscate their origins and acquit the culprits*. A *reductio ad infinitum,* it lets the powers that be off the hook.

Attempts to attribute climate change to the nature of the human species appear doomed to this sort of vacuity. In his essay 'Unconscious Obstacles to Caring for the Planet: Facing Up to Human Nature,' psychoanalyst John Keene seeks to account for the reckless pollution of the atmosphere and humanity's refusal to confront it by referring to the 'evolutionary preference for immediate gratification over longer-term needs'. More specifically, the infant excretes waste matter without bounds, learning, as a first certainty about the world, that the caring mother will take away the poo and the wee and clean up the crotch. As a result, human beings are accustomed to the practice of spoiling their surroundings: 'I believe that these repeated encounters contribute to the complementary belief that the planet is an unlimited "toilet-mother", capable of absorbing our toxic products to infinity.'[20]

Now it is easy to poke fun at certain forms of psychoanalysis, but Keene shares a problem with the Anthropocene narrative: where is the evidence for any sort of causal connection between

fossil fuel combustion and infant defecation or fire manipulation? What about all those generations of *Homo sapiens* who, up to the nineteenth century, mastered both arts but never voided the carbon deposits of the earth and dumped them into the atmosphere? Were they shitters and burners just waiting to realise their full potentials? That which exists always and everywhere cannot explain why a society diverges from all others and develops something new. By the time of the transition, the British social formation did not stand out for post-partum bowel movements or fiddling with matches, any more than it did for breathing or walking. Such abecedarian activities were irrelevant to the very special outcome. A historical explanation – and this is what is needed – would rather focus on the mechanisms of the novel order, the makeup and reproduction of this structure: something utterly new under the sun.

As for the steam engines, it is entirely banal to point this out, but they were not adopted by some natural-born deputies of the human species. By the nature of the social order of things, they could only be installed *by the owners of the means of production*. A tiny minority even in Britain – all-male, all-white – this class of people comprised an infinitesimal fraction of the population of *Homo sapiens* in the early nineteenth century. Is there any reason to consider it any more truly representative of 'the human enterprise' than the Luddites or the plug drawers or the preachers of steam demonology? It prevailed by superior physical force: would this qualify as a survival of the fittest? Either the Anthropocene narrative is a form of tacit social Darwinism, or it is founded on a category mistake, ascribing actions to an entity that could not possibly have performed them. The choice of a prime mover in commodity production could not have been the prerogative of the human species, since it presupposed, for a start, the institution of wage labour. Capitalists in a small corner of the Western world invested in steam, laying the foundation of the fossil economy; at no moment did the species vote for it either with feet or ballots, or march in mechanical unison, or exercise any sort of shared authority over its own destiny and that of the earth system. *It did not figure as an actor on the historical stage*.[21]

Steam won because it augmented the power of some over others. It was considered invaluable for the great assistance it provided in the struggle between antagonistic subsets of a human population, intra-species contradictions conditioning its ascent through and through – and then we still have not touched upon the spread of steam to other parts of the planet. In *Fossil Empire,* we shall see how a clique of white British men employed steam power as a literal weapon against the best part of humankind, from the Niger delta to the Yangzi delta, the Levant to Latin America. Yet the events on the British Isles should in themselves be enough to conclude that stationary steam was *foisted upon the rest of society,* a power device backed up by the power of the gun, without which it might have been burnt to the ground (the ability to manipulate fire a key resource of the resistance, against which the mills had to be made *fireproof)*.

How about the later stages of the fossil economy? Has humanity lined up behind the capitalist pioneers and availed itself of the blessings of the stock, stepping forward like so many children of Icarus to spread their wings – or has fossil power remained just that? These are questions for any number of other studies. We shall venture some observations in the following chapters; a few basic ones are in order here. The succession of fossil-fuelled technologies following steam – electricity, the internal combustion engine, the petroleum complex: cars, tankers, refineries, petrochemicals, aviation… – have all been introduced through investment decisions, sometimes with crucial input from certain governments but rarely through democratic deliberation. The privilege of instigating new cycles of burning appears prima facie to have stayed with the class in charge of commodity production.

Reflecting an intra-species concentration on another level, as of 2000, the advanced capitalist countries or the 'North' composed 16.6 percent of the world population, but were responsible for 77.1 percent of the CO_2 emitted since 1850, subnational inequalities uncounted. The US alone accounted for 27.6 percent, while Nigeria stood at 0.2 percent, Turkey at 0.5 percent, Indonesia 0.6 percent, Brazil 0.9 percent – these being countries with a historical responsibility sufficiently large to make it on a top-twenty list. Most left even smaller marks. Counting differently, the OECD countries were behind 86 of the 107 parts per million by which the CO_2 concentration rose from 1850 to 2006.[22] What about the homeland of it all? In one list of national contributions to global warming from fossil fuel combustion up to the year 2005, the United Kingdom ranks number five, having caused a rise in temperature three times larger than India, fifteen times Thailand and Argentina, thirty times Nigeria and Colombia, and so on. In the early twenty-first century, the poorest 45 percent of humanity generated 7 percent of current CO_2 emissions, while the richest 7 percent produced 50 percent; a single average US citizen – national class divisions again disregarded – emitted as much as upwards of 500 citizens of Ethiopia, Chad, Afghanistan, Mali, Cambodia, Burundi. There were few signs of fossil fuel combustion being equalised within the human species. Rather, the data suggest a widening polarisation.[23] Are these basic facts reconcilable with a view of *humankind* as the new geological agent?

The best shot for the Anthropocene narrative in this regard remains population growth: if it can be shown that fossil fuel combustion is fanned by the multiplication of human numbers, the species may be held causally responsible. Thus the leading Anthropocene theorists like to foreground excessive reproduction as *the* major perturbation of the biosphere.[24] Undeniably, human numbers and CO_2 quantities are somehow connected – 20 people have a smaller capacity to burn coal than 20 million – but global emissions increased *by a factor of 654.8 between 1820 and 2010,* while population 'only' did so by a factor of 6.6, suggesting the presence of another propulsive force.[25] In recent decades, on disaggregated levels, the correlation has been revealed as outright negative. Development scholar David Satterthwaite compared the growth of population and emissions between 1980 and 2005: the former tended to be fastest where the latter was slowest, and vice versa. China's annual population growth stood at 1.1 percent as against 5.6 percent for emissions, South Korea's at 0.9 percent and 5.3 percent respectively; at the opposite end of the spectrum, inverting the relation, Djibouti's scored 3.5 percent and 0.8 percent, while Chad's figures were 3.2 percent and –1.6 percent – rapid population growth, *falling* emissions. Sub-Saharan Africa accounted for less than 3 percent of growth in global emissions, but for 18.5 percent in population. Northern America reversed the profile: 14 percent of emissions, 4 percent of population. In short, *the rise of population and the rise of emissions were disconnected from each other,* the one mostly happening in places where the other did not – and if a correlation is negative, causation is out of the question.[26]

More than a third of humanity is not even party to a *proto*-fossil economy: as of 2012, 2.6 billion people still relied on biomass for cooking.[27] Taking into account that the capacity of undernourished humans subsisting on one meal per day to afford to emit any greenhouse gases is small, that low-income households primarily use carbon-neutral transport methods – walking, bicycling, at most riding crowded buses and trains – and that people who scavenge dump sites for waste to recycle and grow forests on their land have *negative* emissions, Satterthwaite concluded that one-sixth of world population 'best not be included in allocations of responsibility for GHG emissions'. Their contribution hovers around zero. In the words of Vaclav Smil, ultra-

prolific authority on energy systems, 'the difference in modern energy consumption between a subsistence pastoralist in the Sahel and an average Canadian may *easily be larger than 1,000-fold*' – and that is an *average* Canadian, not the owner of five houses, three SUVs and a private airplane.[28] Depending on the circumstances in which a specimen of *Homo sapiens* is born, then, her imprint on the atmosphere may vary by several orders of magnitude. No other creatures on earth – think of the beaver, the bonobo, a species of zooplankton or cyanobacterium – exhibit anything like a similar disparity in environmental impact. Surely, something is unique about humans.

Given these enormous variations – in space and in time, present and past – humanity appears too slender an abstraction to carry the burden of causality. Now, proponents of the Anthropocene might object that from the standpoint of all other living things, and indeed from the biosphere as a whole, what really matters is that *climatic disruption originates from within the human species,* even if not *all* of it is to blame, and so a species-based term for the new geological epoch is warranted. Whether a Tuareg stockman or a Toronto stockbroker, every burner of fossil fuels is, by definition, human. This might look like a compelling argument for the Anthropocene. It is indicative of the term's origins in the natural sciences, geologists, meteorologists, biologists and others having detected an overwhelming human influence on ecosystems, now ranged alongside natural selection, solar radiation or volcanic activity. 'The Anthropocene' registers this moment of epiphany: the power to shape planetary climate has passed from nature into the realm of humans.

As soon as this is recognised, however, the main paradox of the narrative, if not of the concept as such, comes into view. *Climate change is denaturalised in one moment* – relocated from the sphere of natural causes to that of human activities – *only to be renaturalised in the next,* when derived from an innate human trait. Not nature, but human nature – this is the Anthropocene displacement. It backs away from the vertiginous depth of perhaps the most groundbreaking scientific discovery of our time, which tells us that human beings have caused global warming *over the course of their history*. This kind of history does not appear in the biography of any other species: to all intents and purposes, beavers and bonobos continue to construct their own micro-environments as they always have, generation upon familiar generation, while a certain human community may burn wood for ten millennia straight and then coal the next century. Realising that climate change is 'anthropogenic' is to appreciate that it is *sociogenic*. It has arisen as a result of temporally fluid social relations *as they materialise through the rest of nature,* and once this ontological insight – implicit in climate change science – is truly taken on board, one can no longer treat humankind as a species-being determined by its biological evolution. Nor can one write off divisions between human beings as immaterial to the broader picture, for *such divisions may have been an integral part of fossil fuel combustion in the first place*.

Following climate science out of nature, we should dare to probe the depths of social history, not relapse into the false certitude of a transposed natural inevitability. The Anthropocene narrative could here be seen as an illogical and ultimately self-defeating foray of the natural science community – responsible for the original discovery – into the domain of human affairs. Geologists, meteorologists and their colleagues are not necessarily equipped to study the sort of things that take place between humans (and perforce between them and the rest of nature), the composition of a rock or the pattern of a jet stream being rather different from property and power. Now that the latter remould the former, some confusion is perhaps to be expected. 'The Anthropocene' represents an attempt to conceptually traverse the gap between the natural and the

social – already blended in reality – through the construction of a bridge *from one side only,* leading the traffic, as it were, *in a direction opposite to the actual process*. In climate change, social relations determine natural conditions; in Anthropocene thinking, natural scientists extend their worldviews to society.

The most extreme naturalisation is found in the idea that climate change is caused by the existence of fire on earth, the Anthropocene a realisation of 'the planet's own phyrophytic tendencies' in the hands of the genus *Homo*. In *Fundamental Processes in Ecology: An Earth Systems Approach,* environmental scientist David M. Wilkinson extends the argument to *any* conceivable planet endowed with life based on the element of carbon. Such life will inevitably sequester some carbon, as the bodies of dead organisms descend into sediments; a species that learns to harness carbon as a source of energy will be favoured by natural selection; any intelligent species will proceed from burning biomass to burning fossil fuels and thereby 'have profound effects on its planet's carbon cycle,' global warming being the unavoidable sum of carbon-based life + natural selection + intelligence.[29] History in a primordial soup.

All these varieties of naturalisation have an easily recognisable form. 'Certain social relations appear as the *natural properties of things,*' with Karl Marx: production is 'encased in eternal natural laws independent of history, at which opportunity *bourgeois* relations are then quietly smuggled in as the inviolable natural laws on which society in the abstract is founded' – or the human species in abstract, or even intelligent life. In bourgeois political economy, capital is portrayed as though it had dangled in front of human beings 'since the time of Adam as the ultimate and only goal of their existence'; it is 'held to be a necessary feature of the *human labour process as such,* irrespective of the historical forms it has assumed; it is consequently something permanent, determined by the nature of human labour itself.'[30] De-historicising, universalising, eternalising, *naturalising* a mode of production specific to a certain time and place: these are the most quotidian – not to say hackneyed – strategies of ideological legitimation.

They block off any prospect for change. If the fossil economy is the outcome of the knowledge of how to light a fire, or the nursing of a baby, or the presence of combustible solid matter, or the conjunction of intelligence and sequestered carbon, how can we even imagine dismantling it? If things were *bound* to develop this way, how could anything else be possible in prospect or retrospect? For Clark, these are indeed matters 'of an ontological nature – and as such they exceed the domains of negotiation and decision-making'; for Pinkus, the current 'carbon economy' is 'intrinsically tied to human energy, production and *life itself*'.[31] Doomed we are and have always been. The distance from this belief to the infamous denialist propaganda of the Competitive Enterprise Institute – 'CO_2: They call it pollution. We call it life' – is disturbingly short.

But there is a noteworthy difference between bourgeois political economy and the Anthropocene narrative. Even if they end up saying almost the same thing, scholars naturalising climate change are rarely if ever working on behalf of the vested interests of business-as-usual. Most would likely wish to see them gone. Insofar as it occludes the historical origins of global warming and sinks the fossil economy into unalterable conditions, 'the Anthropocene' is an ideology more by default than by design, more the product of the dominance of natural science in the field of climate change and, perhaps, the general blunting of critical edges and narrowing of political horizons in the post-1989 world than of any malicious apologetics. It is not necessarily any less harmful for that. It is one of several theoretical frameworks which happen to be not only

profoundly defective, but also inimical to action. 'The Anthropocene' might be a useful concept and narrative for polar bears and amphibians and birds who want to know what species is wreaking such terrible havoc on their habitats, but alas, they lack the capacity to scrutinise and stand up to human actions; for those who may do so – other humans – species-thinking on climate change conduces to paralysis. The failure to understand the rise of steam power is, again, symptomatic of more general deficiencies: hence the need to start all over from the beginning.

Putting the Cart of Force before the Horse

The anomaly of steam is no less threatening to productive force determinism. As a matter of fact, the steam mill did not give us society with the industrial capitalist, but precisely the other way around. The arrow of causation can be in little doubt once we recognise that 1) capitalist relations of production antedated the steam engine, 2) such relations coalesced in a factory system based on waterpower and 3) the eventual incompatibility between them and the flow of energy induced the transition, in flat contravention of Marx's law in *The Poverty of Philosophy*. Moreover, steam did not possess any intrinsic technical advantage at the time of the shift; manufacturers let the brightest promises of water go to waste. Cohen's model of techno-historical change fits ill with the data on every count: scarcity did not hang over the agents; knowledge of the engine was not a sufficient condition for its adoption; communal deliberations over its pros and cons were conspicuously suppressed, the quasi-democracy of the treadmill story about as far as one can come from the decision-making process as it actually panned out.

In technological determinism, machines are postulated as having a primordial existence of their own in a realm from which they burst into human relations. 'New technologies,' writes Carlota Perez, a leading exponent of Schumpeterian technicism, 'irrupt in a maturing economy and *advance like a bulldozer* disrupting the established framework and articulating new industrial networks': crashing into society, demolishing walls, throwing the rubble this way and that until the road is clear.[32] But the very notion is a logical fallacy. To become a bulldozer in motion, a machine *first* has to be driven by some humans – that is, taken up in the sphere of relations – or it will remain an unmoved idea in the garage of the inventor's mind. As we have argued repeatedly, a novel device becomes a *material* force only through an active move by relevant agents to adopt it.[33] Thus a growth tendency cannot be an intrinsic property of the productive forces. Rather, *the relations have to be structured in such a way as to make investment in the forces attractive for the decision makers,* be they an egalitarian riverbank community as in Cohen's fairy tale or a class of savvy capitalists: without a relational spur to put them into practice, ideas will be mere ideas. Technological determinism turns out to be an impotent idealism.

In societies where the means of production are the properties of some people to the exclusion of others – what we know as class societies – productive forces will materialise only *through their being exclusively owned*. Steam power was immersed in the plasma of such relations from the start. It cannot be conceived outside of it. Being owned – being monopolised by some people in contradistinction to others – was as fundamental an attribute of the engine as were emissions of CO_2 – nay, the latter were *epiphenomena* of the services the prime mover offered its proprietors. It could not have had any ontology or ecology prior to property relations, and the same must apply to all subsequent technologies of fossil fuel combustion in class societies: their stunning power to change the climate of the earth has followed from *their value for their owners* as distinct from non-owners. A belief in the machines themselves as causes of our predicament,

as self-moving artefacts doing this and that – irrupting, selecting, growing, emitting – is not difficult to diagnose. One of the first Marxists to launch an assault on productive force determinism was Georg Lukács, in a 1925 review of Nikolai Bukharin's *Historical Materialism,* whose attempt 'to find the underlying determinants of society and its development in a principle other than that of the social relations' inevitably 'leads to fetishism'.[34] Things are ascribed powers and agency of their own, when in reality they are the embodiments of relations between human beings.

Marx himself does not escape the charge: the hand mill/steam mill aphorism was no slip of the tongue. It accurately summed up a conception of historical change in general and steam power in particular developed by Marx and Engels over the 1840s, along lines not dissimilar to Cohen's.[35] But as Marx settled down in London, he began to veer in another direction. Wading through piles of economic tracts, reports of the factory inspectors, parliamentary inquiries and private misery on his tortuous path to *Capital,* he jotted down his ideas along the way as they evolved. In the notebooks that make up *Manuscripts of 1861–63,* among observations on such writers as Ure and Tufnell, we find him returning to the self-acting mule, the wool-combing machine and other old acquaintances. A means to defeat strikes, such machinery 'appears as a form of capital – an instrument of capital – a power of capital – over labour – for the suppression of any claim by labour to autonomy. Here machinery comes into play as a form of capital inimical to labour in intention as well.' It is intimately tied to a certain prime mover. '*The introduction of steam as an antagonist to human power,*' Marx quotes and emphasises Gaskell.[36]

A more transformative discovery for Marx himself, however, concerned an energy source to which he had hitherto paid little attention: water. At some point in his investigations, he apparently realised the need to research waterpower to understand the roots of capitalist production. Thus the *Manuscripts* include enormous excerpts from a German *Geschichte der Technologie,* published in 1807, through which Marx traces the winding path of the waterwheel from Asia and Rome via the feudal estates of Europe to the mills for fulling and hammering, boring and veneering and, finally, spinning of cotton. Then he proceeds to steam: excerpts on the history of Savery and Newcomen; lengthy calculations of the proportions of steam and water in the British textile industry; analysis of Watt's patents. To fully comprehend the mechanical workings of the rotative engine, Marx draws a detailed picture of one.[37]

A new historical sequence now emerges. 'The spinning machine was not really complete until a large number of such machines, a reunion of such machines, *received their motion from water,*' Marx concludes – and at this moment, 'the organisation and combination of labour resting on the machinery first becomes complete.' Overturning the previous chronology, he grasps the fact that the industrial organisation of labour ripened with water, or, in other words, *that the most distinctive capitalist relations rode forth on a technology known since antiquity*. In *Capital,* the lessons appear in refined form. The Roman Empire, we read in Volume I, 'handed down the elementary form of all machinery in the shape of the water-wheel'.[38] Not the steam but the water mill gave us society with the industrial capitalist – but as a productive force, it had been around for centuries.

As much as the rivers were the first hosts of capital, however, the guest eventually grew impatient with the liquid. 'The flow of water could not be increased at will, it failed at certain seasons of the year, and above all it was essentially local.' Steam, on the other hand, had one very tangible advantage:

> Not till the invention of Watt's second and so-called double-acting steam-engine was a prime mover found which drew its own motive power from the consumption of coal and water, was entirely under man's control, was mobile and a means of locomotion, was urban and not – like the waterwheel – rural, permitted production to be concentrated in towns instead of – like the water-wheels – being scattered over the countryside and, finally, was of universal technical application, and little affected in its choice of residence by local circumstances.[39]

When steam 'transplanted the factories from the waterfalls of the countryside into the centres of the towns, the "abstemious" profit-monger found his childish material ready to hand, without having to bring slaves forcibly from the workhouse'. With these reversals, Marx explicitly corrects the account he and Engels offered in the 1840s: 'The steam-engine itself did not give rise to any industrial revolution. It was, on the contrary, the invention of machines' – by which Marx means machines for spinning cotton – 'that made a revolution in the form of steam-engines necessary'.[40] The threads are pulled together in a passage of characteristic density:

> Machinery does not just act as a superior competitor to the worker, always on the point of making him superfluous. It is a power inimical to him, and capital proclaims this fact loudly and deliberately, as well as making use of it. It is the most powerful weapon for suppressing strikes, those periodic revolts of the working class against the autocracy of capital. According to Gaskell, the steam-engine was from the very first an antagonist of 'human power,' *an antagonist that enabled the capitalists to tread underfoot the growing demands of the workers, which threatened to drive the infant factory system into crisis*.[41]

Here things are falling into place: the engine as an antagonist to labour *enabling* the capitalists to defeat a revolt, which threatened to drive the *infant* factory system into crisis. In the drawn-out confrontation over that system, labour lost to capital, in a disaster Marx considers typical: 'The substitution of the steam-engine for man *strikes the final blow* in this, as in all similar processes of transformation.'[42] If Marx in his youth perceived the engine as the wellspring of bourgeois rule, he here suggests that it *consolidated* such rule *after* the industrial capitalist – knee-deep in accumulation – had decided to adopt it. At that point, bourgeois power fused with mechanical. We may thus distinguish between two stages in Marxian thinking on steam: one early determinism and one late *constructivism,* the *Manuscripts of 1861–63* forming the bridge between the two. In the latter, Marx flew past the theoretical stumbling blocks left in his path by a Smith, a Malthus, a Ricardo, developing a truly original – if sketchy – account of steam. Much work remains to fill in the details. But the kernel is in plain sight: the relations preceded, selected – constructed – the prime mover that best suited their own dynamics.

Now one would expect that these empirical findings would have led Marx to renounce productive force determinism as a general philosophy of history, but it seems he could not bring himself to do this, for the formulae of forces-bursting-relations reappear even in his latest works.[43] Eviscerated by Marx's own research, that philosophy became one of his many legacies. With a little help from the messenger Engels, the Second and Third Internationals then codified it as the one materialist *doxa,* often with the hand mill/steam mill aphorism as a confession of faith, the whole spectrum of Marxist congregations – from Kautsky and Plekhanov to Lenin and Trotsky and indeed Stalin – united in *this* particular belief.[44] When Louis Althusser declared war on reductionist 'temptations' in *For Marx,* he knew to take aim on 'that well-thumbed piece on the steam engine,' epitome of all-too-prevalent *'economism* and even *technologism*'. But around this time, in the 1960s, the winds began to shift. Just as most quarrelling Marxists had hitherto agreed on putting the cart of force before the horse of relations, they now rearranged the carriage

of history: Maoism and autonomism, Braverman and Marcuse, Thompson and Althusser all pivoted towards a constructivist view.[45] But no school did so with greater confidence and clarity than political Marxism, the current founded by Brenner and Wood. It is with their help we can begin to reconstruct an alternative theory of the rise of steam power in particular and the fossil economy in general, *starting out from capitalist property relations,* the root system all rejected candidates ignore. If productive force determinism postulates the sequence

human and extra-human nature → productive forces → relations of production,

constructivism alone can posit

relations of production → productive forces → human and extra-human nature.

This is the line to follow, if we are to reach a theory of capitalist destabilisation of climate. First, however, an objection must be preempted.

Bracketing the Smallpox

Capitalism gave birth to the fossil economy. The rise of steam power – the critical moment in the delivery – occurred in a country with a distinctly capitalist mode of production: two centuries later, the context remains the same, the umbilical cord as strong as ever. Yet a fossil economy does not necessarily have to be capitalist. Indeed, under our definition, it would seem to correspond as much to the reality of the Soviet Union and its satellite states, which had their own growth mechanisms connected to coal, oil, gas. No less dirty, sooty, emissions-intensive – perhaps rather more – than their Cold War adversaries, those formations surely left their signature on the atmosphere. So why focus on capitalism as the mother of the fossil economy? What – a common objection to ecological Marxism – reason is there to delve into the destructivity of capital, when the Communist states performed at least as abysmally?[46]

In medicine, a similar question would perhaps be: why concentrate research efforts on cancer rather than smallpox? Both can be fatal! But only one still exists.[47] History has closed the parentheses around the Soviet system, leaving North Korea and to some extent Cuba the sole remnants of the bloc, and so we are back at the beginning, where the fossil economy is coextensive with the capitalist mode of production – only now on a global scale. The Stalinist version deserves its own investigations, on its own terms – the mechanisms of growth being of their own kind and still poorly understood – but there is a very good reason to follow the example of history itself and bracket it.[48] We do not live in the Vorkuta coal-mining gulag of the 1930s. It is no more. But the world that Lancashire founded in the 1830s encompasses us all as the ecological reality we have to deal with.

Today, notes an editorial in *Global Environmental Change,* esteemed journal in the field of sustainability science, capitalism 'forms the basis of the political institutions and social relations which define our collective ability to effectively respond to environmental change' – 'ever present, yet largely unsaid'. Most debates in the field take it as a given, less open to question than the air we breathe. It has become 'the elephant in the room,' in confirmation of Fredric Jameson's epigram: 'It is easier to imagine the end of the world than the end of capitalism.'[49] It is no longer easy even to imagine capitalism as an object of historical inquiry precisely because it

is perceived as a condition of life, more timeless than the very ecological foundations of existence, which, frail and tottering, seem to give way at any moment. But if we wish to understand how we ended up here, the permanent and the transient must *if only in the historical imagination* be reversed: in the beginning, the heavens and earth were solid. Then capitalism delivered the fossil economy. Or: today, the biosphere is unstable and capitalism stable, but to understand why we have reached this place, the two must switch positions. Only thus can an imaginative space for the history of the fossil economy – and any hope of dismantling it – be carved out.

CHAPTER 13

Fossil Capital: The Energy Basis of Bourgeois Property Relations

The Perpetual Fire of Accumulation

Woodpeckers work on the excavation of wood. The bills are their tools. Striking their sharp-nosed hammers with a signature mechanical sound, they can bore mouth-sized holes into tree trunks, like shafts for mining ants and termites, beetles and their grubs. Because the tools are at one with the bodies of the birds, they cannot be concentrated. No master woodpecker can collect bills and pile them up on a central site and tell the other members of the population, their faces strangely flat, to submit to his command and get access to the tools they need to break through the bark or refuse and starve in freedom: for this reason, if for no other, property relations among woodpeckers are impossible. Their equipment for metabolism cannot be distributed between owners and non-owners, nor can it be collectively controlled by a commune.

This is the essence of 'property relations': a matrix of positions for the members of the species vis-à-vis the means of production. Or, in the more elaborate definition given by Brenner:

> By property relations, I mean the relationships among the direct producers, among the class of exploiters (if any exists), and between the exploiters and producers, which specify and determine the regular and systematic access of the individual economic actors (or families) to the means of production *and* to the economic product,

– a set of rules, as it were, for how humans relate to their equivalents of bills and beetles.[1] Now humans create, of course, toolboxes infinitely larger and more varied than their own bodily organs. 'Nature,' Marx says, is their 'original tool house,' out of which they assemble advanced implements for spinning, boring, grinding, pressing, cutting, throwing, pumping and any number of other activities. Humans alone can fan out over the earth as a whole, construct instruments out of whatever useful material they encounter and annex them to their bodies: make the earth an 'inorganic body,' in Marx's words – a sort of prosthetic extension of themselves.[2] No other species can be so flexible, so universal, so omnivorous in relation to the rest of nature – *but for the very same reason, no other species can have its metabolism organised through such sharp internal divisions*.[3] If a broad set of extra-somatic tools is a distinctive feature of Homo sapiens sapiens, it is also the point where that species ceases to be a unity. Precisely because the bills

required for breaking through the bark of matter may draw upon all forces of nature and open the wide earth for appropriation, some humans can be cut off. A material, a machine, a prime mover can become private property. The individual might need them like she needs her own lungs, but they are outside of her body, caught by others in a net, versatile *and* off-limits, and so she may have no choice but to go via a master to access them: she is snared in property relations.

Before that capture happens, human beings are a bit *like* woodpeckers, in the sense that they are united with their means of production – not physically, but socially. On the land, in the household and the guild, farmers and artisans possess their own tools, the individual producer relating to the earth as 'the workshop of his forces, and the domain of his will,' still at one with the means 'like the snail with his shell'.[4] Capitalist property relations begin the moment that bond is broken. Deprived of what they need for their subsistence, ex-farmers and ex-artisans no longer own anything but a capacity to perform labour, or labour power, naked and unequipped, a mere potential screaming for tools with which to work. On the opposite side of the fence, they confront a class monopolising those same means of production as private assets. A historical divorce has occurred, in which producers and means have been separated from each other.

But the distance cannot be allowed to last. If people who own nothing but their own labour power never got in contact with the means of production, they would be unable to work and feed themselves: 'No boots can be made without leather.'[5] If, on the other hand, the land, the frames, the piles of leather remained untouched by the fingers and hands of working people, nothing would come out of them, and they would be of no worth to their proprietors. While the separation is the unshakable foundation for capitalist property relations, it has to be overcome, momentarily but continuously, for society to reproduce itself: producers and means must be *reunited*. Now the capacity of a living person to perform labour – her ability to exert muscles and mind, expend energy, operate her body parts during hours of concentration and strain – is quite a different thing from a pound of leather or a mule or a wheel; indeed, these are incommensurable entities. Hence their reunification can come about only via the mediation of a universal equivalent against which *anything* can be exchanged and in whose reactor all qualitative characters dissolve: what we know as money.

The worker needs money too. She sells the right to dispose of her sole property – her labour power – for specified periods of time, in return for a quantum of the universal equivalent – the wage – with which she can purchase the goods needed for her metabolism. Both at the end and at the beginning of the cycle, she possesses commodities: first her labour power, then a sack of potatoes and a fresh set of cutlery and a dingy apartment covered for another two weeks. The formula she follows is Commodity – Money – Commodity, or C – M – C for short.[6] The one C is distinguished from the other by its qualities, or its use-value: bare labour power is of no utility to its owner, but food and utensils and shelter are essential objects of consumption. But now consider an agent who *starts off* with money. Venturing out on the market, it is he who purchases labour power and means of production – say, a hundred workers ready to weave and be paid for two weeks at a time, a factory building, a steam engine, power looms, warp and weft – and *thereby affect the reunion* like an indispensable matchmaker. The result is a fine calico, which he sells on the market. For this he gets money. The cycle has come to a first end, in accordance with an opposite formula: M – C – M, beginning with money and ending with money, the commodity phase a mere passage to the ultimate goal.

But why change money for money? One sum of money cannot be distinguished from another in quality, only in quantity. The sole point of the exercise is the difference between the amount of

money thrown into circulation and the amount yielded at its end – to pocket an increment in exchange-value, or, simply put, to make *more* money. The full formula is thus M – C – M′, the M with a prime signifying that the sold commodities command higher exchange-value than the ingredients acquired to produce them. Our agent has garnered a profit. That is the whole purpose of the procedure, and *given the chasm between labour power and means of production as commodities on a market, there can be no other*. The two are brought back together in the hands of the capitalist, inserting himself as a permanent 'middle-man' or screen between the partners, purchasing them with the single aim – he has spent money, after all – of reaping a monetary gain.[7] In a society that has undergone the historical divorce, capital is the necessary medium for arranging a productive rendezvous between incommensurable entities that can never be discontinued nor fully completed. The interpolation must never cease.

'I conceive that a capitalist will not risk his money in business without he covers a profit,' said cotton manufacturer G. A. Lee from Manchester to a Parliamentary commission in 1816.[8] He would never do so if he expected to make a loss. If the business forecast told him he would get back 95 percent of his initial outlay, the capitalist would be wise to keep the money in his bank account; if it said he would stand a good chance of getting 100 percent of the expenses covered but no more, he would still be prudent to abstain from the investment. The effort would be pointless. One might perhaps imagine a capitalist who repeatedly banks on his own losses, but this person would be a mad deviant guaranteeing his own disappearance; similarly, one could visualise a capitalist who keeps placing his assets in ventures that give him zero in return but no losses – perhaps this is a philanthropic gentleman who appreciates the outlets for what they actually do. He would certainly not be a very successful capitalist, rather running the risk of being overtaken by others who have adopted the full formula: anything else than the profit motive requires sacrificial dispositions on his part. The sole rational goal for him *as a capitalist* is profit. Logically and historically, the quest for it is inscribed into capitalist property relations as their one 'driving fire'.[9]

So the capitalist cares naught for the material qualities of his goods: 'He does not manufacture boots for their own sake,' nor cutlery to put on his own table, nor houses to accommodate his children, but items to be sold to others. But he cannot sell *the idea* of boots or cutlery or houses. For his goods to attract demand, they must *be* such articles, endowed with a minimal use-value of allowing for walk on uneven terrain, scooping up food or shielding against cold and rain. To earn his profit, the industrial capitalist must take a detour through nature, setting up some version of 'the metabolic interaction [*Stoffwechsel*] between man and nature, the everlasting nature-imposed condition of human existence' within his precincts. Here the materials of nature are appropriated not for their own concrete comforts, but for the sole purpose of embodying exchange-value: 'Use-values are produced by capitalists only because and in so far as they form the material substratum of exchange-value, are the bearers of exchange-value.'[10]

The concept of 'material substratum' is crucial. A commodity commands exchange-value on the surface of the marketplace – and this is what counts for the capitalist – but it can never be severed from the layer beneath: if the labour expended in its production is subtracted, 'a material substratum is always left. This substratum is furnished by nature without human intervention.'[11] Whatever exchange-value is called forth on the premises of the capitalist, it has to rest on a bed of biophysical resources. Commodity production is the production of exchange-value *through nature,* with nature being precisely a substratum, subordinated and subsumed under a purely quantitative logic. The full formula for the circuit of industrial capital – that is, capital engaged in

commodity production – therefore has a pivotal P in its midst:

$$M - C \ldots P \ldots C' - M'$$

More precisely, the commodities bought by the capitalist fall into the two categories of Labour Power (L) and Means of Production (MP), giving the following extended formula:

$$M - C\,(L + MP) \ldots P \ldots C' - M'$$[12]

The meaning of P in these formulas is Production, or a closely regulated *Stoffwechsel*. Resources are withdrawn from nature and placed in the hands of workers as means of production to be applied, refined, worked up. Apart from machines and other instruments, they include raw materials, a subcategory of which is 'ancillary materials' or 'accessories' in Marx's terminology. These are the substances that do not enter into the product itself, as cotton does in a thread, but form necessary parts of the *process* of production, dissipated by it and then seen no more; in the finished commodity, they can only be traced as a virtual legacy or embodiment (much like the labour that has gone into it). 'An accessory may be consumed by the instruments of labour, such as coal by a steam-engine, oil by a wheel, hay by draft-horses,' fulfilling their function and instantly expiring.[13] As all other means, they have to be procured in the right amount and then *consumed,* for the production of commodities is also a process of consumption, just as a plant grows by consuming water, light and air. Marx takes the apposite example of combustion.[14] It is, indeed, a paradigmatic case of productive consumption: in the material metamorphosis of capital, some means – some accessories – are combusted, reverted to their elements, turned into ash and smoke and released back into nature.

From the viewpoint of capital, 'the production process appears simply as an unavoidable middle term, a necessary evil for the purpose of money-making,' impossible not to repeat. The cycle is by its constitution unlimited. Returning with a profit after every circuit, capital 'ignites itself anew' like a driving fire that never goes out, so that the general formula can be extrapolated in perpetuity:

$$M - C \ldots P \ldots C' - M' \rightarrow M' - C' \ldots P \ldots C'' - M'' \rightarrow M'' - C'' \ldots P \ldots C''' - M''',$$

and so on.[15] Capital is quantitative in nature: thus it recognises no end point. It reconverts the profit from the first circuit into more labour power and means of production for the next, moving on relentlessly through reinvestment, 'expanded reproduction' or simply *accumulation of capital;* it resumes production on a larger scale, and on a larger scale again, so that the *Stoffwechsel* 'changes into a spiral'.[16] For every consecutive circuit, capital will ceteris paribus appropriate greater chunks of nature. A manufacturer of cotton thread – Marx's favourite example – accumulates capital via a growing input of raw cotton, coal and machines, the productive consumption of which is augmented and accelerated. Put differently, the accumulation of capital is realised through a speedup of the material *throughput:* increased quantities of biophysical resources withdrawn from nature and, after being used up and degraded,

discharged back into it. The fire demands its fuel.

And the spiral is self-sustaining: 'The more the capitalist has accumulated, the more is he able to accumulate.' The more biophysical resources he has withdrawn for profit-making, *the more is he able to withdraw in the following round*. The increment in exchange-value from the first cycle allows capital to acquire greater quantities of material substrata in the second, or, in the words of Hornborg: 'To accumulate money is ultimately to be able to increase one's claims on other people's resources,' in an expanding whirlpool of resource dissipation whose agents are continuously 'rewarded with even more resources to dissipate'.[17] This is the ecological curse of growth. Must capital call it down on earth? Could one not imagine profit-making without ceaselessly growing output, accumulation within a production capped so as not to swell from one cycle to the next – what Marx called 'simple reproduction' and what ecological economists refer to as a 'steady-state economy'?

First, one should note that constant throughput could be damaging enough for certain key indicators (notably CO_2 emissions): growth only makes matters *worse*. But as ecological economist Frederik Berend Blauwhof has demonstrated, the latter is the expected outcome. If output were to be fixed, the profit from the first cycle could not be reinvested in additional machinery and workers in the next: it would have to be consumed, devalued or both. The only way for capital to throw it back into production and keep accumulating at the same rate of profit would be to pay workers less, fire some of them while output stays the same, avoid taxes or obtain subsidies and other services from the state – measures whose potentials would quickly be exhausted. 'When growth is impossible, further accumulation of profits by capital can only have the effect of continuous transfer of income from wages to income from property,' or, 'in other words, if profits cannot be made by growing the pie, it is to be done by cutting the rest in smaller slices.'[18] That strategy is doomed to hit a wall. Rates of exploitation cannot rise indefinitely; at some point, the rate of profit would inevitably slide down towards zero, and since it is the lure of profit that motivates investment, capitalists would simply cease operations and refuse to set production in motion – or move their capital to someplace else, where the constraint on output does not apply. Then there is also the hypothetical possibility that GDP could grow while throughput stays flat or falls thanks to a declining material *intensity* of production, a decoupling of value and nature. We shall have some words for this vision later.

Whence, then, does profit come? Hidden within the production phase – C…P…C′ – there must be some source of increase in exchange-value, something with the curious ability to create more such value than it costs: what is it? The Marxian answer to this riddle is, of course, labour power. If it takes four hours for a power loom weaver to produce cloth whose exchange-value equals her wage, she might well go on working for another four or six or eight hours, even though her reproduction – potatoes, cutlery, rent – has already been secured. If I buy a bicycle, the cost of it bears no relation to the distance I can go with it; within its physical capacities, I can spin the pedals for a time entirely unrelated to the price.[19] A similar blessing is bestowed upon the capitalist, with the critical difference that the commodity of labour power does not have a particular use-value like the bike (transportation from A to B) but the general use-value of *generating fresh exchange-value:* once she has worked for the four hours required to cover her wage, the operative can be spun to continue manufacturing cloth, or whatever other commodity is being produced, for sale on the market. During the remainder of the day, she produces surplus-value, which becomes profit when related to the invested capital as a whole, so that capital accumulation is in fact *the production of surplus-value:* ABC of Marxism, and still the most

plausible account around. After all, labour is the activity that sets anthropogenic products apart from those of raw nature; if profit had any other source, 'money would be growing magically on trees' and capitalists could just walk around picking it like a golden fruit.[20]

Thus capitalist property relations give rise to 1) the profit, 2) the compulsion to chase it incessantly, 3) the necessity of growing material throughput – all stemming from the fundamental intra-species fracture. Capital is the expanding gas forming in the cracks and hollows between the better part of humanity and the rest of nature. By its very definition, it *is* the circulatory, spiral-like process of valorisation or self-expanding value; but it is also – by its very definition – the relation between capitalists and workers, for capital exists 'only by sucking in living labour as its soul, vampire-like'; but if labour is its soul, extra-human nature is its utterly corporeal body. In the tracks of self-expansion, capital must deposit a 'mass of commodities' that is 'constantly growing,' a mountain range of transformed matter rising through the social ridges.[21]

The crux of this theory of growth is historical specificity. When not in his determinist mood, Marx wants us to *defamiliarise* growth: however familiar it might appear to someone born and bred in an advanced capitalist society, it has to be seen for what it really is: a quirk of history, an eccentricity of the present. Capitalist relations alone, Marx affirms in *Theories of Surplus Value,* 'stimulate unrestrained development of the productive forces and of wealth', but *'these relations are conditional.'*[22] The systematic tendency towards self-sustaining growth is an emergent property of these property relations, whose existence is due to certain events in time. Unlike Ricardian-Malthusian, Anthropocenic, techno-determinist and, not the least, various neoclassical theories of growth as an innate pursuit of the human species, this theory can account for the basic empirical observation, in one part of the world after another, of 'a "hockey stick", whose horizontal handle represents zero or slow growth, while the upward-sloping blade represents the relentless growth of unprecedented magnitude characteristic of capitalism,' in the words of economist Michael Joffe.[23]

The compiler of the data represented in figure 12.1, Angus Maddison, leading authority on historical growth statistics, calls the global advance in per capita income between 1000 and 1820 'a slow crawl'.[25] A jump occurred around 1820, a year Maddison derives from Crafts, but as we have seen, self-sustaining growth had already taken hold of at least one department of British industry decades earlier. Yet the aggregate hockey stick had the typical shape for Britain as well: between 1820 and 1913, per capita income grew three times faster than in 1700–1820. Rather than explaining away the horizontal blade as a long slumber, a *lack* of something or a not-yet-there stage, it should be seen as a sign – to speak with Brenner – of *different rules for reproduction*.

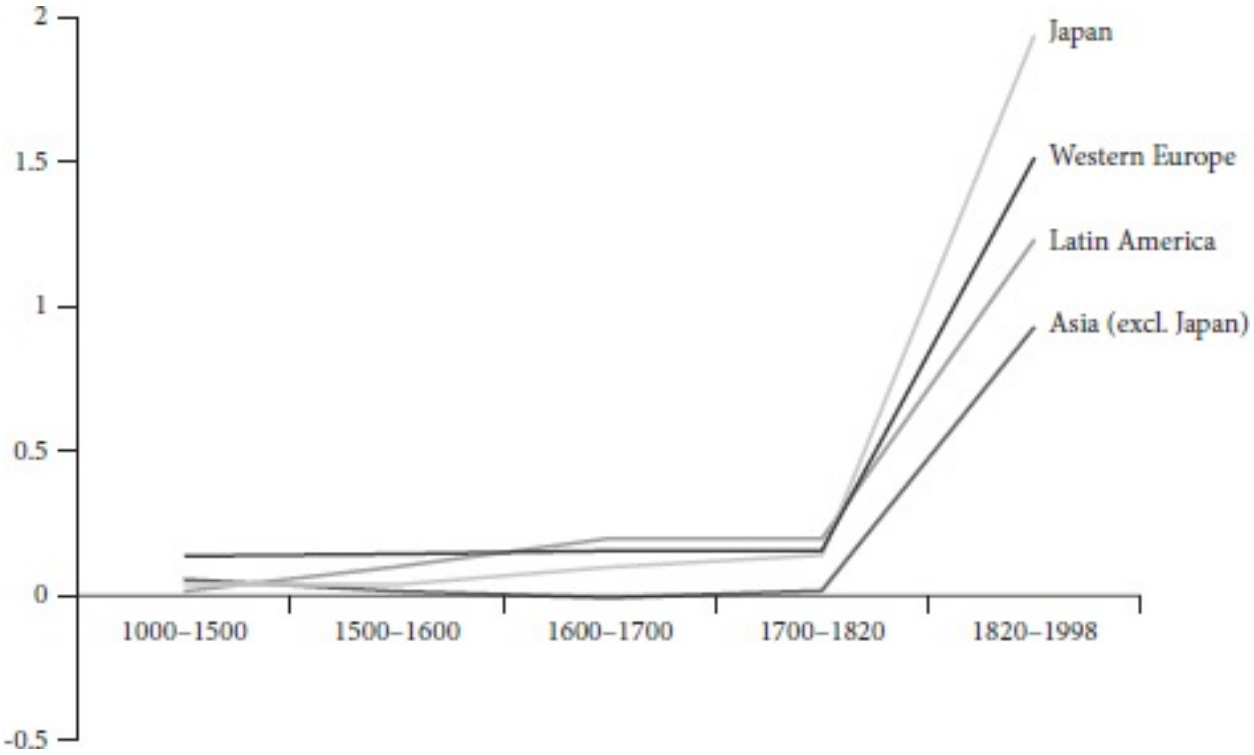

Figure 12.1. The growth hockey stick. Growth of per capital GDP, 1000–1998 (annual average compound growth rate).[24]

In societies where the bills remained fused with those pecking the wood, capital had nothing to recombine, no function, no way of being. Neither the direct producers nor their exploiters had to pass via the market; potatoes for the peasant or swords for the lord, use-values ruled the roost. Hence there was no insatiable appetite to devour nature. 'Use value in itself does not have the boundlessness' of exchange-value, Marx points out in the *Grundrisse:* things taken from nature 'can be consumed as objects of need only up to a certain level,' fizzling out in the sphere of private consumption. But capital recognises *no* boundary in nature. The moment it becomes comfortable with 'a boundary, it would itself have declined from exchange value to use value, from the general form of wealth to a specific, substantial mode of the same'; the function of money as capital is 'to resume its circular course always anew like a *perpetuum mobile';* solely concerned with the expansion of abstract value, it can drain nature on biophysical resources without really noticing what is in there, its eyes firmly fixed higher.[26] Planetary boundaries do not appear on the radar. Capital qualitatively ignores nature while quantitatively overtaxing it; the material aspects of production are irrelevant, yet value would not be valorised without annexing all the material substrata on earth: the blindest bull locked in the most fragile china shop.[27]

We discern here a major contradiction in human *Stoffwechsel* under capitalist property relations. On the one hand, members of the species scavenge remote corners of the planet for useful materials, burrow into hidden stores, integrate an ever-widening variety of components into their tools, universalise their metabolic interaction with the rest of nature. On the other hand, magnates of metabolism form a distinct subclass of the species: human *Stoffwechsel* expands and splits. Moreover, it expands *by dint of* being split. It transcends every external barrier on the basis

of internal barriers cutting through the populations, or, to paraphrase Marx: the contradiction between the universal biospheric power of capital and the private power of capitalists develops ever more blatantly, more destructively, *and it is the inner rupture that drives the extension*.[28] The nature of the divide between humans determines how they – some of them – shatter the rest of nature. Following this theory, derived from classical Marxian thinking cleansed of determinism, we can now propose:

The General Formula of Fossil Capital

At a certain stage in the historical development of capital, fossil fuels become a necessary material substratum for the production of surplus-value. But they are not merely necessary as leather for boots, raw cotton for cotton textiles or iron ore for machines: they are utilised *across the spectrum of commodity production* as the material that sets it in physical motion. Other sources of mechanical energy are pushed to the fringes, while capital expands in leaps and bounds, energised by fossil fuels. These have now become *the general lever for surplus-value production*. With F for fossil fuels, as a portion of the means of production, we can thus write the general formula of fossil capital:

$$M - C\,(L + MP\,(F))\ldots P\ldots C' - M'$$

The more capital expands, the larger the volumes extracted and combusted; integral to the *Stoffwechsel,* fossil fuels are now subjected to productive consumption in ever-growing quantities, with an inevitable chemical byproduct of which Marx and Engels were aware. In the second volume of *Capital,* Marx explains that the time expended by the capitalist on buying and selling goods, on prowling the market and securing transactions in meetings with other businessmen, is not value-creating time, but nonetheless 'a necessary moment of the capitalist production process in its totality': nothing sold, nothing gained. Efforts must go into the realisation of the value, even if it creates no value in itself. Then Marx draws a parallel pregnant with meaning. The time spent on buying and selling

> is somewhat like the 'work of combustion' involved in setting light to a material that is used to produce heat. This work does not itself produce any heat, although it is a necessary moment of the combustion process. For example, in order to use coal as a fuel, I must combine it with oxygen, and for this purpose transform it from the solid into the gaseous state (for carbon dioxide, the result of the combustion, is coal in this state: F.E.), i.e. effect a change in its physical form of existence or physical state. The separation of the carbon molecules that were combined into a solid whole, and the breaking down of the carbon molecule itself into its individual atoms, must precede the new combination.[29]

When Engels edited the posthumous second volume of *Capital,* using his initials to mark insertions into Marx's manuscripts, the science of chemistry had made progress since the days of Babbage, but nothing indicates any apprehensions on his part or that of Marx about the noxious effects of the gas. We may nevertheless take Marx's analogy literally, reverse it and state that constantly increasing quantities of CO_2 are a no-less-necessary aspect of the production of surplus-value than market transactions; the combustion of fossil fuels in their solid form and the consequent release of CO_2 do not in themselves generate any value for the capitalist, but they are material requirements for value creation. The extended formula of fossil capital thus reads:

$$M - C(L + MP(F)) \ldots P \overset{\cdot CO_2}{\cdot\cdot\cdot} \ldots C' - M'$$

Since fossil energy now fuels the perpetuum mobile of capital accumulation, always igniting itself anew as a driving fire that never goes out, the cycle continues indefinitely:

$$M - C(L + MP(F)) \ldots P \overset{\cdot CO_2}{\cdot\cdot\cdot} \ldots C' - M' \rightarrow M'(L' + MP'(F')) \ldots P \overset{\cdot CO_2'}{\cdot\cdot\cdot} \ldots C'' - M'',$$

and so on. Fossil capital, in other words, is *self-expanding value passing through the metamorphosis of fossil fuels into CO_2*. It is a triangular *relation* between capital, labour and a certain segment of extra-human nature, in which the exploitation of labour by capital is impelled by the consumption of this particular accessory. But fossil capital is also a *process*. It is an endless flow of successive valorisations of value, at every stage claiming a larger body of fossil energy to burn. One could think of it as the biophysical shadow of Marx's general formula of capital, coming to the forefront only at unexpected biospheric dusk.

The general formula of fossil capital, in these simple, extended and extrapolated versions, does not, of course, capture the entire field of fossil fuel combustion even in a capitalist society. First, there is a form of consumption preceding fossil capital by centuries if not millennia: the purchase of use-values whose very usage emits CO_2. Heating cottages with coal falls into this category, as do, to take but two examples, driving to work in a car and surfing the web with a computer (insofar as these run on fossil energy). The immediate cause of combustion is here the satisfaction of some need or other in the sphere of private consumption, where the utility of the coal, the car, the computer is enjoyed. Here the formula would rather be:

$$C - M - C(F) \overset{\cdot CO_2}{\cdot\cdot\cdot}$$

We might call this the formula of *consumption of fossil use-values* or, in short, *fossil consumption*. It can be repeated, obviously, but it would not contradict its own premise if it came to rest with a certain quantum of C(F); it is not wired to slide into reiterative magnification. It predates the circuit of fossil capital, but it cannot, as we have seen, give rise to a fossil economy on its own, for *individual consumption is neither the ignition mechanism nor the driving fire of capitalist growth:* there is nothing self-sustaining about it. Yet it might be key to our current predicament. We shall have a few words to say on it later.

Second, the F in the formula of fossil capital must come from somewhere. Since the capitalist encounters it as a purchasable commodity, and since it is not, like labour power, a capacity of a living person but a dead thing, it must have been brought to the market by some other capitalist for whom it is *an output*. This is the business of extracting coal, oil or natural gas. Here the fossil fuels are not accessories consumed in the production of something else, but *that which is produced* as use-values commanding exchange-value and holding the promise of profit, in accordance with the following formula:

$$M - C\,(L + MP) \ldots P \ldots C'(F) - M'$$

- which can indeed be extrapolated as any other cycle of valorisation. Like fossil consumption, this circuit predates that of fossil capital: there were collieries run as capitalist firms centuries before Watt. Its existence is a necessary precondition for the emergence of the other two formulae. For a private consumer and, more importantly, an industrial capitalist to be able to acquire fossil fuels, there must already be a capitalist specialising in the provision of F to the market *as his own immediate object of profit-making,* his material detour to the accumulation of capital. We shall call this the circuit of *primitive accumulation of fossil capital*. It might be central to both past and present developments, and so we shall return to it below.

In the history of the fossil economy, the processes summed up in the three formulas have, of course, become thoroughly intertwined with one another. It could be pictured something like the model in figure 12.2. Highly simplified though it is, it puts the spotlight on the core dynamics of the fossil economy, by which all energy that is solid melts into air. It revolves around the circuit of fossil capital. The other two processes have their critical functions, naturally, but *only in fossil capital is self-sustaining growth in general welded to the combustion of fossil fuels*.

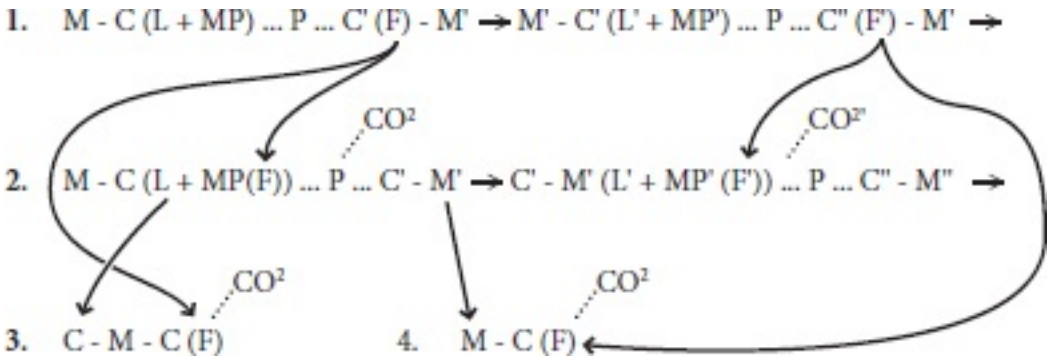

Figure 12.2. A stylised model of the fossil economy. 1: Primitive accumulation of fossil capital. 2: Fossil capital. 3: Fossil consumption, by workers. 4: Fossil consumption, by capitalists consuming part of the profit.

With coal placed right under the driving fire of capital accumulation, as the fuel transmitting motion to the labour process, a spiral of growing fossil fuel combustion was, for the first time, integrated into the spiralling growth of commodity production. But why did capital latch onto fossil fuels? Why did capital in general become *fossil* capital? What tensions in the relationship between capital, labour and the rest of nature – or, what properties of capitalist property relations as a matrix for *Stoffwechsel* – prompted this portentous step?

The Fossil Anarchy of Competition

Robert Thom came to grief, but history is replete with instances of successful management of common water resources, including for mills. One fascinating case is al-Andalus, or Islamic Spain. In a typical Andalusi valley, water mills – mostly with horizontal wheels – were sited at the end of a canal system. They received flow and runoff from irrigated land above. By placing the mills at the valley floor, rather than at the top or in the middle, conflicts between millers and farmers – between the needs for mechanical energy and irrigation – were precluded, both parties having their fill in turn. The system was based on collective ownership of water by the Andalusi tribes, regulating and monitoring themselves, including the public utilities of their mills.[30]

The banks of the Nile are home to particularly instructive cases: 'No land ever depended on water management more than Egypt,' Alan Mikhail points out in *Nature and Empire in Ottoman Egypt: An Environmental History*. The country known under that name can be defined as 'a desert with a river running through it'; from its birth, Egyptian civilisation has been suckled by the Nile and prospered by judicious use of its gifts to otherwise parched environs.[31] Fayyoum, a desert depression and sometimes lush agricultural garden to the west of the Nile, thrived in medieval times on efficient and egalitarian principles of water allocation. In the thirteenth century of the Western calendar, the tribes of Fayyoum managed their dams and canals with little if any interference from central bureaucracy, much like in al-Andalus. Sluice gates were opened and closed according to a strict schedule, guaranteeing that all land received water in proportion to size; downstream farmers had a right to larger feeder canals to make up for the loss of water through evaporation and seepage. Again, self-regulation of commonly owned water resources appears to have kept disputes to a minimum.[32]

Following its conquest by Ottoman armies in 1517, Egypt became the most strategic economic province, a breadbasket feeding much of the empire with the plenties of the Nile. The Sublime Porte immediately sought to collect the strings of irrigation in its hands but soon realised that maintenance of established practices would serve its purposes best, and so it delegated responsibility for continued upkeep of dams and canals to the village leaders, elders and peasants themselves. Customary rules for water governance, in place *min qadim al-zaman,* or 'since time immemorial,' were left to operate on a basic principle closely resembling that of res communes: 'Although water was owned by no one, it was in many ways owned by all the users of a particular water source or conduit.'[33]

Peasants were tied together in what Mikhail terms 'communities of water'. They adhered to 'the physical properties of the liquid's movement, viscosity, and flow rate' and

> the notion that *the welfare of the whole always trumped the interests and desires of the few*. This ideal of cooperative and collective responsibility arose from the fact that, throughout the countryside, scores of villages relied on the function of a single set of irrigation features for their entire supply of water – some combination of a canal, a dam, a section of the Nile, a waterwheel, a sluice gate, and other irrigation works. In these hundreds of ecosystems organized around the shared usage of water and irrigation features, *the actions of a few directly affected the welfare of the whole community*.[34]

Consequently there had to be some protocol for conflict resolution, usually of an informal nature. When typical disputes between upstream and downstream communities – the former accused of siphoning off more than their rightful share – could not be settled through direct mediation, Ottoman courts tended to side with the claimants and order a fairer allotment; locals who failed in their duties could be commanded to repair dams and canals. Revenues pooled by the authorities were invested in required infrastructure. Intervening when necessary, the state engaged in balancing acts akin to 'opening and closing valves in a long and complex series of intertwined pipes': effectively a form of planning – locally designed, centrally supervised – of the utilisation of the flowing commons.[35] Mikhail contends that it worked remarkably well.

Spanning wide distances, similar phenomena have been charted in Yemen and Peru: close coordination between upstream and downstream users, community assemblies, mechanisms for conflict resolution, customary norms of fairness in operation up to the present day.[36] More famous is the fieldwork of Nobel laureate Ellinor Ostrom and her colleagues among Nepalese farmers, highly skilled in creating mutually beneficial water rules: general assemblies held at

least annually, committees formed to distribute water between plots, informal communication maintained on a daily basis, rule-breakers sanctioned. Disputes – someone taking more than his share, at an unauthorised time, without contributing his input: but particularly quarrels between users at the heads and tails of canals – have traditionally been resolved through mediation, often overseen by community leaders.[37]

What are the requirements for the successful management of 'common-pool resources' such as water for irrigation? According to Ostrom, 'as long as mutual dependencies are clear to all participants, and they expect to relate to one another for a long time into the future, farmers in the developing world demonstrate substantial capabilities to craft rules' for the efficient, relatively harmonious utilisation of their commons.[38] Trust is a decisive component. Participants should communicate face to face, express and perceive emotions, share a set of values, engage in dense social networks, learn to associate locally and act collectively over time.[39] Farmers in al-Andalus and medieval Fayyoum would have recognised themselves in those mirrors.

All of these instances – and hundreds more could be adduced – are united by lasting success in that 'co-operation of all interested in the improvement of a mill-stream' so sorely lacking in the British hills. 'All narrow and immediately selfish views must be entirely kept out of view,' Thom vainly exhorted his fellow manufacturers – but from al-Andalus to the Andes, there were well-oiled mechanisms in place for suppressing precisely such aberrations. Continents apart – geographically, ecologically, culturally – these societies had one common denominator: *their property relations were not capitalist*. Producers and means were like birds and bills; land and labour power were not freely transferable commodities; resources were owned or controlled by communal associations; no profit monomania had seized hold of production. Under such relations, *the nature of the flowing commons did not represent a problem,* or at least not an unmanageable one.

But in capitalist relations, *competition* is law. Now that labour power and means of production are disjointed commodities, capitalists have to buy them on the market, retreat to their private premises for manufacturing and return to the market to unload the products alongside others who have done the same. Dependency on the market – not as a voluntary choice but as the mandatory place for acquiring workers, materials, tools: all prerequisites for production – *forces* capitalists to engage in competitive behaviour. To sell their goods successfully, they must set prices near the average and preferably below it; lest they be undercut by others, they must take onboard the best techniques; unless they reinvest and expand, they may be crowded out by rivals who enlarge more aggressively; only by maximising profits can they stay ahead. Competition, in Brenner's words, is a 'mechanism of natural selection' by which those who do not wage efficient economic war on their neighbours are eliminated. It drives the capitalists forward 'with a constant *march, march!,*' says Marx; it is 'nothing other than the inner *nature of capital,*' for by its workings, 'what corresponds to the nature of capital is posited as external necessity for the individual capital': it is the whip that enforces all the dynamism, dash and destructivity of this mode of production.[40]

In pre-capitalist property relations, direct producers and exploiters – if indeed any such exist – have immediate access to their means of life or luxury, their terraces and wheels, commons and courts. 'As a result,' Brenner observes, 'their survival and reproduction is not dependent on the sale of their products on the market; consequently *they do not have to compete* in terms of their productive powers.'[41] Since what they need most is reserved for them by custom or violence, they are not under compulsion to cut costs, innovate, adopt, accumulate. Rivalry between feudal

lords plays out not on the field of productive prowess, but on the field of battle. As long as labour power and means of production are locked away from investment, the exploiters do not primarily relate to each other through economic competition and *so will not systematically develop the productive forces* – whereas competition renders it obligatory 'for each producer to be continually on the watch, to discover improved methods by which the cost of the article he manufactures may be reduced,' with Babbage.[42] Self-sustaining growth proceeds through a never-ending tournament of industrial combatants on the highest horsepower.

For the Marx of *Grundrisse,* the original condition of humanity is 'direct common property' of the land through family, clan, village or some other collective association, sanctifying the principle of 'cooperation in labour for the communal interests'. Then the earth, the tools, other means of production are transferred to private ownership. Cooperation breaks down under the 'collisions between mutually indifferent individuals'; the earth is no longer 'managed by them as their common wealth'; atoms of authority, the proprietors of the means now act 'in total isolation of their private interests from one another'.[43] This is the road from the Nile to the Irwell.

The mutual dependence and trust of Ostrom's commons are foreign to capitalists; deliberate coordination contravenes the principles of the market. 'Everywhere that the bourgeoisie is at home,' writes Rosa Luxemburg, *'free competition* rules economic relations as their one and only law. This means the disappearance from the economy of any kind of plan or organization': the form of bourgeois economic 'government is not despotism but *anarchy*'.[44] While meeting each other ex post in the marketplace, the actors have no reason to share plans for production ex ante; competition throws a spanner in the works of mutual adjustment, blocks the sharing of information and upsets collective plans.[45] Capitalists may meet in general assemblies to discuss all sorts of matters – including price fixing and union busting – *but not to elect distributors with the right to regulate their use of resources*. Here anarchy must prevail.

In early nineteenth-century British industry, capitalist property relations came close to the ideal anarchical form. Mill-owners did not – could not – share the communal bonds of an Andalusi or Nepalese valley; their deployment of mechanical energy was a private affair guarded with special jealousy. Heart of the factory, the wheel or the engine determined the dimensions of production, dictated the speed of the machines, corresponded, via the shafts, to minute requirements; given this status of the prime mover, it is no wonder that the reservoir schemes fell apart. However valuable water may have been on the whole, prime movers ought to stand 'in total isolation' from one another. In the structural crisis, the spatiotemporal profile of the flow proved a poor basis for continued expansion of the many capitals. The onset of overproduction – an ordeal possible only when manufacturing for the market has gone from optional to imperative – brought home the contradiction in full.

The authoritative compilation of juridical praxis in the period, the British *Law-Dictionary* from 1835, spelled out the inopportune social nature of running H_2O:

> *There is no property in the water*. Every proprietor has an equal right to use the water which flows in the stream, and consequently no proprietor can have the right to use the water to the prejudice of any other proprietor without the consent of the other proprietors, who may be affected by his operations.[46]

Ninety-nine years later, the *Harvard Law Review,* that most venerable of American journals in the field, ran an article titled 'Natural Communism'. Detailing the unbroken tradition from the days of res communes, Samuel C. Wiel, an expert on water rights and disputes, claimed that

communism in four things is necessitated by nature: air, running water, the sea and the seashores. Energy from the flow would fall within the same purview. A man may put running water in a tank, but then it is taken 'out of its natural condition'; as long as it remains there, his property is flushed away. 'Constant mobility, interchange of parts, and perpetual renewal and disappearance make dominion or control of the corpus as impossible for running water as for air, and free it, therefore, from any ownership'; the agents who use the water *'necessarily use it in common, since there is only one source for all';* the utilisation can only be 'rationed' among so many borrowers.[47]

Now Wiel was anything but a communist. 'In most things, communism is depressing,' he averred: it is 'a prison where no man can do what he likes, and every man but the guards must do what he is told'. The American ideals of freedom and reward for industry and intelligence shone the light on mankind. But in some things, Wiel argued, communism simply could not be avoided: remembering that a source of water 'is the mingled result of rain, seepage, evaporation, and transpiration the parties' interests in it *must continue to be undivided so long as we cannot command and divide the wind and the rain and the heat of the sun*'. The good in question comes into existence independently of capital. Or, in the words of the *Law-Dictionary:* 'A water-course does not begin by prescription, nor yet by assent, but begins *ex jure naturae* [by the rule of nature], having taken this course naturally.'[48]

But if some parts of nature prescribed communism, the way out for capitalist property relations would be to base themselves – in that most crucial department: power – on some other segment of the earth. Swimming deeper into water in the second quarter of the nineteenth century, British capital would have been caught by its currents of communality. Power needs had reached a stage in which large-scale reservoirs were required, and technically possible, and economically lucrative, but they were so many quasi-communist prison bars. The alternative was a source of energy that *did* begin by prescription. Steam power 'is called into existence by the will of man,' we have heard Hugo Reid exclaim, continuing: 'There is no mystery about its action; it is perfectly under his control; it can be increased or diminished in its strength at a moment's warning; and there is a perfect knowledge of all the circumstances from which variation in its power can arise' – the exact opposite of the logic of water.[49] Hence the birth of the fossil economy coincided with the under-utilisation of the rivers of Britain's manufacturing districts, in a scenario inverting the 'tragedy of the commons': here the commons were harvested *below* their capacity because of the irrationality of the private profit-maximisers who, rather than uniting in promising reservoir schemes, took flight in the isolation of coal.

So it came to be that the tournament of self-sustaining growth switched to fossil horsepower. The very rules of competition demanded it, since only the stock had a spatiotemporal profile easily donned by the rivals: dis-embedded, solitary, fissiparous. Note here that it was not the liquidity of water that constituted its commonality – oil would later in history exhibit the same virtues as coal – but precisely that profile; conversely, the advantages of the stock derived from its exteriority to landscape and weather. Two tons of coal piled up in two yards had no relation to each other; two cubic metres of water flowed contiguously, as did gushes of air or shafts of sunlight. The anarchy of capital had to become fossil.

The Production of Abstract Space by Means of Fossil Energy

The historical divorce means that peasants are pushed off their land. It can happen by enclosures,

punitive rent hikes, land clearings, introduction of agricultural machinery, crushing competition from agribusiness, military confiscations, bans on inheritance of small plots or some other blow that makes continued life on the land impossible, but regardless of form, the rule is general: industrial capital hinges upon a popular exodus from the countryside. Released from their attachment to land, the 'free' workers congregate in the factories where production *takes place*. Marx describes the process in *Theories of Surplus Value:*

> If we consider the material element of *accumulation,* it means nothing more than that the division of labour requires the concentration of means of subsistence and means of labour at particular points, whereas formerly these were scattered and dispersed as long as the workers in individual trades – which could not have been very numerous under these conditions – themselves carried out all the manifold and consecutive operations required for the production of one or more products … Hence, *conglomeration* of workers, *concentration* of raw materials, instruments, and means of subsistence.[50]

Birds with bills can fly around. As long as producers and means are united in their homes – think of the spinner and the wheel, the weaver and the loom – production will be diffused in space. Founded on their disjunction, capital realigns them within the confines of its properties: capitalist commodity production has a spatial logic of *centralisation*.[51]

The basic receptacle is, of course, the factory, but it immediately points beyond itself, towards a place for the 'conglomeration' of all manner of inputs not under one roof, but within the town where mills, warehouses, banks, stock exchanges, machine workshops, wholesale traders and, not the least, houses for hands are crowded together.[52] Macro-receptacle and magnet for means of production, the town receives the influx of 'free' workers, the amassing of proletarians the flip side of the haemorrhaging of the countryside. A reserve army of labour takes up residence. It is a necessary condition for the production of surplus-value: only a shadow of potential substitutes will keep a worker aware that she is fortunate to have her job. The threat of dismissal is 'perhaps the most effective means yet discovered to impose labour discipline in class-divided societies,' Brenner notes; feudal lords could not make use of it against their serfs, but capitalists must be able to wave it as a credible option before their operatives. The barracks should be located in the vicinities. As critical geographers Michael Storper and Richard Walker argue in *The Capitalist Imperative: Territory, Technology, and Industrial Growth,* a large, dense, concentrated supply allows for 'flexible labour turnover policies,' whereas a small, thin, spatially dispersed labour market forces firms to treat their employees as precious minerals. Moreover, when a multitude of workers live together in the same neighbourhoods, submission to factory discipline may appear as a calling, a normal way of life and expected future: the town is the place where the ethos of wage labour – so repulsive to the first recruits – takes root.[53]

Capitalist property relations engender concentration in space: capitalists sticking with water in early nineteenth-century Britain would eventually have to expand *out from the centre*. It would have been different if all that abundant, cheap water had been located in a hole in the ground, in a trunk around which a town could bush out or follow some other vertical configuration – but then water would not have been water. As water, it flowed on the surface of the British landscape, fully available but incongruous with the spatial logic of the prevailing relations. The contradiction was present from the first days of the factory system, but it did not play out linearly or incrementally over time; in a belle époque for business, when rates of profit are high, there are margins for enduring the drawbacks of suboptimal sites.[54] The onset of crisis erases them. Profits vanishing, competition tightening, it becomes imperative to reside in the most favourable place –

where the largest markets can be courted, the latest machines purchased, maximum surplus-value squeezed out of labour – so as not to fall off the cliff. This is, of course, exactly what happened after 1825: the structural crisis threw the underlying contradiction between the spatial profile of the flow and the spatial logic of capital into sharp relief, ushering in their resolution through the transition to the stock.

Countries with less complete historical divorces were not driven by the same compelling dynamics to take that step. France is a case in point. In *The Domestic and Financial Condition of Britain,* published in 1834, George Browning offered the following comparison:

> The French labourers do not like the sedentary life of a weaver, or the immured existence of a miner, *whilst their smiling fields and luxuriant groves are so tempting and so much more congenial. Hence their population is comparatively scattered* – their roads bad – their canals few – *their immense strata of coal and iron lie buried in primeval beds* – and their power of competition is viewed by the British manufacturer with easy indifference.[55]

Surely underestimating the sway of capitalist relations over France, Browning nonetheless put his finger on the distinguishing predicament of Britain: no other country in the world had come even remotely as far in tearing its population away from fields and groves. For that reason – not for any unique strata of coal – did it breed fossil capital.

None of this means, of course, that it is *always* in the interest of capitalists to stay put in established growth centres and never to leave for the peripheries. Towns teeming with workers might become traps. Relocation into relatively pristine lands is, as we shall see, a vital strategy for capital in the perennial search for labourers easily procured and trained to industrious habits. But such moves are simply another manifestation of the fundamental freedom 'to place the power amongst the people, wherever it was most wanted,' as Kennedy put it: it is the spatial mobility *as such* that matters to capital.

Two modalities of space here collide. In *The Production of Space,* Henri Lefebvre distinguishes between 'absolute' and 'abstract' space, the former being 'made up of fragments of nature located at sites which were chosen for their intrinsic qualities (cave, mountaintop, spring, river)'. He exemplifies with architecture – temples and sanctuaries built on sites with inherent properties, such as a peak or well – but industrial water mills would be no less typical. 'Then the forces of history smashed naturalness forever and upon its ruins established the space of accumulation.'[56] There emerged *abstract space,* where capital tears material components from their natural beds and heaps them up in places of its own choosing. Instead of going reverently to the mountaintops and rivers and establishing businesses there, as some temples on holy ground, capital carries away what it needs and pours it out in places where the production of more exchange-value can best proceed. Capital *produces* abstract space, as a matrix of nodes and arteries that evolve not through their revealed biophysical attributes, but through the circuits of capital itself.

The modality of abstract space 'has something in common with the rationality of the factory'. Absolute, natural space 'juxtaposes – and thus disperses: it puts places and that which occupies them side by side. It particularizes.' By contrast, abstract, social space 'implies actual or potential assembly at a single point, or around that point. It implies, therefore, the possibility of accumulation.' For the first time, there is now a space in which property relations take precedence 'over nature itself'.[57] In the words of Neil Smith, prominent disciple and populariser of Lefebvre, capital strives relentlessly to emancipate itself from 'natural space' and produce a

space 'in its own image'.[58] But abstract space remains eminently terrestrial. Like exchange-value, it must have its material substratum in 'first' nature; the raw materials for it can only come out of the earth itself, as fragments wrenched away and plugged into whatever circulatory space capital produces. 'Thus', with Lefebvre, 'primary nature may persist, albeit in a completely acquired and false way, within "second nature" – witness urban reality': the city would be nothing without the constant withdrawal of biophysical resources from its hinterlands.[59]

Only the stock could ground the production of abstract space. Though bound to rock formations impossible to reproduce, it was buried at a remove from the space inhabited by humans – under a mountaintop, a seabed, a desert plain – as a relic of a landscape long dead and gone: the optimal if not the only conceivable source of energy for the breakout into spatial abstraction. By virtue of being concentrated in subterranean sites of no other use or meaning, parts of the stock could be brought into the world of earthlings as loose fragments, passing from hand to hand, circulating freely inside the circuits, releasing the full force of accumulation. Giving up on spring and river, capital dug into a source whose most concrete quality was abstractness, permitting it to circulate *through* nature rather than *around* predetermined places in the landscape.[60]

The mobility of capital in an abstract space under permanent reconstruction is made possible – a logical paradox – by *immobile* strata of concentrated energy. The enhanced freedom to locate and relocate, refine and manufacture, order and dispatch, import and export is guaranteed by mines, wells, gas fields: large concentrates of techno-mass inseparable from the ground below.[61] A mine cannot be sent to another place; it should be regarded as a site in absolute space, albeit one established *to serve abstract space* from its fixed position. Furthermore, to suffuse the economy with fossil energy, enormous physical infrastructures amounting to entire landscapes in their own secondary right – railways, canals, steam engines, coal depots: some of the swarthy scenes Leifchild saw in the mining districts – have to be put in place. 'It takes a specific organization of space to try and annihilate space,' with Harvey.[62]

Similarly, it takes a specific kind of nature to annihilate it. Fossil fuels are the material substrata for an abstract space and a second nature steeped in exchange-value, the bedrock for the biospheric universalisation of capitalist rule. The production of space entails – Lefebvre is perfectly clear on this point – the destruction of nature: in a prescient formulation, he writes of 'the city, which consumes (in both senses of the world) truly colossal quantities of energy, both physical and human, and which is in effect a constantly burning, blazing bonfire'. Written in 1974, *The Production of Space* contains almost biblical moments of despair:

> It is becoming impossible to escape the notion that nature is being murdered by 'anti-nature' – by abstraction, by signs and images, by discourse, as also by labour and its products. Along with God, nature is dying. 'Humanity' is killing both of them – and perhaps committing suicide into [sic] the bargain.[63]

But if humanity is an entity within quotation marks, by which Lefebvre hints at a subset, the cause of death might be other than suicide.

The Production of Abstract Time by Means of Fossil Energy

When a capitalist buys the right to command labour power, it is restricted in time: otherwise there would be slavery. If the worker is a living bicycle the manufacturer seeks to spin into

utmost exertion (with the help of some other mechanical power than his own, of course), this urge is compounded by the form of acquisition being a *temporary* hire, ending every day with the worker returning to her home for rest, recovery and recreation – and then starting anew the next morning, but always with a daily limit. For reasons to do with the basic metabolic needs of the human organism, labour cannot continue indefinitely. It can only be extracted during stints specified in the employment contract, and the capitalist must avail himself of the commodity before its bearer leaves his premises and resumes her life: he must make sure the worker *performs as much labour as possible within the given time frame,* be it six or fourteen hours. Labour has to occur during that time – not when the weather is right, or when the sun has risen, or when the worker happens to be in the mood for hard labour, for such events may bear no relation to the period agreed upon in the exchange. Purchased time without actual labour is wasted money; actual labour outside of purchased time is beyond the control of the capitalist. He acquires time from another life as a vessel to be filled to the maximum.

One modality of time now supersedes another. In *Time, Labor, and Social Domination: A Reinterpretation of Marx's Critical Theory,* Moishe Postone distinguishes between the two as 'concrete time' and 'abstract time'. The time it takes to cook rice is concrete: it is measured by an actual event. So is the time required to say one paternoster, or the time of spring or religious holidays. In its concrete form, time is a dependent variable, the function of an occasion, process or sensuous rhythm; it does not exist as a neutral framework but is rather constituted *by* qualitative appearances. It is inside, not outside them. It structured social relations before capital.[64]

In defining 'concrete time', Postone draws heavily on E. P. Thompson's classical essay 'Time, Work-Discipline, and Industrial Capitalism,' in which pre-capitalist conceptions of time are illustrated with a range of ethnographic and historical examples: 'In Madagascar time might be measured by a "rice-cooking" (about half an hour) or "the frying of a locust" (a moment)'; Englishmen once used 'pissing while' as a temporal yardstick ('a somewhat arbitrary measurement,' Thompson wryly comments); but above all, this sort of time is *embedded in natural cycles*. A petition from Sunderland in 1800 describes 'a seaport in which many people are obliged to be up at all hours of the night to attend the tides and their affairs upon the river,' the fishermen and seamen performing their labour in intervals *set by nature itself,* in a rhythm of tidal waves from which their activities could not be extricated. The artisan has to down his tools when darkness falls. In peasant households, the cows must be milked in the morning, the grain harvested before the rains, the firewood collected when autumn arrives: 'hours and tasks must fluctuate with the weather.'[65]

Prior to capital, the labourer works in a mode of 'task-orientation,' a concept Thompson borrows from anthropology. With her eyes on fulfilling a task – be it catching so and so many fish or sewing a jacket – the timing and tempo of the labour process are determined by requirements internal to it, not externally imposed. A smallholder will not harvest because his employer is shouting at him, but because the wheat is mature. A fence is mended when it needs to be mended; tools are repaired when broken. Production is still oriented towards use-value, and this holds even for the most rampant feudal exploitation: a portion of the grain will be wrested from the farmer when time has come to grind. Most labour – including compulsive surplus labour – would, to quote anthropologist Tim Ingold, have to '*fall in* with the rhythms of their environment: with the winds, the tides, the needs of domestic animals, the alternations of day and night, of the seasons and so on'.[66]

This is not to say that labour in concrete time is all joy and reward: it can be just as stressful, excessive, disciplined and punishing as any other. When a peasant sees the clouds gathering on the horizon, he may have to work without rest for a whole day; in the report quoted by Thompson, 'people are *obliged to be up at all hours*' by the very movements of the river. Concrete time is not constituted by leisure, but by *fluctuation* in rhythms and speeds of labour attending on the seasons and weather shifts, which decides when the time for various tasks is ripe. Such temporality seems to inhere in agriculture, but also – so Thompson argues – in certain relations:

> The work pattern was one of alternate bouts of intense labour and of idleness, *wherever men were in control of their own working lives*. (The pattern persists among some self-employed – artists, writers, small farmers, and perhaps also with students – today, and provokes the question whether it is not a 'natural' human work-rhythm)

– doing things when they need to be done, not *on time controlled by someone else*.[67]

'Abstract time,' on the other hand, is empty. It is a mathematical hollow, an incorporeal repository of events which stands independent of them all and never betrays their influence. Motion, action, procedure occur *within* abstract time, under a regime of constant, equal units: hours as long today as tomorrow or at any other point of the year. Time is transformed 'from a result *of* activity into a normative measure *for* activity'; things can now happen *on time* and more specifically on *clock*-time, be the weather as it may.[68] No less than its concrete predecessor, abstract time is, of course, derived from nature – namely from the motion of planets in outer space, so far from the floods, the snow, the monsoons, the sandstorms as to appear disconnected from the cycles on earth, or at least external enough to allow for rigid calculation of hours, minutes, seconds. It is a homogenous schedule, an independent variable lending itself to the measurement of subsumed activities: if concrete time is 'pissing time,' a piss might take thirty-five seconds, less or more, under abstract time.

The time span of the working day represents an investment to the capitalist. It must not be squandered by workers loitering around or waiting for a signal from nature: time has become money. Locked in competition, the capitalist must see to it that his commodities are produced at least as fast as those of his rivals – slower than the average, he will have to expend more labour and set a higher price on his goods – and so he becomes intensely preoccupied with productivity, the factor perhaps most characteristic of abstract time: output as measured against a fixed time unit. Always looking over his shoulder, he asks, 'How long did this operation take – how much labour went into it?' and searches for ways to speed it up.[69] As Lukács notes in *History and Class Consciousness,* the working day is successively divided into ever smaller fractions, each with its own price tag, and so 'time sheds its qualitative, variable, flowing nature; it freezes into an exactly delimited, quantifiable continuum filled with quantifiable "things"': it is *reified,* stiffened, converted from flow into finely cut pieces.[70]

The flow of energy belonged to the era of concrete time. Waterpower was a legacy from that era: abstract time inhered in capitalist property relations. The contradiction was there from the beginning, but capital did not have to resolve it before reaching the fork in the road that was the Factory Acts. The Ten Hours Bill of 1847, Marx pronounced in his inaugural address to the First International, constituted 'the victory of a principle,' nothing less than 'the first time that in broad daylight the political economy of the middle class succumbed to the political economy of the working class'.[71] Up to that point, capital had primarily been accumulated through the

production of *absolute* surplus-value: extension of the working day beyond the hours necessary for the workers to produce the equivalent of their wage. Already with the Act of 1833, the screws on absolute surplus-value were tightened; with the Ten Hours Act, it was *absolutely reduced* through the shortening of the legal hours. How did capital respond to that challenge?

Marx's answer is well-known: 'Capital threw itself with all its might, and in full awareness of the situation, *into the production of relative surplus-value,* by speeding up the development of the machine system.'[72] Relative surplus-value is generated by curtailing the necessary labour time – if the worker formerly needed eight hours to cover her needs, now she might make it in six only – so that the surplus is extended *backwards* into the day, rather than forwards as in the absolute variant. This is achieved primarily by means of new machines (raising the productivity of labour), but also by stricter discipline (increasing the intensity). The coming of the Factory Acts marked the shift from absolute to relative surplus-value as the dominant strategy of accumulation: fewer hours remaining, more had to be produced within them, provoking another round of abstraction of time. In Marx's words, the acceleration and intensification of labour caused a *'condensation of labour time,*' or, even more suggestively: 'The pores of time are so to speak shrunk through the compression of labour.'[73] With the pores shrinking, even less room was left for the fluctuations of concrete time, abstract time becoming ever more sovereign in its demands on labour.

The regime of absolute surplus-value attenuated the contradiction between flow and abstract time. As long as the latitude of the working day was so unrestrained as to absorb within it the swings of the flow, water remained a viable basis for capital; concrete time could still be reconciled with the abstract demands of accumulation, at the expense of the operatives who had to perform all the extra hours of work. But the Factory Acts ushered in a new regime of *more labour in shorter time, without bulging pores of interruption,* making the contradiction squarely unsustainable. The temporality of relative surplus-value – the shrinking of the pores; the heavier, more extensive machinery – demanded that breaks in mechanical energy be banished, underlining the benefit of a prime mover that could be sped up at will.

And so it turns out that abstract time, no less than its concrete victim, is written in the signs of tellurian nature. Instead of the rhythms of day and night, of seasons and winds and tides, we get the stock: dead, frozen, ejected from perceptible natural cycles through burial underground. In fossil fuels, the time of photosynthesis hundreds of millions of years old is compressed so that living labour can be condensed, their timelessness the material prop for a tyranny of the abstract. The perpetual circulation of capital, its fluid move from one circuit to the next, is made possible – a logical paradox – by absolutely *inert,* noncyclical, non-flowing strata of concentrated energy. In this dimension no less than in space, abstraction has its substratum firmly placed within the earth's crust: capital can fly high above all qualitative determinants only by digging and drilling into it.

The Abstract and Fossil Spatiotemporality of Capital

Capitalism, writes critical geographer Noel Castree, has its own 'distinctive *spatio-temporality*'. It does not proceed *in* space and *through* time, as if the two were fixed coordinate axes along which capital politely developed without altering their characters; rather, capitalism produces its *own* abstract space and abstract time. Components of the very process of accumulation, the two dimensions form a unity, one single spatiotemporality which lies not outside but *inside* capital as

its 'DNA or, if you prefer, its operating hardware'.[74]

Marrying Castree with Brenner, we can see that this abstract spatio-temporality springs straight from the fundamentals of capitalist property relations: the historical divorce must be overcome in specially designated locales and hours. A primordial rift in the relation between humans and the rest of nature is propagated in space and time, severing human beings from the qualitative properties of both as labour is relocated to places and moments set aside strictly for the purpose. Prior to capital, production was rooted in home and weather; with capital, it must be uprooted from both, since its purpose is no longer use- but exchange-value. The two dimensions of abstraction reinforce one other. To take but one example, a regime of relative surplus-value spurs instalment of the most up-to-date machinery, easiest to get hold of in urban centres; more fundamentally, as Jonathan Crary argues in his superb study of capitalist temporalities, *24/7: Late Capitalism and the Ends of Sleep,* the modern factory was the launching pad for the war against seasonal and diurnal cycles *as well as* 'an autonomous space in which the organization of labor could be disconnected from family, community, environment, or any traditional interdependence or association'.[75] The ecological significance of that site can hardly be overestimated.

None of this is to suggest that capital wipes out absolute space and concrete time from the surface of the earth: to the very contrary. Absolute space can be spotted in every coal mine and oil platform, while concrete time is a bone of contention in many a conflict between labour and capital – think of workers demanding vacation time in the summer, unions defending the breaks needed for taking a meal or going to the bathroom, a team of carpenters arguing that this is the time *actually required* for building a wall in heavy rain. Qualitative ruffles do not disappear, but are rather *dominated* by abstract uniformities, as a consequence of exchange-value being (quite literally) on the front burner of production. 'The money form,' writes Postone, 'is abstracted from the sensuous reality of various products': the polar opposite to use-value. If production had remained oriented towards use-value, absolute space and concrete time would have been part of the texture of life – nothing much to fuss about, as Fairbairn hinted in his 1864 *Treatise*: 'It is only at out districts, and *where the mere wants of the inhabitants have to be supplied,* that water mills can be used with profits.'[76] But supplying the mere wants of the inhabitants was no longer the purpose of production.

If the abstractions of capital have sometimes been perceived as a kind of farewell to nature or a detachment from the earth, nothing could, strictly speaking, be more erroneous. The more capital tries to extract itself from the absolute, concrete qualities of space and time, *the deeper must be its exploitation of the stock of energy* located in their exterior. The abstract spatiotemporality of capital is just as entwined around nature as what came before it – only a very special segment of nature, with a spatiotemporal profile harmonising with its own.[77] Capitalist growth, then, did not become welded to fossil fuels because it is a linear, neutral, incremental addition of wealth, output or productive forces: it is no such thing, and no such thing exists. That growth is a set of relations just as much as a process, whose limitless expansion *advances by ordering humans and the rest of nature in abstract space and time* because that is where most surplus-value can be produced. The mystery of a shift to the expensive source is dispelled. Once we rid ourselves of the perception of growth as a transhistorical snowball, we can see that capitalist growth had every reason to discard water despite its abundance, cheapness and general excellence.

Real Subsumption of Labour by Means of Really Subsumed Nature

When capital first appears on earth, a creation is already in existence. A new genus of exploiters set about making history, but they find themselves in circumstances not of their own choosing: instruments, raw materials, technical know-how, work organisations are left intact from previous occupants. The original act of the capitalists is to insert themselves in the metabolism between human beings and the rest of nature *as it is,* like a spider taking over another one's web. Technologically speaking, the direct producers continue to work as they have always done, weaving on the looms and spinning on the wheels of old – only they do it for capitalists, in the guise of putters-out or owners of primitive workshops, to whom they hand over the products and from whom they receive wages. In *Results of the Immediate Process of Production,* one of the many preparatory sketches for his magnum opus, Marx, of course, defines this original takeover as 'the formal subsumption of labour under capital'.[78] Novel technologies are not yet introduced to enhance productivity; profit pivots on absolute surplus-value; capital circulates and expands, but without being *embodied*.

It is a brief overture. Formal subsumption – capitalist property relations as empty shells – is bound to be racked by wild contradictions, most fundamentally because labour power is a very special commodity. In fact, it is a commodity only in the weak sense of being bought and sold on a market, but not in the full sense of being *produced* for sale (there being no establishments for the manufacturing of people). Labour power is rather a faculty of human beings, an attribute of their vitality, in itself 'subjectivity' or 'subjective power' – *potenza* in Italian – as emphasised by Antonio Negri in his autonomist classic *Marx beyond Marx: Lessons on the Grundrisse*.[79] A source of wealth without which capital would be unable to get anything produced, it possesses an irreducible, elusive, frustrating *autonomy*. There is no guarantee that the buyer actually gets what he pays for. Because the worker has a life that cannot fully pass into the hands of the capitalist, she may withhold some of her utility: slow down, fiddle away the morning, ignore guidelines, go on strike. The process of extracting her labour engages armies of overlookers, but as long as subsumption is merely formal, they are fighting a losing battle, since the only weapon they can load is their own frail personal authority (shouting, flogging, fining, prosecuting…).

As struggles with autonomous labour intensify, however, subsumption soon moves from being formal to becoming *real*. The capitalist unrolls his machines. Inherited instruments are replaced with fresh productive forces obliging the operative to follow their own speed, execute the operations they decree in a metallic voice, watch them, mend them, remove the finished products; henceforth, the worker's activity is 'determined and regulated on all sides by the movement of the machinery' as *'the power that the capitalist has through this thing*'. Above all, Marx underscores, the machines assert their imperious power through 'perpetual motion'.[80] The worker need not lift a finger to get the process of production rolling: it rolls when she turns up in the morning and again after lunch, by a force completely oblivious to her presence. A pygmy, a minder, an assistant who adjusts a slide or quadrant, the worker enters the factory to fill some tiny gaps in an overpowering mechanical current. No longer a mere formal claim, the appropriation of her living labour has become a technological imperative, the process of extraction delegated from overlookers to the very means of production, to which the operative must submit if her work is to be done at all.

The shift from the handloom to the power loom may be taken as an exemplary switch from formal to real subsumption, while the self-actor accelerated the process – underway since

Arkwright – in the spinning department. In both cases, the historical sequence inverted the prescripts of productive force determinism: '*the relations of production are within the productive forces,*' in the words of Raniero Panzieri, writing in the legendary autonomist journal *Quaderni Rossi* in 1964.[81] This is the logic of real subsumption. Now the spider spins his own web, all the better to catch surplus labour; profit comes to pivot on relative surplus-value; dressing in overbearing materiality, the masters ceaselessly revolutionise the means. But it is an ongoing process, never at rest, since the autonomy of labour cannot be extinguished: real subsumption is a valence of power, not a final solution.

External coercion can take a step back. Machinery itself enforces 'a barrack-like discipline' through the summoned 'forces of nature,' chief among them mechanical energy.[82] Conquered fragments of nature reworked through human labour, machinery represents *dead labour,* but – 'a highly mysterious thing' – it comes alive by connection to the prime mover. Now it rises over the worker 'as a mighty organism'. When the automatic centre is switched on, the machinery turns into 'a mechanical monster whose body fills whole factories, and whose *demonic power,* at first hidden by the slow and measured motions of its gigantic members, finally bursts forth in the fast and feverish whirl of its countless working organs'.[83] A mighty organism, a mechanical or 'animated' monster, a demon, also likened to a leech and a vampire: Marx here approaches full-blown steam demonology.[84] Indeed, his choice of words can hardly be interpreted as anything other than an assimilation of that proletarian idiom. Unmasking Victorian machine fetishism, he traces the movement of capital leading up to machinery *as a source of social power* which has the appearance of a thing – and in fact also *is* that thing.

But what prime mover can sustain such subsumption? Marx never takes up that line of inquiry, but he crosses its path in the most remarkable discussion of the relative benefits of water and steam in all of his works, in the third volume of *Capital,* at the beginning of the long sections on ground rent. 'Assume,' Marx opens his excursion, 'that the factories in a country are powered predominantly by steam-engines, but a certain minority by natural waterfalls instead'. Water is far cheaper, Marx further assumes – this is written in London in the mid-1860s; his assumption is perfectly realistic – and so provides its beneficiaries with 'exceptionally favourable conditions'. A smaller quantity of constant capital and living labour is required to produce the same amount of commodities, raising the profit 10 percent above all the rest. Having evoked such an imbalance between a majority of mediocre steam capitalists and a minority of outstanding owners of water mills, Marx identifies the fundamental reason for why water should be cheaper: the winners owe their super-profits

> to a natural force, the motive force of water-power which is provided by nature itself and is not itself the product of labour, unlike the coal that transforms water into steam, which has value and must be paid an equivalent, i.e. costs something. *It is a natural agent of production, and no labour goes into creating it*.

But in the next moment, Marx – advertently or not – illuminates the instability of the flow for capital, however cost-effective it may be:

> *It is in no way just up to the capital to call into being this natural condition of greater labour productivity,* in the way that any capital can transform water into steam. The condition is to be found in nature only at certain places, and where it is not found it cannot be produced by a particular capital outlay. It is not bound up with products that labour can produce such as machines, coal, etc., but rather with particular natural conditions on particular pieces of land.[85]

Capital can come across a waterfall in the country like a spider's web, but not spin it. *The subsumption of this force of nature is bound to be ever formal*.

In one respect, the flow of energy is like labour power: a commodity only in the weak sense of being hired for use, not in the full sense of being produced for the market. That is why water had no exchange-value, why it was so much cheaper than steam and *why it had to be discarded*. The stock, on the other hand, is but a dormant potential, awakened as a force of nature only through the touch from the resources of capital, its acquired means and labour. That is why coal had exchange-value, why steam was more expensive and *why it had to be chosen*. (It is likewise the reason for the existence of primitive accumulation of fossil capital and the absence of any equivalent on the side of the flow.) We see here another series of paradoxical reversals: the renewable, common, already activated source of energy appears to capital irreproducible, exclusive, disabling. Only the stock can be conjured up as a *power in motion internal to capital itself,* setting it free from flowing nature and, indeed, from everyone else, in a sort of thermodynamic autoeroticism.

Labour power runs through the veins of living beings, waterpower does not, but from the standpoint of capital, the two are alike in another respect: the flow can withhold some of its utility. There is no guarantee that the leaseholder actually gets what he pays for. As a self-generated, fickle and place-bound *potenza* of nature, the flow possesses an autonomy similar to that of human labour; we have followed the analogous interruptions throughout the second quarter of the nineteenth century, some of the myriad ways in which water, like workers, subverted capitalist authority. A source of wealth without which capital would be unable to get anything produced, nature possesses an irreducible autonomy: but some parts of it can be more thoroughly internalised – really subsumed – than others. The web of fossil energy has to be actively spun.

Internal to capital by virtue of being external to landscape and weather, the stock possessed a seductive halo which would, however, later turn out to be a chimera. For the transition engendered another paradox: water was quasi-autonomous and immune to real subsumption because *unproduced by labour,* whereas steam had all the opposite characteristics because *the stock could only be picked by labour* – and so by shifting from the former to the latter, capital necessarily became *more dependent on human labour* in one very special sphere: the production of energy itself. The substitution of machinery for living workers rested on a greater role for living workers in the provision of fuel. As soon as capital sold its soul to the stock, seeing in it the magical formula for real subsumption of labour by means of really subsumed nature, problems of control would reappear in a different form – we shall return to them below. But none of them altered, of course, the original dynamics post-factum; in the moment of crisis, the formula corresponded to a most pressing reality.

One cannot have real subsumption of labour with only formal of nature. If the autonomy of the working class is to be fought by a regiment of machinery, the prime mover – the field commander – had better be reliable.[86] The vertical waterwheel was one of the instruments inherited by capital from previous exploiters; found on hand, it was retrofitted for accumulation and coupled to the first machines for spinning cotton, real subsumption in the spinning department commencing on the basis of water – an asymmetry rectified in the crisis. At the beginning of its career, capital 'relies on the crutches of past modes of production,' Marx writes in the *Grundrisse,* but as it matures 'it throws away the crutches, and moves in accordance with its own laws'.[87] Waterpower was such a crutch, and capitalists who kept walking with it – the

Ashworths, the Gregs – eventually appeared as dinosaurs with their demands for renewed legal powers for formal subsumption and absolute surplus-value: no clemency towards unions, unlimited working days, doors locked to the inspectors.

Seen from another angle, a concatenation of events in the crisis spurred the shift. Several victories wrung from capital by the militant labour movement – the repeal of the Combination Laws, the high wages of the cotton spinners, the upsurge in unionism, the Factory Acts of 1833 and 1847 – were *countered* with the turn to the stock. Capitalists using steam were one step ahead in the process of subsumption, because they had a motive power bent to their own laws of motion. In the engine, the relations were within the force – and precisely for that reason, violence was required to subdue the resistance: had steam-powered machinery not represented a materialised dominance over labour, British workers would not have opposed it as stridently, and there would have been little need to call out the cavalry. The use of extra-economic force to protect steam attested to the mechanical nature of that power. As Brenner has consistently stressed, property relations are constituted through political struggles and must, in the last instance, remain 'sanctioned by force': equally so fossil capital.[88]

Real subsumption of labour and of nature were at one, but not identical; in some critical respects, labour power is sui generis. The flow can be outright replaced with the stock (a true commodity), but there will always be a residuum of human labour (as a pseudo-commodity) – and therefore of autonomy, if only flickering – in the process of production. Capital will therefore encounter fresh incentives to push workers further to the wall by means of machinery, in new rounds of automation resting on growing withdrawal from the stock. The differences between the two processes of subsumption – one more complete than the other – ensure that more fuel is poured on the fires.

Stabilising Power, Destabilising Climate

'Man's power over Nature,' C. S. Lewis once observed, 'turns out to be a power exercised by some men over other men with Nature as its instrument'. Herein lies a fundamental truth about the structure of social power *and* that of environmental degradation. Using Lewis's statement as his epigraph, anthropologist Richard Newbold Adams, in a book now mostly forgotten, outlines a theory intended to fuse the two aspects: 'It is the actor's control of the environment that constitutes the base of social power.' More specifically, power itself can be defined, Adam suggests, as the control that one actor exercises 'over some set of energy forms' which constitutes *'part of the meaningful environment of another actor';* having this power in his hands, A may submit B to his will.[89] Power, in other words, is a *tripartite* relationship. Human being A is superordinate to human being B due to his utilisation of the forces of nature C.

Now one can imagine modes of power in which the control over strictly physical, thermodynamic energy is at most of tangential importance – think of the spiritual authority a teacher wields over her students, or the psychological manipulation a man might use against his partner – but *in the sphere of production,* energy is what makes everything work, and so control over it will prop up power-as-domination. Indeed, *all* economic activities are ultimately a matter of energy conversion, be they manufacturing, transportation, construction, commerce or drilling: objects in the world can only be transformed, transferred, treated in whatever way by means of energy. At the points of large-scale commodity production, that universal force must be concentrated. The power of capital over labour is conditional upon control over it – particularly

over its mechanical forms, the ones that set the instruments in motion, without which all production would stand still. On this score as well, working humans are unlike woodpeckers, bonobos or any other animals, no matter how intricate the tools they construct: among humans alone, 'the unity between the motive force of labor and the labor itself is not inviolable,' in the words of Harry Braverman.[90] Beaver B fells the tree with her own motive force; she does not operate an instrument impelled by some external current of energy seized and delivered by beaver A. Due to this peculiar human capacity for energetic division, the idea might also arise – under certain historical circumstances – that living labour can be *replaced* by the dead labour of machines, answering mutely and exclusively to the masters.

The road to enhanced power over labour thus passes through nature, and resistance from B may curve back upon A, prompting him to dig deeper into C to preserve and expand domination: part of what occurred in the shift to steam. With the stock as a power at their command, capitalists inflated their power vis-à-vis workers; capital became *more powerful* in both senses of the term – as in 'a powerful explosion' and 'a powerful proprietor'.[91] By dint of their exceptional purchasing power, capitalists could buy steam engines and coal alongside slices of human lives over which they could then exercise reinforced power on the shop floor, in an original construction of the fossil economy neatly fitting into Adams's theory: the transition expressed 'an increase in control over the environment' indistinguishable from 'an increase in the power within the human system'.[92] Moreover, in the ensuing circuit of fossil capital, every unit of F *further increases* the power of capital insofar as it serves as a lever for surplus-value production. F is here fuel on a fire that progressively elevates some humans to powerful kings on the backs of others, in contrast to the sphere of fossil consumption: if you pay 500 euro for a long-haul flight, your action certainly induces emissions, but it does not in itself augment your future claims on the time and resources of other people (you have spent your money, not invested it). Only if combustion is a moment in the *accumulation* of capital – only if it plays its part in generating profit – will the actor possess renewed, expanded power to purchase and command human life at the end of the process.

In fossil capital, the consolidation of power at the top would then proceed in tandem with the dissipation of the stock. Contrary to fashionable conceptions of power as horizontally dispersed throughout society, the pattern here would be a vertical *centralisation* of power in the dual sense, followed by atmospheric diffusion of the waste products, the carbon trail an index of how far that process has proceeded (picture a smokestack). Can capital be taken to task for it, with the knowledge we now have? According to Steven Lukes, 'the powerful are those whom we judge or can hold to be responsible for significant outcomes,' even if unintended – indeed, unintended outcomes may be 'obvious *instances* of power'.[93] A chunk of the excess CO_2 currently in the atmosphere, yet to be quantitatively specified, might be regarded as a biogeochemical instantiation of the power accumulated/dissipated by capital. As for emissions originating in the sphere of production (with the Stalinist states within brackets), it would be difficult to judge any other party more directly responsible. A question of greater interest, however, is what light a theory of fossil capital might shed on our current predicament. But before we take it into the present, we need two more tours into the past.

A Brief Comparison with the American Transition

Our theory of fossil capital is modelled on the transition to steam in Britain: not a very broad or stable foundation for a general theory, however salient that single case might have been. We should have at least one more before we bring it any further. The second pillar of the fossil economy, responsible for more historical emissions than any other, is, of course, the United States. Can the theory be applied to its first dealings with coal? We have no room for a comprehensive inquiry here; a quick glance at some fundamentals will have to do.

Steam engines set foot on American soil at an early date, but were extremely slow in conquering the economy. Waterwheels provided the bulk of mechanical energy until after the Civil War; in terms of total industrial horsepower, steam edged them out only in the census of 1870, with 52 percent as against 48 percent – a national shift occurring some four decades later than in Britain. 'As valuable for manufacturing in the nineteenth century as the energy from petroleum is today,' water had several recognisable attributes: safe, familiar, found in tremendous quantities over enormous stretches of territory, cheap.[94] 'If it is simply a question of power, without reference to anything else, water power is cheaper, far cheaper,' said a comparison printed in *Publications of the American Statistical Association* in 1888; when the transition eventually took place, water remained way ahead of steam in this respect, its supplies far from fully utilised, including in the most heavily developed region of New England.[95]

Running water carried the cotton industry to the heights of American commerce. In 1850, a trifling 11.5 percent of the mills were steam-powered; only in the 1880s did the now spurting engines exceed 50 percent of hp and surpass the business model first developed at Lowell.[96] There, on the rapids of the Merrimack, a company of Boston entrepreneurs built dams, dug canals, bought land and constructed capacious reservoirs à la Greenock – there are signs of inspiration from Thom – renting the water to cotton capitalists, who availed themselves of the regular, cut-price flow. By the 1830s, such collective reservoirs were a common sight in New England. The Lowell model followed a pattern stretching back to the earliest days of colonisation, when waterfalls were perceived as ideal locations for settlements, the pioneers grouping around the primordial gristmill; in the early and mid-nineteenth century, land was still easily acquired and fresh factories attracted to the frontier sites *after* the design of water systems.[97] On the Irwell, Thomas Ashworth sought to unite 754 already well-established mills – many with lineages going back to the time of the Domesday Book – whose owners were locked in cutthroat competition. On the Merrimack and other eastern rivers, corporations could *first* develop the reservoirs through local monopolies catering for incoming investors, in a land and industry that still appeared empty.

But ere long disputes plagued the colony complexes. At Lowell, the director of operations – nicknamed 'the chief of police of water' – had to juggle the interests of the tenants, clamp down on managers overdrafting water or disturbing the supplies of their neighbours, answer to complaints and respond to requests for out-of-hour operations and, in general, superintend 'the aggressive, competitive, often demanding spirit of management in the textile corporations,' in the words of Hunter.[98] The more the industry grew, the tighter the competition, the greater the tendency to overproduction in the final decades of the century, the harder it became to keep manufacturers seated and still at the table of a shared watercourse; continued expansion required *closer coordination* at the very moment when internal rivalries sharpened. In the late year of 1894, Boston engineer Joseph P. Frizell published a paper in the *Transactions* of his corps lamenting the fashions of the day: 'How often do we hear it said that water-power has had its day. It is going out of use. It is being superseded by steam, etc.,' when in fact the American

rivers still waited for businessmen to profit from their cheap currents – if only they could let wisdom reign, if only large enough reservoirs were created and tight schedules for the release of water adhered to. There was only one catch to the solution.

> The construction of a system of storage reservoirs, or any similar enterprise, in the common interest of a number of mill owners, presupposes a concert of action and *a spirit of mutual concession and accommodation among the parties very rarely met with*. Mutual jealousies and bickerings over trivial points usually prove fatal obstacles to such projects.[99]

The anarchy of competition craved to be fossil.

As in Britain, many of the best falls tended to be found in places otherwise perceived as forbidding or unsuitable for industry: over time, a centrifugal dynamic evolved. In fierce debates over the two prime movers erupting in the 1840s and continuing for half a century, the spatial factor was constantly held against water. 'A man sets down his steam-engine where he pleases,' argued the *Scientific American* in 1849 – that is, 'where he is sure of always having hands near him, without loss of time in seeking for them'. One champion of water conceded that the advantages of 'a thickly populated neighbourhood' were often considered 'equal to the extra expense of steam,' while his opponent harped on the expenses of colony construction and pointed out how easily they could be evaded in seaports already filled with 'help' – another euphemism for workers – who 'gladly go into mills in their immediate vicinity'.[100] But only after the Civil War did such arguments acquire real urgency.

In the subsistence economies of the early American settlements, water was the perfect source of mechanical energy: close at hand, free of charge. A population sprinkled in agricultural enclaves, only tenuously connected by trade across long distances arduous to traverse, corresponded well to the distribution of streams. In the 1840s – and here the contrast to Britain could scarcely be sharper – most American manufacturing still occurred within the fold of this rural frontier economy. In 1840, a mere 10.8 percent of the population could be classified as urban (living in towns with at least 2,500 inhabitants), falling to 10.7 percent in 1860. Then urbanisation suddenly roared through the nation, the figure jumping to 28.1 percent in 1880.[101] In Hunter's analysis, *this* constituted the watershed moment: 'The accelerating concentration of manufacturing in cities was the principal factor in the drastic reversal of the status of water-power in the postbellum generation'; more than anything else, 'it was the *mobility* of steam power that brought about its adoption.'[102] Contemporary observers drew the same conclusion. In 1887, the president of the American Society of Civil Engineers looked back upon the prodigious increase of steam – between 1870 and 1880, total hp capacity rose by 80 percent as against 8 percent for water – and offered a simple explanation:

> A convenience of access to business and labor centers has tendered very largely to the increase of steam power. And although there are immense water powers yet undeveloped, and the cost of steam power is largely in excess of that of water power, yet *position and its relations* have decided in favor of steam.[103]

Position and its relations: a simple formula for abstract space.

The centralisation of the working population after the Civil War proceeded in lockstep with another, no less critical development, namely the formation of a truly integrated national market. Interlinked by trains and steamboats, the last vestiges of self-contained colonies now collapsed on one giant field of competition. Manufacturers could serve distant consumers through speedy

and punctual delivery: patience with seasonal flux was lost. A paper on the costs of steam power in the *Transactions of the American Society of Civil Engineers* in 1883 explained how farmers for centuries had dealt with failing water simply by switching to other tasks – harvesting in dry weeks, hauling logs before the snowmelt – and had succeeded in holding milling in abeyance without any financial damage. But 'such a state of things is not possible with the manufacturing interests of modern times. Large contracts are to be filled,' 'hundreds of thousands of dollars of capital are invested – the mills cannot be stopped if the owners hope to compete with others': hence the itch to take up steam.[104] A terrible drought gripped the northeastern and middle Atlantic states in 1879.[105]

Distinctly non-fossil up to the Civil War, the US economy never experienced anything like the long proto-fossil prelude of Elizabethan stamp. As late as in 1850, nine-tenths of the nation's heat was generated from wood, an abrupt shift to coal occurring only in the second half of the century *concomitant with the shift from water to steam* – even more pointedly than Britain, it was the engine that towed barges of coal to the fires.[106] The concrete conditions and conjunctures of the birth of the American fossil economy were thus unique, but the most important difference might have been strictly chronological: the *lateness* of the process, its essential *repetition* of what had already occurred in the homeland of steam. The basic contours were strikingly similar. In America as in Britain, capitalist property relations, with their peculiar spatiotemporality, cut the chains to the flow and chained self-sustaining growth to the stock.

The Elizabethan Leap and the Primitive Accumulation of Fossil Capital

In the final part of the first volume of *Capital,* Marx turns to the question of how it all began: where did the first M come from? To place a satellite in orbit requires prior assemblage on earth; to throw capital into the spiral of unremitting accumulation presupposes some initial amassment of money – what Marx describes as *'ursprüngliche* Akkumulation,' connoting origin and root.[107] The standard English translation is, of course, the infelicitous *'primitive* accumulation,' giving the impression of a crude and immature stage unrelated to the workings of advanced capital. Wary of that misleading association, we shall retain the generally accepted term. For Marx, it denotes a dual process of social rupture: on the one hand, the emergence of capital ripe for investment; on the other, the appearance of 'free' workers, disjointed from the means of subsistence and production and therefore available for wage labour – another word, then, for the historical divorce.

In analogy with this analysis, we have suggested that the circuit of *fossil* capital can only come about if another circuit, in which F is the output – the commodity produced for the market – has already been established. But to complete the analogy, we need to add a version of the second moment as well. Primitive accumulation of fossil capital is the process by which capital is invested in the production of fossil fuels *while at the same time dissolving the bond between the direct producers and the earth,* fencing off nature as private property, dispossessing farmers, hunters, herders, fishermen and others hitherto independent of the market, *contributing* to the creation and expansion of capitalist property relations. Where in history can we search for it? The obvious first candidate is the Elizabethan leap. For more than half a century, however, the dynamics of this takeoff in coal production have been read almost exclusively through the lenses of Ricardian and Malthusian thought. The point of departure for all discussions has been John Nef's two-volume *Rise of the British Coal Industry,* from which one sentence is often extracted:

> All the evidence suggests that between the accession of Elizabeth [in 1558] and the Civil War, England, Wales, and Scotland faced an acute shortage of wood, which was common to most parts of the island rather than limited to special areas, and which we may describe as a national crisis without laying ourselves open to a charge of exaggeration.[108]

Here is the source of the notion of a 'timber famine' in sixteenth-century Britain, compelling the nation to switch to coal as its main fuel for heat.

Now decades of research have proven that Nef was, in fact, guilty of exaggeration on this particular point. In the 1950s, historians pointed to evidence of stable or even *growing* forests: 'So far from there being a timber famine,' concluded one, 'it is abundantly clear that the supply of both timber and cordwood during the two centuries after 1550 was enormously increased with surprisingly little increase in prices.'[109] Then in 2003, Robert Allen presented the most comprehensive data so far on English and Continental fuel prices in the early modern era, showing an outright *fall* in most of England during the sixteenth and seventeenth centuries. Even the price of charcoal dropped in the run-up to the Elizabethan leap – the very opposite of what would have happened in a nationwide 'famine'. Most recently, W. Edward Steinmueller has reconstructed the productive potentials of English forests, yields, rents and prices: the average cost of wood hovered close to that of coal per unit of thermal energy up to 1700, and then coal became *more expensive*.[110]

But unlike in the shift from water to steam, there is, in this case, no smoke without fire. All the talk of a timber famine has *some* foundation in reality – namely in London. This particular city did suffer from a fuel crisis by the time of the leap. Wood prices shot up in the middle of the sixteenth century, lending coal a 50 percent discount over the following one hundred years; forests within the reach of the swelling capital – its population increasing tenfold between 1520 and 1700 – were denuded. The crisis Nef spotted was 'an urban bottleneck, not a systemic constraint,' writes Allen. Nothing like a nationwide dearth of wood, there was a concentrated 'explosion of demand in London,' the central node in an emerging world economy into which money and people flowed in copious amounts – a spearhead of abstract space.[111] Yet this does not diminish the fact that scarce and dear wood figured in the background. The metropolitan shift in relative prices had no equivalent – not even in or around the Cottonopolis – in the contest between water and steam in the 1830s or 1840s. Moreover, there are some indications of similar disequilibria on the local fuel markets in other rapidly growing English towns in the late sixteenth century, which may have converged into shortages of at least regional proportions.[112] Nef exaggerated, but he did not confabulate.

If the famine narrative made up one leg – somewhat shaky – in Nef's account, a second one has received far less attention. For a large-scale coal industry to see the light of day, the rules for ownership of the land and its contents first had to be rewritten. A lucky prospector would have to abrogate all other claims on the site, fence out various plebs who might want to continue using it and make sure it belonged exclusively to him – otherwise he would not invest his money, and there would be no extraction.[113] These were not the kinds of property relations that prevailed in England prior to the leap. But in 1566, eight years into Queen Elizabeth's reign, a royal court excluded all mineral resources except gold and silver from the *regale,* or the ownership and control of the Crown. With the stroke of a pen, coal deposits were transformed into *private property*.

Before the edict, however, it was not so much the Crown that impeded exploitation of the

stock as the church, whose holdings included most of the land where the great northeastern mines would soon open. It evinced little interest in expanding the industry. Coal from monastic pits was dug, sold and burnt, but only with poor equipment, in shallow seams and on a small scale, according to medieval routine. 'If the deeper seams, which alone could supply coal in large quantities, were to be reached, investments of many hundreds and even thousands of pounds were required,' Nef observed, but 'churchmen were *not disposed to invest large sums of their own* in mining, and they did not encourage their lessees to do so' – to the contrary, when the Bishop of Durham leased mines to a tenant, he imposed high rents, short terms and *restrictions on output,* guaranteeing that the enterprises would be puny.[114] Merchants were kept at arm's length. The bishops and monks were not dependent on the market for their reproduction, hence under no compulsion to increase productivity or reinvest surpluses; thriving on sword and cross, they could afford to stay aloof from subterranean riches.

But the Tudor state freed the soil and all that was in it from the stifling grip of the church. Starting with Henry VIII's moves towards Reformation, the Crown dissolved the monasteries and gradually confiscated their properties, including most of the mineral wealth of the kingdom – but not for itself to harvest. Following the edict of 1566, coal seams were thrown into the ballooning market for land transactions, either as nominal Crown holdings leased to tenants or as full properties of landlords, who might then exploit or lease them in turn. Rents were slashed, terms lengthened into century-long contracts, all output restrictions done away with; mining rights could now be bought and sold by investors with a *direct interest* in digging up as much coal as possible. Only by maximising production would they earn the profit necessary to recover their investments, keep hold of the lands and, preferably, purchase more. Unlike bishops and monks, landlords and tenants operated in insecure competition with each other and were under the *compulsion* to produce for the market; freed from the ecclesiastical yoke, moreover, they could pour capital into the depths of the mines, without fear of a sudden squeeze from above.[115]

Over the course of the sixteenth century, the Bishop of Durham lost all seams on the Tyneside to the merchants of Newcastle, who already knew how to live by the market. Their attitude to business was the opposite of that of the church, and while they had hitherto *traded* goods, they now began to *produce* the commodity of coal. *This* instigated the Elizabethan leap, in the 1570s and 1580s, right on the heels of the expropriation of the church and the privatisation of 1566. The pattern was repeated across the English coal districts: 'Throughout the country we find that it is in manors lost by the Church that the principal mining enterprises of the late sixteenth and early seventeenth centuries are started,' Nef noted, stressing how these transfers of property accounted for 'the remarkable expansion of the industry'.[116] Capital had been unleashed under the ground.

But what about the people *living* on the land? Suddenly, their houses and fields might sink into cavities. Cattle would stumble into unfenced shafts, grass turn poisonous, pits and machinery usurp space hitherto available for agriculture. Under customary law, tenant farmers were entitled to move cattle on commons, take wood and even coal for domestic use and roam freely across adjacent wastes – ancient practices that had to be terminated to allow commercial collieries to open. Until the middle of the sixteenth century, enclosures and expulsions were almost never inspired by riches underground, but after Elizabeth's accession to the throne, such motives came to the fore. Lords would simply appropriate land where they suspected that minerals lay buried. Several of the most high-profile enclosures of the early seventeenth century were undertaken to prevent any interference with extraction, and much like their sheep walk twins, the coal encroachments provoked furious resistance: in 1605, the freeholders and customary tenants of

the Earl of Derby's manor broke into the common land he had fenced in, carried away the coal, threw it in the bushes 'and filled up the pits, which they thought a menace to their cattle'.[117] The Sutton manor – later growing into one of the largest pits in Lancashire – had its enclosures pulled down sixteen times by freeholders who claimed 'common of pasture'. On what would become the Shropshire coalfield, local inhabitants waged a stubborn campaign to shut down the collieries, destroying gates, seizing machinery and stoning labourers, in a corner of a battlefield stretching across the country: 'Many were the obscure battles fought with pitchfork against pick and shovel to prevent what all tenants united in branding as a mighty abuse.'[118]

The Elizabethan leap took the form of persistent warfare against traditional ways of life in the countryside. 'Copyholders lived *in constant fear of the discovery of coal* under their land' and did all they could to thwart extraction, keeping seams secret, sabotaging searches, throwing earth into pits as fast as the colliers dug them out.[119] Not infrequently, the operators had to station armed guards at the shafts night and day: a wall of physical force around the budding proto-fossil economy. Already at this stage, landlords inclined to accumulate capital had secured the backing of a formidable state apparatus, thrashing the resistance in a thousand disputes; by the end of the seventeenth century, exclusive private property to coal-rich lands had been conclusively enforced, the customary tenants and commoners deprived of virtually all of their rights.[120] Far from *relieving* pressure on the land, the shift from wood to coal would have been received by the affected laypeople as a *withdrawal* of that most precious resource.

The result was separation. On the one hand, ownership of the stock – including ipso facto the surface above it – came to be concentrated in the hands of a few; on the other, the rise of coal contributed to the eviction of tenants and the general decline of peasant proprietorship in England.[121] In some regions, coal enclosures were paramount in divorcing the direct producers from the land: an underappreciated aspect of the centuries-long process generating the distinctive social structure of this country. Here was the sine qua non of the proto-fossil and fossil economy. In 1708, a writer hiding behind the initials J. C. published *The Compleat Collier: Or, the Whole Art of Sinking, Getting, and Working, Coal-Mines, &c., as is Now Used in the Northern Parts, Especially about Sunderland and Newcastle,* one of the first mining manuals ever written. The aim of the text was to incite owners of estates with coal, extending to them a very private carrot. 'If Incouragement (or Profit) were not allow'd to the Adventurers, what would those Persons do to live,' J. C. asked, going on to state that '*if no Profit can be raised, I see no Reason why any Man should Adventure his Money*.'[122]

Thankfully, profits from collieries were generally handsome in the late sixteenth and early seventeenth centuries, often above 40 percent, sometimes as high as 130 percent. Indeed, so successful was this accumulation of capital that the coal industry came to suffer from *overproduction* in the second half of the seventeenth century, when demand flattened out while mines continued to be dug: markets glutted, prices falling.[123] Such ailments were sure signs of a supply-driven process. The shift from water to steam and the rise of the fossil economy were, as we have seen, called forth by demand; the Elizabethan leap and the inception of the proto-fossil economy likewise had their demand component – after all, profits were possible because coal had become a subsistence commodity in London and other urban markets – but were fundamentally realised through truly revolutionary transformations on the supply side. 'Only in Great Britain', observed Nef, 'were the rights of the landowner to all minerals, except gold and silver, made absolute'.[124] That principle had no precedent or analogue anywhere else in the

world. In post-Song China, for instance, the state maintained full control and stamped out private mining of coal.[125]

Although merely scratching the surface, this reinterpretation of the Elizabethan leap allows us to flesh out a theory of the primitive accumulation of fossil capital. The leap constituted such a process by 1) initiating the accumulation of capital through the provision of F to the market, 2) having its origins in the expropriation of land and the conversion of the stock into private property and 3) spreading and consolidating capitalist property relations. It laid the foundation for the subsequent rise of the fossil economy by filling the markets with coal *and* by furthering the very relations that eventually made the turn to steam exigent. Indeed, the case can be made that abstract space and abstract time germinated in the early mines: domestic fuel from the stock made possible the unparalleled enlargement of British towns – the sites where 'easily procured' labourers would congregate – while mining introduced an element of dark and dead, unresponsive, aeonian and therefore uniform time into the economy. Unlike most if not all other sites of labour, the pits had no rhythm of their own; wage-earners were sent into their recesses to dig coal during specified hours, for delivery to distant customers with detached schedules.

Once fossil capital had been born, it required constant nourishment from the prior circuit. The pursuit of the general formula of fossil capital (M – C (L + MP (F))…P…C′ – M′) presupposes incessantly rolling primitive accumulation (M – C (L + MP)…P…C′(F) – M′) – or, in simpler terms: for capitalists to burn fossil fuels, there have to be other capitalists specialised in their production, and for the former to burn more, the latter have to deliver it in greater quantities, the two cycles ever intertwined. In the strict sense of a circuit, primitive accumulation of fossil capital is a *permanent foundation for the fossil economy*. As a *political* process, it has reiterated the ordinances of the Elizabethan leap in countless instances over the past two centuries: from the Arabian peninsula to the Ecuadorian rain forests, expanding extraction of fossil fuels has come about only through expropriation of the land and its riches, annihilation of resistant state structures and customary rights, dispossession of local inhabitants, expulsion into shantytowns – a history very much written 'in letters of blood and fire'.[126] Conditional upon the power of capital, the process cements it at every step, first and foremost by extending *exclusive capitalist control over nature*. If there is a faint trace of Ricardian-Malthusian dynamics in the Elizabethan leap, it disappears completely in the more recent iterations – as is well known, the history of petroleum has until very recently been one of overproduction – entirely different factors driving the rigs and drills into the soil. Shell did not go to the Niger Delta because the British population no longer could subsist on plants.

Capital does not eat because someone is hungry: *capital always eats*. The ecological voracity of this relation-in-process cannot be captured by a model of substitution and relief, precisely because it is not embedded within the natural limits of ecosystems. It operates on a higher level, above that of use-value, in the thin, abstract air of exchange-value, and just as it must pump out surplus labour in perpetuity, so it must pump out material substrata from the ground *whether or not they are scarce*. Capital is supra-ecological, one could say: a flying biophysical omnivore with its own peculiar social DNA. It is not a timeless growth pursuit bumping into walls of shortages and transcending them by moving on to abundant goods, not a universal process unfolding through reaction upon specific constraints. Rather, it is a *specific* process unfolding through a *universal* appropriation of biophysical resources, insatiable in its appetite, starting and ever continuing with energy.

CHAPTER 14

China as Chimney of the World: Fossil Capital Today

An Emissions Explosion

On 12 May 2014, the *New York Times* reported that 'a large section of the mighty West Antarctica ice sheet has begun falling apart and its continued melting now appears to be unstoppable.' That would mean at least three metres of sea level rise in the pipeline. The findings were published by two independent teams in *Geophysical Research Letters* and *Science:* the latest additions to an endless background noise of ringing tocsins. Glaciers running from inner West Antarctica towards the Amundsen Sea have hitherto been held back by ice shelves, functioning like plugs in a bathtub, but the warming oceans are transporting more and more heat towards the continent, melting the shelves and pulling the plugs. The balance of forces overturned, the tub is draining, the glaciers unhinging from the ground, no hills or ridges preventing them from sliding into the sea.[1] 'Today we present observational evidence that a large sector of the West Antarctic ice sheet has gone into irreversible retreat,' one of the lead authors said in a press conference called by NASA: 'It has passed the point of no return.' A couple of centuries would likely be necessary for all of it to reach its destination, but, the *New York Times* noted, even 1.2 metres would suffice to inundate land on which nearly 4 million Americans currently live. What is more, continued emissions of greenhouse gases would initiate the same processes on the even larger ice sheets of East Antarctica and Greenland. 'If we have indeed lit the fuse on West Antarctica, it's very hard to imagine putting the fuse out,' commented Richard B. Alley, expert in the field – 'but there's a bunch more fuses, and there's a bunch more matches, and we have a decision now: Do we light those?'[2]

On the very same day, the *New York Times* reported that 'Canadian oil companies are proposing many new and expanded pipelines that would connect the oil sands fields with new markets in China and across the world.' Not beaten by the delays in the Keystone XL project, designed to transport oil from the tar sands region of Alberta through the United States all the way down to Houston, the companies were planning pipelines that would snake towards the Canadian coasts, both eastern and western, from whence oil could be ferried to combustion in, above all, China. Oil sands production would climb by more than a fourth in the next decade, even without Keystone XL. Several companies would double or triple their output. Not since the

1950s had so many pipeline projects been on the table. They faced diverse resistance – from First Nations, environmental activists, local communities worried about the spoiling of scenic views – but the vice president for oil sands at Shell Canada stated their compelling rationale: 'For us, for future investment, it's pipeline,' he told the *Times*. 'We want more capacity. Long term, we need to see access to global markets.' The government risked 'violent confrontations' if the most controversial projects were implemented, but the prospects for most of them, the *New York Times* concluded, 'appear bright'.[3]

Counting from 1751 to 2010, half of all CO_2 emissions from the combustion of fossil fuels occurred after 1986, in just twenty-five years, when one of the greatest research efforts in history produced the science of climate change.[4] The turn of the millennium marked another crossing. Widespread awareness of the catastrophic implications of global warming essentially belongs to the twenty-first century, and since the year 2000, the rate of growth in CO_2 emissions has been triple that of the 1990s. Not because of any climate policies, but due to the crash in capital accumulation, emissions shrank – a truly extraordinary event – by a little more than 1 percent in 2009, only to rebound in 2010 with a near 6 percent climb and then stabilise around the annual average of 3 percent. Exceeding the worst-case scenarios developed by the IPCC, that novel clip of business-as-usual puts the world on track to a rise in temperatures of 4 degrees by 2060, far beyond the level to which humans can be expected to adapt with any reasonable sense of civilisation intact.[5] Things are out of hand. We may legitimately speak of a post-2000 *emissions explosion*. A theory of fossil capital should have something to say about it.

Two basic facts about the explosion immediately strike the eye. First, it has been centred on a single country: the People's Republic of China. Between 2000 and 2006, 55 percent of the global growth of CO_2 emissions happened there; by 2007, the figure stood at *two-thirds*. In 2004, China became the world's largest extractor of fossil fuels; two years later, it eclipsed the US as the top emitter.[6] Second, the explosion appears to stand in some relation to globalisation. From the early 1980s up to 2008, world trade grew by 8 percent per year – markedly faster than output – but the true novelty lay in booming foreign direct investment (FDI): from the 1980s onwards, FDI flows increased faster than cross-border trade; from 1990 to 2009, they quintupled, reaching a peak before plummeting during the financial crisis and then rebounding. As it happened, this tendency was also centred on China. The main destination for FDIs, the country's inflow in 2008 was nearly twice those of Russia and India combined; two years later, China deposed Germany as the top exporter of manufactured goods.[7] Beyond those well-known figures, what has been going on here? What combustible mix of China and globalisation has set off the emissions explosion, whose power to light a whole bunch of fuses on earth seems little short of overwhelming?

An Explosion for Export

The baseline of the bourgeois ideology known as eco-modernism is a belief in more affluence as the remedy to ecological woes: if only people were modern, high-tech and sophisticated enough, there wouldn't be so much pollution around. More precisely, countries follow the environmental Kuznets curve (EKC). Poor and underdeveloped, they leave little imprint on the environment; as their incomes begin to grow, so do their impacts – but only up to a turning point, after which increasing wealth *reduces* environmental degradation, pushing it back towards the point of departure. Having passaged from neutral agriculture and dirty industry to clean services, the most

advanced economies end up with populations prosperous enough to care about their surroundings, efficient technologies, responsible institutions: all that is needed to tread lighter on earth. Others ought to travel that royal road. The best way to open it is to promote globalisation – or so runs the argument in force since the early 1990s, when the idea of the EKC emerged in debates over NAFTA and economist Wilfred Beckerman summed up its political traction: 'There is clear evidence that, although economic growth usually leads to environmental deterioration in the early stages of the process, in the end the best – and probably only – way to attain a decent environment in most countries *is to become rich.*'[8]

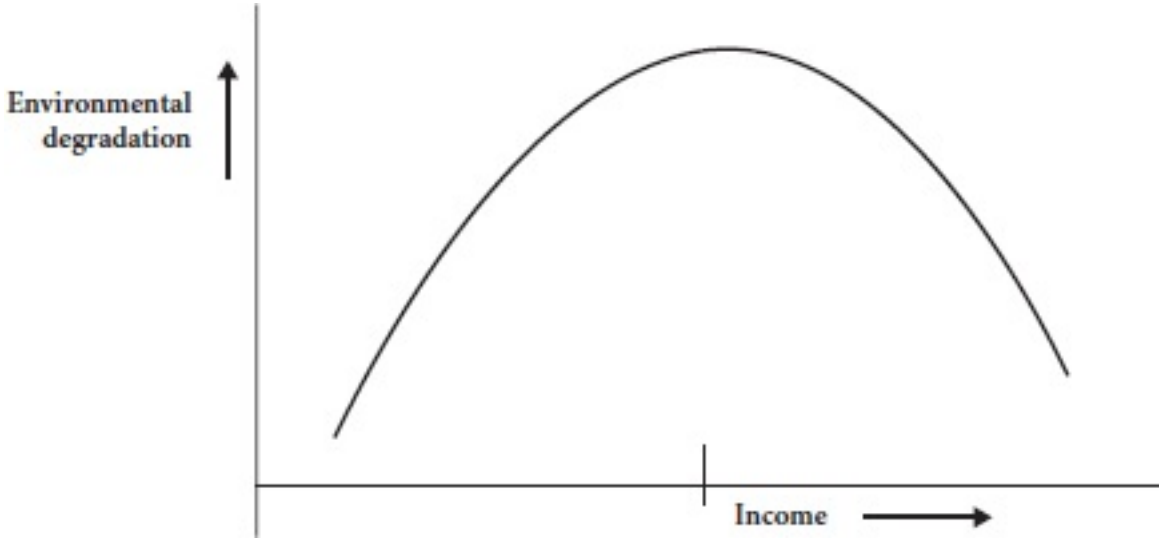

Figure 14.1. The environmental Kuznets curve.

Now, decades of research have produced scant evidence for the existence of any EKC in perceptible reality. As for carbon dioxide, there is one variable that seems to follow the curve: the *intensity* of pollution, or the amount of CO_2 released *per unit of production*. But what counts for climate is, of course, *total* emissions, and for that critical measure, there is no downward turn, only a secular rise with income.[9] (Yet intensity might be a central variable in the emissions explosion, and so we shall return to it below.) Moreover, the EKC can be faulted for overlooking precisely the globalised nature of the world economy. The carbon footprint of a smart, tech-savvy, happy-go-lucky art director is not a function of what he produces, but of what he *consumes,* much of which will be imported from other nations still doing the dirty work of manufacturing. There are absolutely no indications that people at the right end of the income axis cease to purchase laptops, smartphones, shoes, jeans, cars and long-haul flights and revert to hermitic asceticism. To the contrary, the ecological burden of their existence grows without fail – only it is being off-loaded to distant producers, to which it then *seems* to belong.[10] The lightness of the MacBook Air crowd is an illusion grounded in myopia.

In the case of CO_2, most emissions associated with a commodity originate in the process of production, not final consumption: a Swede does not emit CO_2 by wearing a T-shirt from Bangladesh. It has already been emitted from the factory where the T-shirt was sewn and the power plant providing the electricity by the builders and machine-makers and those further back in the supply chain, forming a sequence of emissions – an invisible legacy of the burnt

accessories – *embodied* in the commodity. The actual volumes of CO_2 caused by the importing consumers may thus stretch far beyond the borders of their homeland. Indeed, the tendency of late has been for more CO_2 to be discharged in the production of commodities ultimately consumed in a different country: in 1990, 20 percent of all emissions; by 2008, the share had grown to 26 percent.[11] Official statistics, on whose basis climate negotiations are conducted, still allocate emissions to the territorial states where the smoke actually leaves the ground. But why should Bangladesh be held accountable for CO_2 released for the benefit of Swedish T-shirt wearers? Catching up with the growth of 'emissions embodied in trade' (EET), a rising chorus of researchers, activists and politicians from certain countries advocate a reallocation of responsibility, a shift from production-based to consumption-based accounting, which would provide a more realistic picture of *'how* and *why* human actions affect CO_2 emissions'.[12] In plainer language: do not let the well-off Westerners get off that cheaply.

Again, China is at the centre of both the phenomenon of EET and the ensuing pointing of fingers. In the period 1990–2008, fully 75 percent of the growth in emissions imported to Annex B – the developed countries with obligations under the Kyoto protocol – emanated from the People's Republic. In 2001, China entered the WTO, dismantled the remaining barriers to investment, abolished restrictions on foreign ownership, relaxed requirements on local cooperation and, in general, flung the gates wide open: then the real explosion began. While a third of the increase in Chinese CO_2 between 1990 and 2002 could be directly attributed to export, the share rose to *half* in the following three years; moreover, according to one estimate, as much as 48 percent of the country's *total* emissions between 2002 and 2008 were generated in the export sphere.[13] Here was the main source of the plume of smoke shooting up from Chinese territory. Other drivers were comparatively puny: for the years 2002–5, population growth and 'changing lifestyles' contributed 2 percent and 1 percent of the emissions growth respectively, government expenditure and household consumption 7 percent each, in contrast to the roughly 50 percent of export production.[14] No other part of the early twenty-first-century Chinese economy came close to the eruptive dynamism of this sector, and then its indirect stimuli on infrastructure and consumption are not even counted.

The mountains of Chinese commodities mostly ended up in developed nations. While China was the main exporter, the US was the main importer of embodied emissions, swallowing ever-greater volumes, net imports increasing by 250 percent from 1997 to 2007. For the EU, the corresponding figure was 154 percent.[15] Some countries in Western Europe like to believe that they have climbed the summit of the EKC and entered the descending slope, but that self-image is based on production-based deception, for imports have been rising higher and faster. In terminology stemming from debates over the Kyoto protocol, such displacement of emissions is known as 'carbon leakage': at an early stage of climate negotiations, fears arose that if only some countries – those in Annex B – would be covered by mandatory reductions, dirty activities would simply move out. A car manufacturer seeking to emit unlimited amounts of CO_2 could relocate to an unfettered country outside Annex B, such as China; a country wishing to reduce its emissions could import products instead of producing them.

But no carbon leakage of that kind has in fact occurred. No mass flight from Annex B countries could possibly have been triggered by draconian emissions cuts, for no such cuts have been implemented. A distinction is therefore made between 'strong' and 'weak' carbon leakage. The strong variety is the – so far hypothetical – departure of production activities *caused by*

stringent climate policies. The weak is the phenomenon of them leaving *for some other unspecified reason*. Here mainstream research into EET suddenly halts. One team notes that 'the likely cause of the large emission transfers we report here are pre-existing policies and socioeconomic factors that are unrelated to climate policy itself,' but stops short of asking the next natural question: then *what are* these causes?[16] If car manufacturers do not move their factories to China to escape climate change mitigation, *why do they do it?* For all its merits, EET research has not been able to identify the causal drivers at work; precisely when it comes to explaining '*how* and *why* human actions affect CO_2 emissions,' it limits its field of vision.

There is another, related trouble with the framework. Negating the EKC, it tends to jettison the moment of production and lay all its emphasis on consumption. Thus we may read that the proportion of emissions stemming from exports 'is large and significant, which demonstrates China's position in international trade as a "world factory". Those who *consume* the goods made in China should also share the responsibility.'[17] Now contemplate that statement. China is a world factory, emitting a lot of CO_2, and those who *consume* the goods should assume responsibility for them. Is not someone missing from the picture here? What emerges from the consumption-based accounting approach is a view of the Western consumer as an absolute sovereign who sends CO_2 packing to other parts of the world, presumably by standing in front of shelves and picking cheap Chinese commodities rather than expensive domestic ones, the owners of the means of production being neutral, passive, out of sight.

When consumption is treated as a generic Western activity, the argument has the potential to go seriously astray. Studying the embodied emissions in US–Chinese trade, one group of researchers argues that 'workers making goods in the developed world enjoy comparatively lavish lifestyles versus their counterparts in the developing world, a lifestyle which in many cases *induces substantial environmental impact.*' Chinese emissions are 'dominated by the manufacturing of products consumed *by workers*'.[18] Making up the majority of American consumers, they – the workers – should assume responsibility, and this is indeed implicit in much of the research in the field: CO_2 from China falls on the shoulders of ordinary people in the West. No differentiation is made between rich consumers and others – in a premise about as unrealistic as the original EKC curve – and while it is of course undeniable that workers in advanced economies benefit from cheap Chinese commodities bought at Walmart, Tesco or Ikea, putting the blame on them is not very convincing as a science of *why emissions have relocated to China*. American or other Western workers never made the decision to outsource manufacturing. In fact, if there is anyone who has ever resisted such moves, it is they. Neither the EKC nor its standard negation can make sense of the nexus of emissions and globalisation as it has materialised in China. A negation of the negation might do the job better.

Globalised Fossil Capital

The theory of fossil capital outlined above suggests that the stock is the general lever for surplus-value production. On its basis, we may propose a simple hypothesis for the era of globalised production. *Globally mobile capital will relocate factories to situations where labour power is cheap and disciplined – where the rate of surplus-value promises to be largest – by means of new rounds of massive consumption of fossil energy*. The transition is by now a distant memory; it is all a matter of pursuing the spiral.

What do we mean by 'globally mobile capital'? We mean, first of all, industrial capital free to invest across national borders and capable of carrying production technology to the new locations. Capital from source country A is globally mobile if it may construct factories (greenfield investment) or buy companies (mergers and acquisitions) in host country B, and if it can bring machines, technical expertise, management principles and other key assets from A to B – and, of course, if B is flanked by a range of other, similarly available host countries. As the world economy has developed since the 1970s, these conditions have been progressively realised. They imply that capital can transcend borders with roughly constant levels of productivity – or, put differently, the productivity of a transnational corporation (TNC) is a firm-specific asset, something it owns and can insert into the host country regardless of the average levels of productivity attained there.[19] But this only holds – and as we shall see, the distinction is crucial – for immediate production technology, while not for *infrastructure*.

Mobility of this kind represents a foray deep into abstract space: on a quest for optimal profitability, capital roams the earth more freely than ever before. Labour, on the other hand, remains relatively place-bound. Since it is tied to living human beings, with their own neighbourhoods, dialects, memories, families, habits, friends and bars and political parties and innumerable other life components, the commodity of wage labour cannot become mobile like capital (even if there were no pass controls and walls obstructing migration). As time goes by – as capitalist development unfolds in history – workers develop distinctive features anchored to their places of habitation. In one locality, they build up powerful unions enabling them to push up wages, while in another they remain barely organised; some are highly educated, while others have only basic schooling; some are prone to political militancy while others are under the sway of preachers of patience. Wages, skills, manageability and other properties of labour power vary in space: the inextinguishable autonomy of workers gives rise to a rugged, uneven, never fully stabilised geography of class relations. It follows that 'mobility is not a luxury for capital, but a necessity,' in the words of Storper and Walker. Because working-class communities are 'not as plastic, or are less geographically mobile than capital, labour forces must be sought out, fought with and, on occasion, abandoned by industry in its ceaseless process of evolution and restructuring.'[20] On this view, the production of abstract space is not a capitalist monologue but a way of staying one step ahead in the class relation, bolstering the freedom to evade, approach and parry labour from an outer rim of circulation.

When capital has secured its liberty to prowl the globe with portable productivity, it chooses between potential host countries on the basis of *their* specific assets. One profoundly nation-specific endowment is precisely labour power: as capital moves around, it will attach great weight to the national characteristics of the labour supply. It will look for cheap labour: places where labourers are easily procured. It will look for workers amenable to discipline, accustomed to high labour intensity and long working days: a population trained to industrious habits. A favourable combination of these factors will sustain a high rate of surplus-value and ceteris paribus entice TNCs to invest; conversely, if labourers become dearer and more rebellious, TNCs will *move out* of such places. The simplest indicators of high rates of surplus-value are low labour costs, commonly and roughly translated into low incomes, and hence it follows that industrial production will *tend* to move from nations with higher average incomes to those with lower ones – not in a complete evacuation from the former, but in a process of relative relocation.[21]

But things are not, of course, that simple. Features of labour power are an independent

determinant of FDI flows, but far from the only one. A TNC might, for instance, wish to position itself in the midst of a market, serving customers face-to-face in order to better adapt products to their tastes, inflate the value of a brand or excel competitors in some other way: here it is the consumers of the country, not the workers, who attract investment. But if the TNCs *export* their products from the host country, we have reason to suspect that it is the workers – not the consumers – who have enticed them to set up shop there. Labour might figure in a market-oriented strategy as well – a country offering both moneyed consumers and inexpensive workers is a particularly good choice for production in situ – and foreign affiliates may switch between selling to local and external outlets, but as a general rule, export-oriented FDIs are more strongly determined by the attributes of labour power.[22]

In the abstract space of a globalised economy, customers can be served from practically anywhere; sites of production can be dissociated from sites of consumption; capital may pick and choose between export platforms – and the lever by which it reaches and exploits labour is fossil energy. More precisely, there are three moments by which enhanced mobility draws on the stock. A necessary condition for labour power to be cheap and disciplined is, to begin with, the presence of a reserve army of labour: full employment dilutes both qualities. From the classic case of Britain, we may surmise that the best place to find a sizable reserve army is an economy in the throes of the passage from agriculture to industry; a whole new labouring population will be released for procurement, as ex-farmers leave their villages en masse and congregate in towns. But a country experiencing this passage also, in all likelihood, undergoes the transition to a *fossil* economy. To the extent that inflowing capital expedites this process, it extends business-as-usual to places where it did not exist before, other than in undeveloped forms: an *expansion* of the fossil economy accompanies the relocation of production. CO_2 will be exhumed from the chimneys of foreign-owned factories – perhaps in surroundings that until recently were rural, even pristine – but more importantly, the arrival of foreign capital will stimulate enlargement of the *infrastructure* of the host country.

No capital would flow to a place where it would have to establish all infrastructure from scratch. After all, the physical presence of property-less workers can never be a sufficient condition for attracting investment; rather, they will only be de facto accessible for surplus-value extraction if a basic infrastructure is in place prior to arrival – first and foremost, power plants and electricity grids capable of delivering the indispensable *energy*. Cheap and disciplined workers in the darkness and standstill of constant outages would not be of great value. The TNCs must be able to rely on an energy substratum upheld by the host country's state apparatus and count on its capacity to absorb more inflows.[23] Conversely, an item high on the agenda for states wanting to attract FDI – and in the globalised economy, that is the holy grail of development – is construction of infrastructure, and so we should expect a positive feedback loop: operational plants and grids, mines and wires are prerequisites for TNCs to invest; their arrival will encourage further enlargement, which will in turn draw more FDI, and so on. We may identify this moment of the dynamics as *the expansion effect*.

A second moment concerns emissions intensity. In general – and this is the consolation prize for the EKC believers – wealthy nations do have lower carbon intensity than poor ones: more CO_2 is emitted in the production of one T-shirt in Bangladesh than if the same T-shirt were to be produced in Sweden. Between the early 1970s and the early 1980s, a curve really did appear for developed countries, their continuing ascent towards ever greater affluence coevolving with a decline in carbon intensity – that is, a decline in CO_2 emissions per *unit* of production, not in

total amount of emissions.[24] At the end of the day, such 'progress' is of little importance, but now consider a capitalist who is about to reinvest his profit and expand the scale of production. Suppose that he can choose between two countries to invest in: his homeland A and a potential host country B. Suppose, further, that the carbon intensity of production is twice as high in B. We can easily see, then, that if he bets on B, total CO_2 emissions from his expanded business will be twice as high as if he stayed at home: the increase in scale will be compounded by a jump in carbon intensity. If this simple example is stretched out temporally, we may add the assumption that carbon intensity declines simultaneously and equally in both countries, with the gap between the two unchanged; even so, a move from A to B would push up the intensity of production relative to a scenario of staying put. In these cases, the expansionary logic of capital accumulation would not only trump the decline in carbon intensity, as in Jevons's paradox, but rather be realised *through a concomitant relative rise in carbon intensity* – and needless to say, that would be all the worse for the CO_2 concentration in the atmosphere.

There are some intuitively appealing reasons for why carbon intensity should be lower in high-income than in low-income countries. The former will likely possess the most advanced and efficient technologies for power generation and transport; propped up by well-endowed governments, relying on high wages for tax revenues, their infrastructure will generate low amounts of CO_2 per unit of electricity supplied or good delivered. In developing nations, infrastructure will indeed be less sophisticated. Power plants will use suboptimal equipment and the cheapest available fuel. The scramble to expand infrastructure to keep pace with development will induce governments to set considerations other than costs aside; indeed, inward FDI may incite them to embark on crash programmes for augmenting capacity for power generation, with whatever equipment is at hand and the least expensive fuel mix.[25] While TNCs carry along their firm-specific production technologies, they have no choice – and no other interest – but to utilise the infrastructure on offer: here, they will take what they find. Hence there emerges an environmental Kuznets curve *in reverse*.

If we insert the premise of globally mobile capital into the EKC – vastly enhancing its realism – we are led to the prediction that, when a turning point in income levels has been reached, capital will move *back to countries near the peak of carbon intensity*. It will not move to the poorest countries, for there the infrastructure will be inadequate. Neither will it stay in the richest, most carbon-efficient countries, for there rates of surplus-value will be low: instead, it will hover around the apex of the curve, *increasing carbon intensity through relocation*. If high incomes and low carbon intensity form a single package, as they seem to do, and if low incomes and high carbon intensity are their mirror compound, then a rise in incomes – equivalent to a rise in wages – will, given that capital is globally mobile, cause a shift of industrial production to more carbon-intensive countries – not because capital desires such intensity for its own sake, but because it is thrown into the bargain when it scours the globe for maximum surplus-value. We may call this second moment *the intensity effect*.

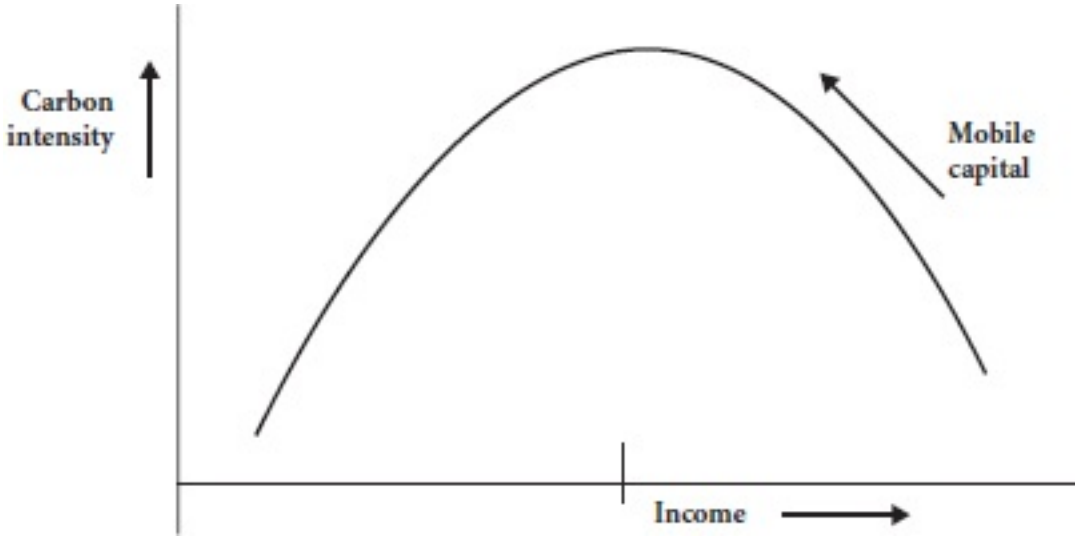

Figure 14.2. The environmental Kuznets curve in reverse.

Thirdly, energy infrastructure is, again, not a sufficient condition for realising the promise of inexpensive, submissive workers. If they are disconnected from major arteries of transport, the commodities will not reach the world market smoothly and perhaps not at all, making their labour power, for all pecuniary purposes, worthless. There have to be rails, highways, containers, warehouses, ports; likewise airports to ferry raw materials, components, finished goods, managers, CEOs between affiliates, markets, factories and headquarters. Since modern transport systems are almost completely reliant on oil, globalised production will translate into larger emissions of CO_2 in this sphere as well: the more fragmented and integrated the circuits, the more extended and dispersed the supply chains, the more petroleum will be burnt on the road, on the sea, in the air. As in the expansion effect, the TNCs will balk at constructing the requisite transport infrastructure and look to the state to ensure it, and needless to say, this imperative will be particularly compelling when the corporations *export* commodities from the host country.[26] This third moment might thus be designated *the integration effect*.

Combining the three moments – expansion, intensity, integration – we arrive at a more precise version of our hypothesis. Here are the dynamics through which globally mobile capital will speed up the consumption of fossil energy *through* its perpetual drive to maximise surplus-value. The environmental Kuznets curve in reverse might stand as a general metaphor: since conditions for accessing cheap and disciplined labour power tend to be bound up with expanding business-as-usual, comparatively high carbon intensity and increased transport, capital will shoot its arrows upwards and backwards, towards the summit of degradation. While not, of course, covering *all* emissions growth, we have here a key to the explosion.

The Chimney of the Workshop

Globalisation is no longer driven primarily by trade. In 2011, the Vale Columbia Center, a leading FDI research institution, declared that 'international investment has become roughly twice as important as trade in delivering goods and services across frontiers.'[27] By the time the financial crisis struck, 'emerging markets' had decisively surpassed developed countries as

receivers of FDI; among them, China outshone all others. Where did the capital come from? The circulation of FDI money through Hong Kong and various tax havens – notably the Virgin and Cayman Islands – before touching down on the Chinese mainland made it notoriously difficult to pin down its origins, but a trend manifested itself after the WTO entry: while neighbouring Asian countries had been the preeminent provenances of FDI in the 1990s, flows from the US and the EU now took off. China became the home for factories relocated from all over the globe; according to one study of the years 2001–4, the US was the number one country of origin for immigrating industry, followed by the EU, Japan, Taiwan, the Philippines, Canada, Singapore and Mexico.[28] For the first eleven months of 2010 – when the tax havens had largely succumbed to the effects of the financial crisis – the Chinese Ministry of Commerce reported the following list of top ten FDI sources: Hong Kong, Taiwan, Singapore, Japan, the US, South Korea, the UK, France, Holland and Germany. Industrial capital settling on Chinese soil had a propensity to *export*. Over the years 1998–2005, 19 percent of domestic manufacturing firms were exporters, as against 63 percent of foreign affiliates.[29]

The secret behind this surge in foreign-financed, export-oriented production was never very well kept. In October 2004, *The Economist* affirmed that the ascent of the People's Republic was safeguarded by its 'almost unlimited supply of cheap labour. By some estimates, there are almost 200m under-employed workers in rural areas that could move into industry. This surplus labour may take at least two decades to absorb, helping to hold down wages for low-skilled workers.'[31] Figure 14.3 shows how Chinese manufacturing wages compared to those of some other countries in 2002.

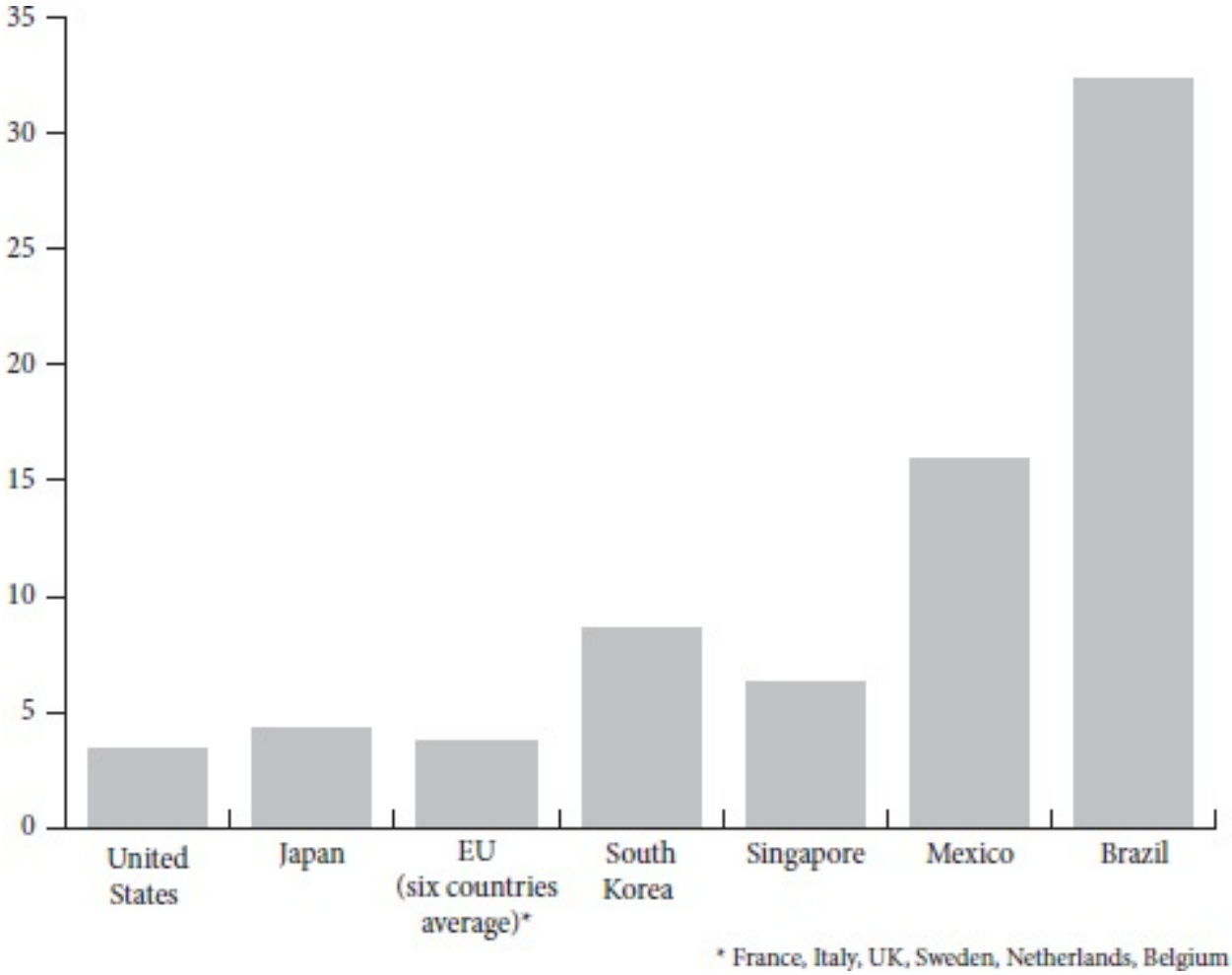

Figure 14.3. Chinese manufacturing wages: average in 2002 as a percentage of the average in selected countries.[30]

As predicted, the relative wages barely rose at all during the first decade of the century, the cost of labour power remaining a trifle of that in developed countries: in 2008, hourly labour compensation costs in China were 5 percent of those in Japan, 4 percent in the US, 3 percent in the eurozone.[32] It was an immensely powerful magnet. One 2006 survey asserted that 'low-cost skilled labor has long been regarded as China's most important advantage in attracting foreign companies to make goods in China'; furthermore, 'Chinese workers are not only cheap, but diligent, motivated to improve, and good with their hands.' In the words of another study, employers in the early twenty-first century became 'accustomed to having a seemingly unlimited supply of very cheap labor, and being able to insist on certain qualities in their workers,' such as 'a compliant and flexible personality, and the willingness to work very long hours'.[33] Easy to procure, trained to industrious habits.

The force that weighed down on Chinese workers and imposed on them these characteristics was, at the bottom, as explicated by *The Economist,* the gargantuan reserve army of labour. Bent on fast-tracking industrialisation, the post-Maoist state released – to interpret it benevolently – hundreds of millions of young farmers from the countryside into the cities. But the 'floating population' retained one foot in the villages, falling back upon traditional sources of income in need, reducing the reproduction costs of labour power; inside the cities, meanwhile, attempts at

independent union organisation were nipped in the bud, the working class subdued and delivered to foreign investors.[34] The Chinese export miracle would not have come about without their presence. In the 1980s, foreign-invested enterprises (FIEs) – that is, either joint ventures or wholly foreign-owned companies – produced a meagre 0.1 percent of the goods exported from China. In 2001, the share exceeded 50 percent for the first time, and it stayed above that mark throughout the decade.[35]

Other methodologies produce even higher figures: foreign affiliates might have accounted for more than 70 percent of total Chinese exports in 2005.[36] From 1990 to 2008, China's industrial output increased by a factor of 26; that of FIEs by a factor of 332. Here was the impellent of capital accumulation in the People's Republic, running on high and rising profits, outshining domestically owned companies in technical prowess as well as in revenues. On the basis of figures similar to the above, *The Economist* argued that the export growth 'has more to do with foreign firms relocating their production to China than with Chinese businesses undercutting other producers'.[38] The conclusion can be extended straight to the atmospheric legacy, inverting the causation implied by the consumption-based approach: the main agents behind EET were not consumers in the West, but *owners of firms relocating their activities*. Decisions on boards of directors preceded and shaped those in front of shelves. Cheap and disciplined labour power was not, of course, the sole attractor in China; the huge domestic market had its own distinctive allure – but for capital moving to China and *exporting* its commodities, the characteristics of labour power must have exerted the stronger pull. Given the role of FIEs in Chinese exports, and that of exports in Chinese emissions, we may thus infer that the quest for maximum surplus-value was indeed a paramount mechanism for igniting the explosion.

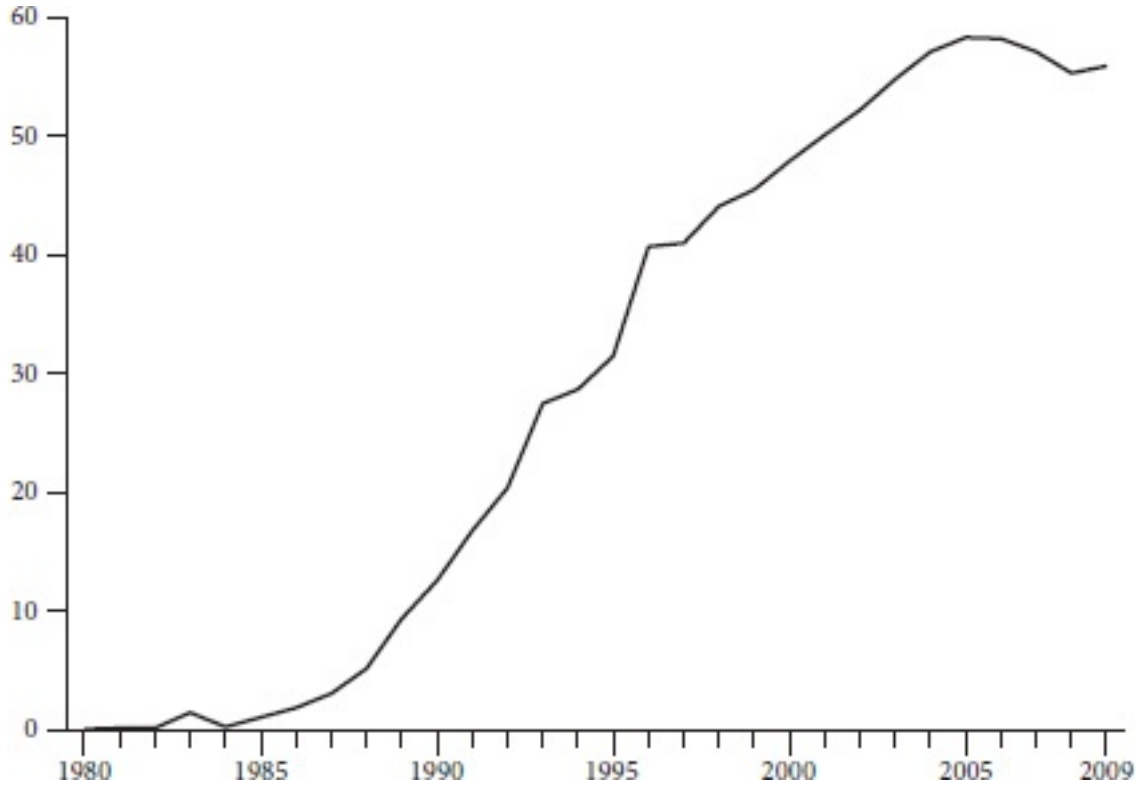

Figure 14.4. Share of foreign-invested companies in exports from China (percentage), 1980–2009.[37]

More concretely, the three effects – expansion, intensity, integration – appear to have been in full swing. There was a spike in fossil fuel burning after accession to the WTO. Of all the massive growth in Chinese energy consumption between 1987 and 2007, over half occurred in just the final five years, with industry the most voracious sector by far. Having lost some appetite in the last three years of the 1990s, the volumes it took swelled again at the turn of the millennium; accounting for more than two-thirds of total final energy consumption, it was a powerhouse in all senses of the term. The relative contribution of households to energy use *declined,* the absolute magnitude of residential energy *stayed level* between 1987 and 2008 – in spite of a 20 percent increase in population – but then people have never propelled the fossil economy. Agriculture, construction, commerce and other services reduced the role of coal in their fuel mixes, so that in 2002, industry absorbed more than 90 percent of all coal consumed in the Republic, three-fourths of it burnt *in the generation of power and heat*. Coal → electricity → manufacturing of commodities for export – such was the sequence at the centre of the explosion.[39] For all the talk of industry having become *less* central to capitalist development, in this case, whose planetary significance is hard to overstate, it weighed heavier than ever. (In fact, an authoritative study suggests the same trends on a global scale: power generation and industry dominate total CO_2 emissions and drive them ever higher, putting buildings entirely in the shade.[41] Mills, not cottages, pour petrol on the fire.)

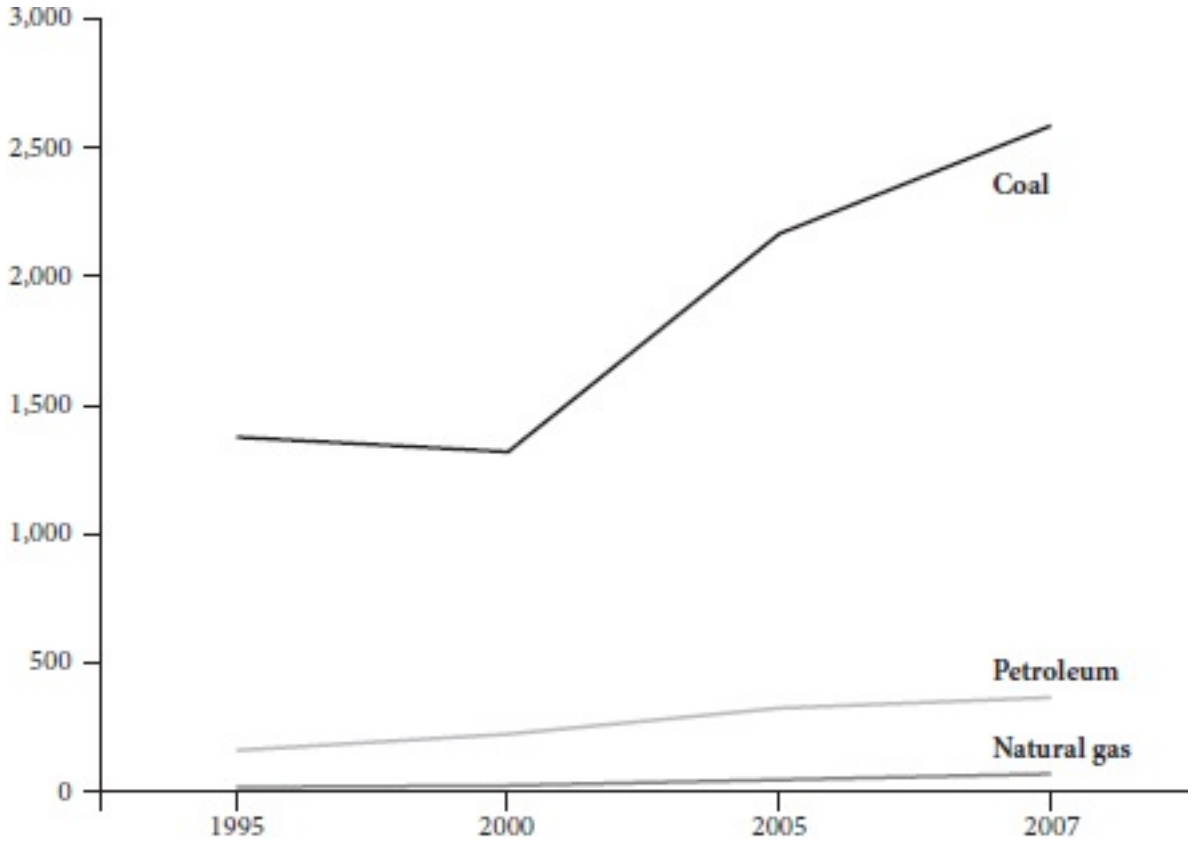

Figure 14.5. Fossil energy consumption in China, 1995–2007. Coal: million tons. Petroleum: million tons. Natural gas: billion cubic meters.[40]

The spike coincided with the coming to fruition of governmental plans to attract foreign

capital. Banking on FDI as the recipe for national development in the 1990s, Beijing resolved to expand energy infrastructure to cater to incomers, ratcheting up the efforts as WTO accession approached. A reminder of the needs came in 2002, when a shortage of oil, electricity and even coal struck the nation. To secure a supply capable of keeping up with expanding industry, the government now further deregulated the coal market, allowing a thousand mines of all sizes and efficiencies to bloom and, not the least importantly, undertaking its own investments in transmission lines from inland power plants, railways and highways to the FDI-dense, bloated cities on the coast. More than 80 percent of all coal burnt in China in the first decade of the millennium originated from the two northern provinces of Inner Mongolia and Shanxi, often travelling two or three thousand kilometres – distances as long as from Paris to Moscow or Cairo to Casablanca, though without crossing international borders – before being piled up inside the magazines of labour power.[42] Chimneys rose to the sky on the foundation of the mobile stock. Until recently a negligible fishing hamlet, Shenzhen became the boomtown of the FDI-export miracle, literally sprouting smokestacks, exhaust pipes and cement buildings where none had existed, posting 14 million inhabitants in 2008; the twin town of Dongguan likewise rose from the backwaters into a conurbation brimming with factories, migrant workers and clouds of CO_2 arising from their combination. It was Lancashire redux, on an unheard-of scale.

But not even the seams of China were enough to feed its bulging industries. The Republic became a net importer of coal in 2007, spurring massive expansion of mines in Australia, Mongolia, the US and a host of other countries; in the first half of 2009, most of the coal imported to the industrial hothouse of Guangdong – the province home to both Shenzhen and Dongguan – came from Vietnam.[43] An oft-noted feature of the early twenty-first century, China's hunt for energy sources extended to the four corners of the world, including, for instance, the oil fields of Angola, where Beijing – honing its skill at producing fossil-abstract space – constructed an entire port city. Alongside the black stone, the Republic thus became progressively more dependent on the black gold. By 2002, only the US consumed more oil; by 2007, more than half of the oil consumed in China was imported, a share projected to reach 77 percent in 2020.[44] Rarely if ever has the formula of placing 'the power amongst the people, wherever it was most wanted' been implemented on such a scale.

The state apparatus of the People's Republic accomplished its mission. In 2010, its Investment Promotion Agency could boast:

> In recent years, the construction of Chinese infrastructure has been improved greatly. The infrastructure in transportation, communication, and the supply of water, electricity and natural gas is almost complete. The ability of supply and quality of energies, raw materials and components has been improved obviously, which provides foreign investors with excellent external conditions in production and operation … The bottleneck effect of infrastructure construction in hardware on the economic development, such as transportation, communication and energies, has been eliminated almost.[45]

Had the state not done its work so dutifully, FIEs would not have arrived in such numbers – and conversely, without the stimulus of FIEs, the imperative to expand infrastructure would have been nowhere as strong. The expansion effect roared through China.

As for the intensity effect, approximately 18 percent of growth in atmospheric CO_2 concentration between 2000 and 2006 stemmed from the 'increasing carbon intensity of the global economy' – increasing, or *deteriorating,* by an annual average of 0.3 percent.[46] The homeland of the trend was, of course, China, its already high carbon intensity rising further and

hosting a constantly swelling portion of the world's manufacturing. Of the three fossil fuels, coal is the dirtiest, most productive of CO_2; a power plant running on coal emits roughly twice as much per Watt as one fuelled by gas – and in 2003, coal accounted for 97 percent of all fossil-fired power in the People's Republic. There were good reasons to choose coal before the slightly less nasty alternatives. The Republic was rich in coal, poor in oil and lacking in gas; more of the black stone could swiftly be extracted by workers in the mines; its cost stood at a sixth of that of oil. Coal dominance is a major determinant of high carbon intensity, and to make matters worse, levels of efficiency in China's coal plants were spectacularly poor: among the fourteen countries responsible for 65 percent of global power generation in 2003, only India came out worse.[47] When manufacturing relocated to the People's Republic in the early twenty-first century, it was plugged into a relatively satisfactory energy supply, predominantly based on coal, transformed into electricity by highly inefficient technologies. Just as we would expect, wages and carbon intensity were inversely related: compare Figure 14.3 to 14.6.

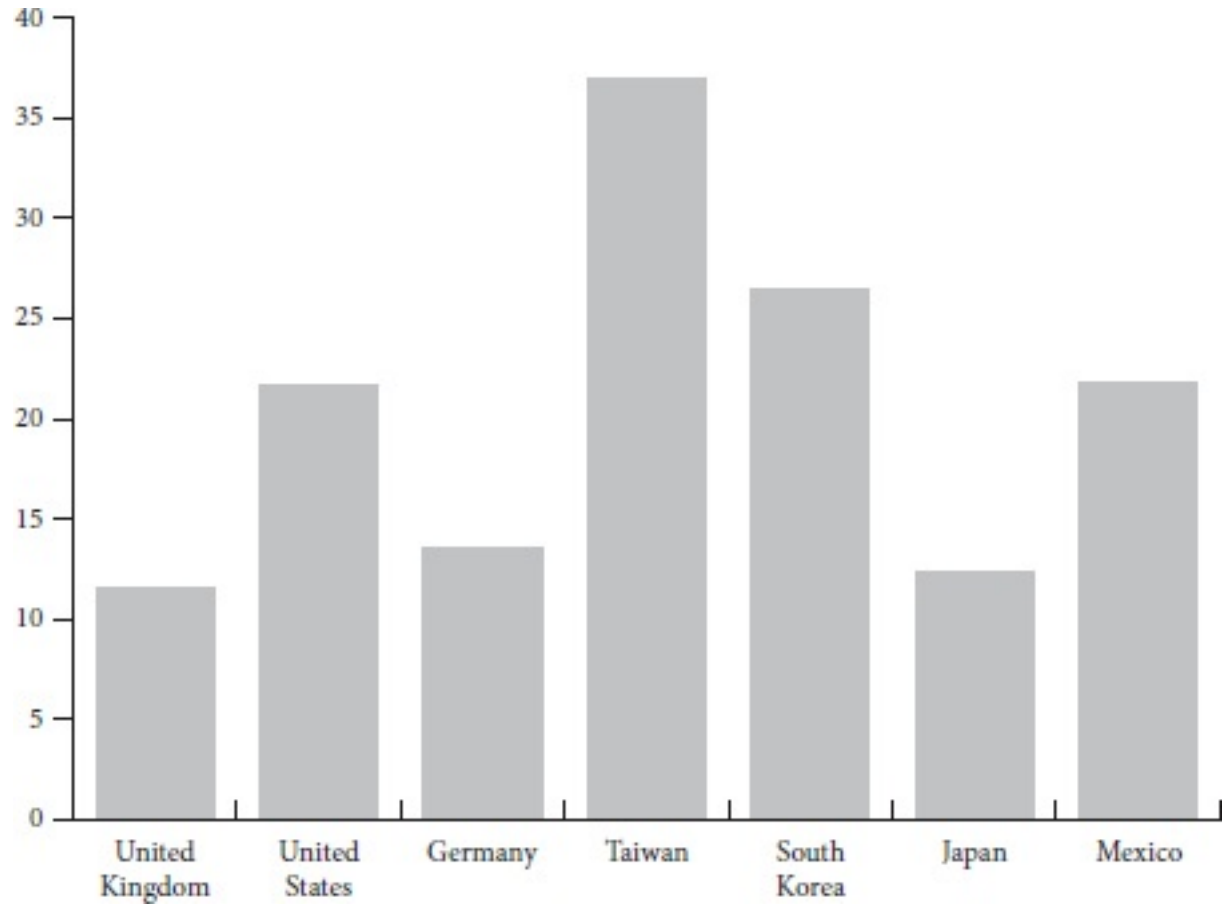

Figure 14.6. Carbon intensity of selected countries as a percentage of China's carbon intensity, 2001–08. National averages for the period.[48]

China had, relatively speaking, low wages and high carbon intensity, certain other countries had high wages and low carbon intensity, and *capital flowed from the latter to the former*. It moved back along the curve towards higher rates of surplus-value *and* higher levels of emissions per unit produced. If all the industry removed to China by, say, 2008 had stayed in the US, South

Korea, Japan, Taiwan, Germany – not to speak of concentrated in an extremely carbon-efficient country such as Sweden – things would have looked very different indeed.

Beijing launched a colossal enlargement of transport infrastructure in the 1990s to pave the way for FDIs, most conspicuously along the southeastern littoral, the traditional gateway for incoming capital now rejuvenated with container terminals, port systems, highways, inter-metropolitan networks for commuting businessmen and other nodes sunk into global circuits. While all coastal cities waved the same basic bait – cheap and disciplined labour power from the inland – they sought to outmatch each other in transport facilities, explicitly conceived to lure footloose investors. The shipping of goods from China left growing traces of CO_2 in the sky; for every insertion of export-oriented production, the distances to be travelled were stretched out, emissions per product rising. In the year 2000, inputs – raw materials, parts and components – accounted for a stunning 85 percent of global CO_2 emitted in the cross-border transport of commodities, final goods only taking the remaining 15 percent. Such emissions from within globalised production chains gravitated heavily towards China.[49]

If Manchester was the 'chimney of the world' in the 1840s, the People's Republic of China assumed that position in the early twenty-first century primarily because *globally mobile capital seized upon it as its workshop*. Or, to reach the centres of populous towns, where labourers were easily procured and trained to industrious habits, capital deployed fossil energy in ever greater volumes, pursuing the modus operandi first laid down by the rise of steam: not in its entirety but in its essence, the Chinese emissions explosion represented an epochal carrying of power to hands. But there were never any guarantees that the bonfire of profits would last.

Capitalists Consider Leaving China

On 28 May 2010, the *New York Times* opened a dispatch with the following words: 'After years of being pushed to work twelve-hour days, six days a week on monotonous low-wage assembly line tasks, China's workers are starting to push back.' Eleven days earlier, at a Honda gearbox factory in the Guangdong city of Foshan, two workers had pressed a red button for shutting down the machinery in the event of quality problems. The turnout soon involved the entire workforce of 1,800 and spread to other plants supplying components to the Japanese auto giant, forcing it to halt all production in the People's Republic; in Zhongshan, the strikers added the demand of free trade unions to higher wages and better working conditions and 'developed a sophisticated, democratic organization, in effect electing shop stewards to represent them,' the *New York Times* reported, apprehension mixed with admiration.[50] Within another few weeks, the wave had engulfed unprecedented numbers of foreign affiliates: a sewing machine factory belonging to the Japanese Brother Industries, a Taiwanese rubber plant in Shanghai, several Toyota works, a Carlsberg brewery, seventy-three factories in the northern industrial zone of Dalian, a Hyundai establishment in Beijing where the union official had once promised the South Korean owners that no strikes would ever happen under his watchful eye. Analysts cited by *China Daily* 'say workers – particularly those among the new generation of migrant laborers – are becoming more confident about their bargaining power and predict these actions could ultimately bring an end to cheap labor in China'.[51]

And indeed, the strike wave enforced whopping wage increases across the board. At its gearbox factory at Foshan, Honda eventually agreed to pay 32 percent more; in the Dalian zone,

the 70,000 striking workers achieved a 34.5 percent hike; at Hyundai's Beijing plant, management conceded a 25 percent rise over two months. Reacting to the turmoil, all but one of China's provinces raised their legal minimum wage, by an average of 24 percent (the first significant increase since the minimum wage system was adopted in 2003). While China was no stranger to mass action, nothing like this – in terms of spontaneous contagion, geographic spread, targeting of FIEs and clear-cut victories – had ever before occurred in the workshop of the world.[52]

The summer of 2010 sent shivers down the spine of bourgeois observers. Contemplating the contours of 'the next China,' *The Economist* declared that 'the popular image of the country's workers as docile, diligent and dirt cheap' had been shattered: 'Recent unrest has put Chinese labour at odds with foreign capital. Firms may have to get used to bolshier workers.' Undergirding the new 'bolshiness' was an unexpected depletion – or withdrawal – of the reserve army of labour, as explained by *Forbes:* 'The size of the workforce peaked in 2010, six years before Beijing's official demographers said it would, and rural residents are increasingly reluctant to move to the cities to work in dreary factories and live in squalid conditions.'[53] Even in the world's most populous nation, supplies were drying up after a decade of breakneck accumulation, boosting the strike forces on the southern coast. How would firms respond to this new situation? In the assessment of *The Economist,* rising wages would erode 'the return on capital,' but

> workers are not the only ones who can migrate [sic]. Capitalists can also go to where workers are abundant. First, labour-intensive factories will move inland. Eventually they will depart China altogether, just as they left Japan and Taiwan before it. That, after all, is why Honda and Foxconn opened plants there in the first place.[54]

In the wake of the strikes, reports of investors planning to desert China abounded. Among the countries identified as new havens were Vietnam, Indonesia, India, Malaysia, Cambodia, Bangladesh; Chinese workers now cost five times more than their Vietnamese counterparts, three times more than the Indonesians, thirteen times more than the Burmese. Other low-wage destinations mentioned – some patently in desperation – were Pakistan, Ethiopia, other parts of sub-Saharan Africa, even North Korea.[55] But the predictions may have been premature: there were obstacles to the exodus, one of them particularly telling. In late 2011, the *Financial Times* spoke to Frank Leung, owner of a Hong Kong–based women's footwear company, about his travels in search of new homes for his Dongguan factories: Bangladesh appealed to him, with wages 20 to 30 percent of those in China. But after his visit to the country Mr Leung was 'shell-shocked. "They have crazy traffic congestion and everyone uses a generator in factories (because the power supply is erratic)", he says. "The logistics make it very hard to work efficiently."' The *New York Times* later pointed out that most of the alluring alternatives in Asia 'have other problems, such as overburdened, unreliable electricity grids,' and for the same reason, the Vale Columbia Center concluded, sub-Saharan Africa would probably not receive much redirected FDI after all.[56] The substratum was simply too deficient.

As for Vietnam, FDIs had already put pressure on the 'creaky infrastructure (power cuts are still common, even in the capital)'; furthermore, 'lengthy traffic jams slow down shipments and drive up costs'. But the state pledged to accommodate incoming capital – above all, by establishing coal mines and coal-fired power plants of low efficiency. In late 2009, the government unveiled plans to develop the largest deposit in the country, twenty times the size of

the biggest mine in operation, meant to 'ensure national energy security by 2025'.[57] A similar situation prevailed in Indonesia, where rampant electricity shortages 'discouraging investment' were combatted by means of 'a "crash program" for expansion of base-load capacity through coal-fired power plants'; some concerns were voiced over the growing dependence on dirty coal, but the great advantage of the fuel was its abundance and low price compared to oil and natural gas, to say nothing of geothermal or nuclear.[58]

For India, one economist drew the lesson that FDI could be attracted if labour power were dressed up like in China: 'quick to learn,' 'highly disciplined,' low wages. While that description of Chinese workers might have already become outdated, the following lesson had not: the main hurdle for larger inflows 'is the lack of infrastructure such as power, roads, railways, oil and gas, aviation, telecommunications, etc. There is also a need to improve transport between the metro- and port cities.'[59] In February 2014, the Indian *Business Today* discussed the opportunities created by the end of cheap labour in China and relayed the conditions laid down by capital: 'The government, say manufacturers, needs to encourage component suppliers. *It must also fix the country's creaky infrastructure* by building highways, power plants and ports.' And indeed, the Indian government vowed to emulate the Chinese model: in 2010, it approved the construction of a new coal-fired power plant every second day.[60] If arrows were to be shot out from China, they would have to land at new summits.

There were alternatives to leaving the Republic. Factories might be moved away from the boiling cost to rural provinces where wages still belonged to another realm, the chimneys of the littoral replanted or replicated in the Chinese interior. But that strategy raised its own problems, as one manufacturer of knitwear complained: 'We need nimble fingers, but we're worried we find farmers who … can't work my machines.' Treading the inland path or not, companies could also put another time-honoured strategy into effect. 'The giant orange robotic arms that swiftly weld together car frames at the Great Wall Motors factory in Baoding might seem like the perfect answer to China's fast-rising labor costs – they don't ask for a raise, get injured or go on strike,' *Reuters* began a story about factories on the frontlines of automation.[61]

Leading the charge was Foxconn, the single largest foreign-owned exporter in China, long anonymous but, after 2010, infamous for assembling iPods, iPhones, laptops and other electronic gadgets for American brands. At Foxconn's mega-factory in Shenzhen, housing 400,000 inmates in a sprawling compound, some of the workers chose another method for revolting against unbearable conditions in that year of unrest: jumping from the roofs of dormitories and cutting their wrists. After a dozen suicides, the company offered a massive wage hike – and immediately began to prepare for automation. A robot called 'Foxbot,' designed for assembling, moving and polishing things, would be engineered in mass quantities; aiming for 1 million units in 2014, management sped up the substitution of dead for human labour. Technology magazine *The Verge* quoted 'Zhang,' a worker in the Shenzhen factory, describing the changes: 'There were about 20 to 30 people on the line before, but after they added the robots it went down to five people, who just pushed buttons and ran the machines.' In a Dongguan town specialising in knitting, firms installed 40,000 computerised knitting machines to rid themselves of 200,000 workers; similar spurts of automation were reported from across the manufacturing spectrum – and not only in China, of course.[62] Robots are on the rise in the world economy. What they mean for energy demand is obvious.

The summer of 2010 really does seem to have constituted an inflection point in the evolution of the workshop of the world. Since then, not only have walkouts hit FIEs on a regular basis and

labour shortages cast a pall over expansion plans, but wages have continued to soar, at double-digit rates each year in Guangdong. In 2013, *Focus on Fashion Retail* snivelled over data on the new basic salary in Shenzhen – 'a frightening figure for factory owners' – and an average rise of more than 30 percent in some cities and provinces since 2010 – 'a heart-breaking figure'.[63] Actual relocations were underway. 'Foreign buyers are fleeing China for Bangladesh, Cambodia and Indonesia not just for cheaper labour but also because of rising tensions between the workers and their employers,' the *South China Morning Post* reported in February 2014; citing 'unpredictable movements in the migrant workforce,' Swedish garment company H&M redirected manufacturing to Bangladesh; Foxconn eyed Indonesia as a new platform. One survey indicated that 40 percent of US firms considered moving out, with many having already begun; FDI inflows to China stagnated and surged in Asian alternatives; in 2013, Indonesia seized the position as the most popular investment choice for Japanese companies.[64] *All such movements were predicated on fossil fuels as the general lever of surplus-value production*.

Indeed, if the post-2010 insecurity around China and its Asian rivals demonstrated anything, it was precisely how necessary a condition that lever continued to be. Without it – without new mines, plants, grids, ports, roads… – the workers that, for the moment, seemed most easily procured and industrious could not be exploited. But states seemed eager to roll out the black carpet. If massive relocation of capital away from the People's Republic were to transpire, it would undoubtedly unleash new expansion and integration effects, though a rise in carbon intensity would be more uncertain (though ironically, there were signs that China had increased the share of imported natural gas in its fuel mix *just as* incomes for working people reached 'heart-breaking' heights).[65] Spreading factories across more Asian countries to safeguard against bolshiness would translate into more chimneys in more places, more fragmented–integrated production chains, more self-reinforcing spirals of accumulation touched off across the continent, whose exploding emissions have other sources as well, but none as flammable as the quest for maximum surplus-value.

Whether factories actually depart in significant numbers remains to be seen. It depends on levels of working-class militancy in China, stability of the state apparatus, potentials for replenishing the reserve army with fresh supplies from the countryside – IMF has produced a list of refill measures, including accelerated mechanisation of agriculture – the possible attraction of richer consumers, movements in currency rates and parallel developments in all of these variables, and more, in alternative host countries.[66] Perhaps the most likely scenario is a pattern of more widely disbursed FDIs, driven by a dynamic non-equilibrium in which capital leaps from place to place, refuelling the combined effects of the drawn-out relocation of industry from old centres to Asia. A collapse of the manufacturing industry in China inducing an absolute *reduction* of its CO_2 emissions seems out of the question – but then again, capital accumulation is a cumulative process, not a zero-sum redivision. The response to labour revolt may simply be to let another thousand chimneys bloom.

The Law of the Rising Atmospheric Concentration of CO_2

In the first edition of *Long Waves of Capitalist Development,* published in 1980, Ernest Mandel scanned the dismal landscape of yet another structural crisis. One of many contradictions related to all-too-powerful labour. With the postwar expansion having exhausted much of the reserve

army in the advanced capitalist countries and lent indispensible workers a high degree of collective self-confidence, rates of profit fell. How could capital regain the initiative? Among the many preconditions for a new upswing, Mandel proposed the following: 'In order to drive up the rate of profit to the extent necessary to change the whole economic climate, under the conditions of capitalism, the capitalists must first *decisively break the organizational strength and militancy* of the working class in the key industrialized countries.'[67] Two decades later, precisely such an epoch-defining victory materialised in China as the workshop and chimney of the world.

The globalisation of production, unfolding since the 1970s and speeding up in the 1990s, caused a tectonic shift in the balance of forces between capital and labour. Endowed with a new ability to remove commodity production to distant countries and *export* from there, capital could twist the arms of unions, their place-bound members now thoroughly substitutable on a global scale. A car assembled in Ghent or Turin for sale on the European market could just as well be manufactured somewhere in Guangdong. China – opened to the world after 1978, but particularly after 2001 – seemed to form a black hole sucking in production, the sound of disappearing factories reverberating across the rest of the globe, echoing in remaining plants from Sweden to Mexico and pushing workers to the wall. In the veiled language of *The Economist,* the flow of Chinese workers 'from farms to factories has held down manufacturing wages – not only in China but also throughout the world'; in effect, the Chinese reserve army became a *global* reserve army, helping to raise rates of surplus-value and widen inequalities throughout the ambit of the dragon.[68]

Chinese workers were themselves harmed by the logic. In late 2010, *Chinese Labour Bulletin* worried that the strikes would yield few long-term results: 'Many low-cost, labour intensive enterprises are currently more likely to respond to workers' wage demands by simply closing down and relocating to a lower cost area, than by actually bothering to negotiate with their workers.' Credible threats of relocation are no less efficient in undermining the bargaining position of Chinese than any other workers caught up in the swirl; indeed, whereas Western labour movements were once allowed to gather force in relative security – production apparatuses still moored in national economies – their latest Chinese reincarnation walks on a rug that might suddenly be pulled from under its feet.[69] No one has better analysed the immediate class dimension of this dance than Beverly Silver in her *Forces of Labor: Worker's Movements and Globalization since 1870*. Drawing on Harvey, she identifies a recurring 'spatial fix' in the modern history of capital: 'Each time a strong labor movement emerged, capitalists relocated production to sites with cheaper and presumably more docile labor, weakening labor movements in the sites of disinvestment *but* strengthening labor in the new sites of expansion.' Escaping the problem of dear and undisciplined labour, capital ended up creating it anew in what was supposed to be the sanctuary. As a corollary, Silver proposes the theorem *'where capital goes, labor-capital conflict shortly follows.'*[70]

We may now add another: *where capital goes, emissions will immediately follow*. This is the class content of carbon leakage. There is, however, no reason to assume that labour always reemerges in the new sites of expansion with the same strength and vigour as in the old; recent decades of globalisation have rather caused a structural *debilitation* of labour – and in this respect, the historical trajectories of conflicts and emissions diverge. Capital dances around enfeebled labour movements, disempowering the global working class through its relentless spatial fixes and permanent exit points, while CO_2 emissions rise exponentially through the same dynamics. Or, *the stronger global capital has become, the more rampant the growth of* CO_2

emissions – indeed, one might argue that the decisive capitalist victory in the long twentieth-century struggle with labour was crowned by the post-2000 rush towards catastrophic global warming. Counting from 1870 to 2014, a fourth of all cumulative CO_2 emissions were belched out in the last fifteen years of the period. This world of exploding emissions is also the world in which eighty-five individuals own as much wealth as the bottom half of humanity, the *anthropos* becoming *less* of a monolith by the day.[71]

Apart from relocation, Silver emphasises another strategy to sap militant labour: automation. An ecological phenomenon through and through, it is one aspect of the relentless rise of machinery over the *longue durée* of capitalist history, expressing the perpetual increase in productivity under this mode of production. For every unit of human labour, more material substrata are mobilised, processed and dissipated: what Marx calls the *technical composition of capital* goes up. In value terms, constant capital (the part of capital invested in materials) grows in proportion to variable capital (another term for labour power), so that the *organic* composition of capital – the value reflection of the technical composition – rises as well. Living labour is squeezed out, shouldering an ever heavier mass of machinery and other matter, dead, unable to produce surplus-value: and so the rate of profit inevitably falls.

This, of course, is the basic reasoning behind Marx's 'law of the tendency of the profit to fall' – law of the *tendency,* because there are 'counteracting factors' operating against it. If, for instance, the elements of constant capital become cheaper, their larger share may not cause a growth in the organic composition. Suppose that a worker has to handle two machines instead of one, while those machines have each been produced in half an hour rather than in one, as formerly: then the *value* proportions remain unaltered. A higher productivity in the machinery-producing sector would, in this case, prevent the value of constant capital 'from *growing in the same degree as its material volume*' – and so the rate of profit might not fall after all.[72] It is merely a tendency, held in check, periodically even reversed when capital advances fast enough on its many frontiers.

What is certain in Marx, however – an iron law of accumulation, impossible to bend or stem – is that the *material* volumes grow, that the *technical* composition rises even if the organic does not: and from an ecological perspective, this is what matters.[73] Given that capitalist machinery has been based on the stock since the early nineteenth century, and given that increased productivity will therefore mean that each hour of labour wields a greater amount of appropriated stock, there seems to be a law of a rising *fossil composition of capital*. The struggle to minimise the share of human labour in relation to machinery and other matter – an unceasing substitution missing in the Ricardian-Malthusian paradigm – causes a rise in the fossil composition, which, operating over the span of capitalist history, translates into a law of a *rising concentration of CO_2 in the atmosphere*. Are there counteracting factors here as well?

There is an analogous possibility, not in value but in material terms: the carbon intensity of production might fall, perhaps so rapidly as to offset growth in scale and productivity. Suppose that a worker has to handle two machines instead of one, while those machines each consume half the former amount of fossil fuels: then the *energy* proportions remain unaltered. But unlike in the history of *value* production, such countertendencies have remained scenarios, vain hopes, pipe dreams of eco-modernist thinking; in reality, Jevons's paradox constantly negates them on a global scale, the spirals of accumulation beating the attempts to save fuel. Moreover, globalised production in general and capital migration to China in particular have induced an *opposite* intensity effect, not cancelling but *reinforcing* the underlying rise in fossil composition: the

carbon intensity of the world economy as a whole is increasing.[74] The law of the falling rate of profit might be at most a tendency, but the law of the rising concentration of CO_2 is immutable. Realised through both relocation and automation, it represents a *unity* of energy and exploitation, in motion since the original transition to steam and running out of control in the present.

Now, needless to say, far from all of the rise in atmospheric CO_2 can be imputed to fossil capital: there have been states, armies, workers' cooperatives, residential areas, land clearings, plebeian transportation systems and other burners outside its circuits. The claim here is only that it constitutes the *main propulsive force* of the fossil economy. If this is at least somewhat correct, any meaningful action on climate change would one day have to challenge fossil capital, which would require, first of all, a sober acknowledgment of power realities. In some of the literature on EET, one finds pious references to the responsibility we all share, without any particular distinctions: 'Ultimately, our daily consumption and production decisions drive global emissions.'[75] In what sense these decisions are in fact 'ours' is not entirely clear. The danger here is that targeting the Western consumer – or, worse yet, Western workers – as an abstract generality guarantees the failure of climate politics, even if moving beyond production-based accounting; the real culprit would remain an elephant in the room. Indeed, the very thought of limiting emissions attributable to global fossil capital as an amorphous but highly centralised locus of power runs counter to the premises of actually existing international climate politics. The gas is left alone, allowed to continue to expand in the fracture zones.

A Commitment to Inertia

Capital is not a being endowed with a will and mind, a cabal, an almighty conspiracy or a central directory preparing its decisions and foreseeing their consequences: anything but. It is a blind process of self-expansion, but one *personified* in capitalists, whose actions and reactions are – and have to be – animated by the compulsion to valorise value. More often than not, the products are unintended. A putter-out of cotton may adopt the power loom as a protection from embezzlement, only to assemble weavers in a position to strike inside his premises; a car company might relocate manufacturing from the strong unions of South Korea to several interlinked sites in southern China and one day wake up to the news of a walkout crippling production. Such sequences of displaced, reshuffled contradictions have appeared not only in the textile, auto, semiconductor and other industries, as mapped by Beverly Silver, but just as much inside the circuit of primitive accumulation of fossil capital.

In *Carbon Democracy,* the most important work on the modern history of that circuit, Timothy Mitchell draws attention to what must be considered a great irony of the transition from flow to stock: it empowered some labour. Now the current of energy presupposed colliers. Escaping from the frying pan of the flow, capital jumped straight into the fire of a fossil economy in which human labour 'connected chambers beneath the ground to every factory, office, home or means of transportation that depended on steam or electric power'.[76] With the power of proletarians in mines – alongside those on rails, canals and docks – to switch off all power, the early labour movement could refine the general strike as its weapon of mass paralysis, the intuitions from the Halifax meeting in August 1842 hardening into an effective strategy for maximising the leverage of the class.[77]

How did capital respond? It took up oil. After a series of frightful strikes on the major

coalfields in Europe and the US – particularly in the wake of the First and Second World Wars – and with correspondingly emboldened labour movements on the advance, the resolve to acquire oil reserves at a safe distance stiffened. 'An important goal of the conversion to oil,' Mitchell argues, 'was to permanently weaken the coal miners, whose ability to interrupt the flow of energy had given organised labour the power to demand the improvements to collective life that had democratised Europe': a more tranquil source of energy would be oil from Middle Eastern deserts.[78] Gushing from the ground, it could be pumped into the landscape by a relatively small workforce – no need for armies of extractors to be sent into the seams – under the permanent supervision of management; thanks to its liquidity, the transport required less labour. From the mid-twentieth century, the fossil economy turned towards the Middle East as its new centre of gravity, in another buoyant spatial fix.

And then the problem reemerged in novel guises: Palestinian guerrillas blowing up pipelines, populist regimes nationalising oil, workers gathering strength enough to disrupt the world economy in general strikes – most notably on the Iranian oil fields in 1978–9 – wars, terror attacks… which in turn spurred the search for 'energy security' in the form of wells far from the Middle Eastern quicksand. In no case, however, did the shift from one fossil fuel to another, or from one region to another, lead to any *absolute decline* in consumption of the troublesome source. Coal never disappeared from the calculus. Today, it is again responsible for more CO_2 emissions than any other fossil fuel.[79] Just as in the circuit of fossil capital, the reappearing autonomy of labour has provided one incentive for the diversification, multiplication and *expansion* of the circuit of primitive accumulation: and wherever capital has gone, more fuels to burn have been uncovered.

But the fundamental incentive has remained the demand for fossil fuels from the rest of the economy. In China, the explosion fed on material from northwestern mines and thus precipitated a boom in extraction, with all the usual repercussions. Known for their biodiversity, the grasslands of Inner Mongolia are the ancestral homelands of nomadic herders, who have never used coal in their daily life – and still do not – but who happen to live upon some of the best deposits in the Republic. Since the turn of the millennium, intensified exploration and processing have contaminated water, dried out streams, released toxic chemicals into the air, reduced vegetation, occupied landscapes, opened invisible shafts into which herdsmen and animals have stumbled. Seeing their traditional way of life under threat, impoverished and displaced, the herders of Inner Mongolia have frequently resorted to blocking coal transports, with the predictable outcome: greater armed presence.[80]

In May 2011, herders from Xilingol raised a roadblock in the path of 100 trucks; on the midnight between 10 and 11 May, some drivers decided to force their way through the barricade, hit a herder known by the name of Mergen, dragged his body for 150 metres and then drove over it several times. The killing put a match to the grasslands. Over the coming weeks, out of sight of world media, the Chinese state stamped out the anti-coal revolt by blanketing Inner Mongolia with police, blocking Internet and telephone connections, sealing off schools, declaring curfews, imposing de facto martial law. A human rights activist spelled out the seething frustration: 'This land has become a lawless zone in which the companies can do what they like, completely disregarding the indigenous people.'[81] As in the English countryside in the Elizabethan leap, the Middle East in the early oil era and countless other places and periods, the primitive accumulation of fossil capital inside China has proceeded through violent expropriation of the direct producers, sinking the hooks of capitalist power into 'the earth, the source of all

production and of all being,' with Marx; once it has taken hold of that source, it is exceedingly difficult to unseat.[82]

As a strictly economic circuit, investment in mines, derricks, rigs, refineries, pipelines and similar structures conform to some well-known laws. These are expensive goods. They are also durable: an oil platform is not consumed over a lunch. In November 1982, a Norwegian platform consisting of nearly 1 million tonnes of concrete became the heaviest object ever moved by people. The money sunk into such installations will return with an increment only after a long time has passed; it might take a couple of years to recover the outlays on a self-actor or a Foxbot, but several decades for a tar sands mine or a trans-Canadian pipeline. As shown by David Harvey in *Limits to Capital,* the result is inertia. 'When capitalists purchase fixed capital, they are *obliged to use it* until its value (however calculated) is fully retrieved': if the platform were to be scrapped one day after inauguration, the loss would be horrendous.[83] The search for flexibility and mobility, which has guided capital since it turned fossil, ends up *fixing it* in ultra-heavy means of production and transportation; for every article of freedom the stock has handed it, the more of it has been locked underground for the long haul.

Immeasurably larger and thicker than in the days of Leifchild, a second crust now girdles the globe: 'Oil and gas fields, coal trains, pipelines, coal-carrying vessels, oil and LNG tankers, coal treatment plants, refineries, LNG terminals' – counting in the tens of thousands, covering millions of kilometres – 'constitute the world's most extensive, and most costly, web of infrastructures,' in the words of Smil. This is a very precious thing for some. Capital, observes critical geographer Wim Carton, 'has a vested interest in the endurance of the fossil fuel landscape,' antithetical to the interest others might have in terminating use of the stock.[84] This is not, however, a matter merely of recuperating expenses: once a power plant has paid back, the owning firm will be wise not to knock it down, but rather to keep it in operation for as long as possible. Already paid for, it can now be treated as costless fixed capital and used as a base for capturing larger market shares; decommissioning the complex and constructing another would be to start all over again. Two-thirds of American power plants built since the 1890s still remain in use. Beyond solid physics and long turnover times, companies will resist the retirement of such assets for as long as these can be maintained and repaired to a reasonable cost – particularly if the product in question is electricity, which the consumer receives in exactly the same shape and form no matter how old the plant is.[85] (Something like a coal-fired power plant may seem to straddle the line between the circuit of fossil capital proper and that of primitive accumulation, but here we shall treat such infrastructure as part of the latter, since it delivers F as an output, even if in converted form.)

We might want to dismantle the fossil fuel landscape as quickly as science tells us we should. For the involved capital, that would be tantamount to an asteroid impact obliterating a whole planet of value, still awaiting its first harvest or ripe for a second or third. The same type of commitment extends to the fossil economy in toto – fixed capital in energy end use might have been triple that on the supply side as of 2005 – but an industrial zone can, at least potentially, be retrofitted for renewable energy.[86] A coal mine cannot. Neither can a coal-fired power plant be fed with wind turbines: it would have to be torn down. Early expiry of that kind is now a necessity. 'If global warming is to be limited to 2°C in 2100,' one study concludes, 'huge quantities of installed coal capacity will need to be prematurely retired between 2030 and 2050. *Such a vast global write-off of capital would be unprecedented in scale':* talk of a transitional demand.[87] Capital has been destroyed before in history, of course – in wars, crises, waves of

deindustrialisation – but this time it would, rather uniquely, be publicly *sentenced* to an untimely death.

Here, then, is one impediment to the transition: capital in the circuit delivering F to consumers. It grows higher by the day. For every moment emissions cuts are postponed, the fixed capital operating as a block against them amasses more weight. Since investments in new and expanded facilities continue right up to the moment when mitigation begins – if indeed it ever does – more astronomic amounts of capital will have to be liquidated on that day than if the work had begun a decade or two earlier: inertia builds inertia, each generation in the fossil economy passing on a heavier nightmare to the next. What needs to be done, of course, is to take off infrastructure for the delivery of F more quickly than it is built – but exactly the opposite is happening. In the first decade of the millennium, more coal-fired power plants were constructed than in any previous decade. The acceleration is quite breathtaking: in the three years from 2010 to 2012, upwards of 2.5 times more coal capacity was added than in the entire decade of the 1990s. A dark cloud of 'committed emissions' is hung over the future. Assuming that they remain operational for forty years, the coal-fired power plants built in the world in 2012 alone will emit 19 billion tons of CO_2 over their lifetimes, to be compared with the 14 billion actually emitted by all operating fossil-fuelled power plants in 2012; currently committed emissions are growing by 4 percent per year, or faster than actual emissions. Such is the war on the future waged by business-as-usual. Nearly two centuries after the rise of steam, the prime ammunition remains coal.[88]

No wonder EURACOAL, the lobby of the European coal industry, in 2014 released a manifesto entitled 'Why Less Climate Ambition Would Deliver More for the EU'. But it is the emissions explosion in the chimney of the world that casts the longest shadow. In the first eight years of the millennium, China added a fresh capacity to generate electricity from coal larger than the entire combined capacity of the five largest EU economies; some thirty to thirty-five years would have to pass before investors could make a profit on these plants. In late 2012, another 1,200 such plants were planned in the world, hundreds of them in Europe but the majority in China and India.[89] By that time, coal suppliers suffered from overproduction, their profit rates declining – but representatives of the industry expected brighter days soon: 'China has exceeded its projections on coal use every time,' said Brendan Pearson, CEO of the Minerals Council of Australia, with confidence. And indeed, by 2010, the People's Republic alone had contributed 37 percent to committed future emissions. But 'committed' should be taken to mean *economically preordained,* not physically predetermined.[90] There is, after all, nothing impossible per se about closing a coal mine. There are just some people standing in the way, infinitely more powerful than a band of herders.

It is imperative to try to grasp the forces any transition would run up against: in 2013, *Fortune*'s list of the 500 largest corporations of the world had Royal Dutch Shell in the lead, Exxon Mobil as number three, Sinopec as four, China National Petroleum five, BP six, State Grid Corporation of China – supplying 80 percent of the country's electricity – seven, Total ten. Only three of the ten largest – Walmart, Toyota Motor, Volkswagen – had their core business outside the circuit of primitive accumulation of fossil capital. But diverse sources flow through that circuit. Financial injections from banks are critical for activating modern coal extraction: from 2005 to 2010 – the years covering Al Gore, the Stern Report, IPCC's Nobel Peace Prize and COP-15: probably the half-decade when awareness of climate change has stood highest on the political agenda – the investment from banks in coal-fired electricity and mining *doubled*. JPMorgan Chase, Citigroup, Bank of America, Morgan Stanley and Barclays threw most money

into the circuit, inextricably entwined with those of financial capital.[91]

Not only structures for extraction that have actually been built, however, but *reserves* of fossil fuels are glittering gold to their owners. Contrary to all talk of impending scarcities, there is enough oil, gas and, above all, coal in the ground to raise the average temperature on earth by between 16 and 25 degrees. That will not happen, of course: every investor would be charred long before it could. But the circuit of primitive accumulation of fossil capital is hell-bent on *moving in that direction,* for here capital subsists directly on delivering the stock to the fires. Corporations are valued on the basis of the deposits they control, display them to shareholders and count on their future exploitation, and if only one-fifth of their assets would in fact be taken above ground and burnt before mid-century, the two degrees target would go up in smoke.[92] A plain demand – a minimum of rationality in the current situation – would be to impose an open-ended moratorium on the development of *new* coal mines, oil wells and gas fields. Against it stands an interest expressed with exemplary clarity by Rex Tillerson, president and CEO of ExxonMobil, in March 2013: 'My philosophy is to make money. If I can drill and make money, then that's what I want to do.'[93]

The Fire Looks at Us So Cheerily

Even if the analysis sketched here is broadly correct, it would still leave one – perhaps *the* – paramount question unresolved: why do not people rebel? Why is it that fossil capital persists, if not unchallenged then safely ensconced in the driver's seat? How is it possible that the passengers do not overwhelm and throw it out, or just wreck the train? Given the gravity of the situation, this might be the greatest mystery of all. Dozens of pieces – the distances between victim and perpetrator, the abstract character of climate science, the convenience of turning a blind eye to disturbing facts and thinking about the brighter things in life, all the creative ways in which societies organise collective denial – would be needed for a satisfactory explanation, but here we shall draw attention to only one.[94] It takes us outside the circuits we have dealt with hitherto and into the sphere of *fossil consumption,* where no capital is accumulated, but where the great mass of humanity integrated into the fossil economy resides.

Mysterious as it may seem, the puzzle is, at closer sight, only a sharpened version of the problem Marxist theorists of ideology have struggled with since Gramsci: why do subaltern classes resign themselves to their fate or even consent to it explicitly? Or, how are the predominant relations of production reproduced? In this tradition, the referent of 'ideology' has undergone a slippage, from a system of ideas proclaimed by meetings and monuments to a structure so deeply ingrained in the very materiality of bourgeois society as to be invisible, inaudible, crushingly efficient because it is unstated and taken for granted. One theory with which to approach the problem might be that of Althusser. For him, ideology is not so much a set of doctrines as a state of existence, in which the subject comes to be enmeshed in the relations; something not thought and said, but *done* and *felt*. More precisely, bourgeois ideology materialises in 'Ideological State Apparatuses' or simply 'ISAs,' an ensemble of institutions with their own distinctive practices.[95]

A person holding a political ideology in the ordinary sense of the term might join a demonstration or attend an assembly to express her convictions, but in the Ideological State Apparatus, it is the practical act that *generates* the ideological affiliation. A Catholic does not go

to mass because she is a believing Catholic; rather, the acts of going to mass, moving her lips in prayer, kneeling down and confessing her sins *constitute* her as a Catholic: material rituals summon the ideological subject into being. The apparatus recruits its subjects, or transforms individuals into subjects, by an operation which Althusser famously calls

> *interpellation* or hailing, and which can be imagined along the lines of the most commonplace everyday police (or other) hailing: 'Hey, you there!' Assuming that the theoretical scene I have imagined takes place in the street, the hailed individual will turn around. By this mere 180-degree physical conversion, he becomes a *subject,*

Althusser here playing with the dual sense of the term: 'subject' as in a freely acting individual, 'subject' as in a subordinate. In the classroom, the teacher interpellates the student when calling on her to respond to a question; on a TV show, the host hails the viewer by welcoming him or inviting him to text his comments, and so on. Althusser again and again stresses that an ideology 'always exists in an apparatus, and its practice, or practices. *This existence is material.*'[96]

Now if we take this hyper-materialist theory of ideology one step further, we can conceive of the sphere of fossil consumption as an Ideological State Apparatus. In *Chimney of the World,* Mosley shows how late Victorian England developed a popular cult of the domestic coal fire, the archetypal site of fossil consumption, where coal itself was the use-value. He quotes *Live Coals; or, Faces from the Fire,* an 1867 book by one L. M. Budgen:

> The dear familiar fire, that lights up our hearth, and faces round it! … The fire which looks at us so cheerily from the bars is the companion of the solitary, the comforter of the sad, the enlivener of the dull, the magnet of social attraction, the pivot and cherisher of tender recollections; in a word, the sun (when the summer sun is wanting) of every domestic system: hence its very *life,* not forgetting its vulgar but particularly *vital* uses, as roaster of the joint, and boiler of the kettle.[97]

The conspicuously fetishistic language of this accolade did in fact, Mosley argues, reflect a widespread experience in the working-class homes of Victorian England: feelings of communion and convenience in the gathering around the coal fire. Here it would have been not a priest, teacher, merchant or any other person *but the material commodity itself* performing the magnetic interpellation. In the commonplace homestead scene described by Budgen, the fire called out a 'Hey, you there!' to the members of the family, who turned their faces towards it. By this mere physical inclination, they became parties to the fossil economy, recipients of its blessings, subjects to – and of – the act of consuming the stock. The material ritual fostered an allegiance so deeply felt as to be unconscious, although sometimes spelled out by authorities of the ISA: 'And to all of us the sitting around [the coal fire] is one of the most cherished features of our home-life. In abolishing it we might save coal, *but we should lose England,*' in the words of a professor in the Department of Fuel Technology at the Royal College of Science, speaking in 1912.[98] So inextricably bound up with the fire had the English subject become that its extinction would have deprived her of her being.

Now consider the equivalents of sitting around the coal fire in the modern sphere of fossil consumption: filling up a car at the petrol station, purchasing a ticket for a flight to some distant beach (or academic conference, or activist gathering), enjoying exotic fruits shipped in from some antipode, buying an iPad produced in China or simply paying the utility bill.[99] The interpellations would be *everywhere,* performed by the objects of use-value in all inflections. But this would seem to signify a step beyond Althusser. In his ISAs – the church, the family, the

parties, the media, the unions, the school – it is invariably people who hail people: the priest the congregation, the teacher the students. The voice is clear and public, anchored in material practices but always louder than their sheer physicality. Can the commodity speak *by itself?* Another possibility might be to view the exhortations to engage in fossil consumption as interpellations: not the flight to the Bahamas, but the advertisement of it on TV and all the similar 'constant chatter,' to speak with Marx. 'In current consumerist societies we are *actively encouraged* to express our sense of identity through our material possessions, and losing these can therefore mean losing our sense of identity,' in the words of psychoanalyst Sally Weintrobe, who proposes this as a critical factor behind popular inaction on climate change.[100]

But the gist of Althusser's theory is hyper-materialism, or perhaps rather a Spinozist dissolution of the dichotomy between spirit and matter, allowing for no separation between body and symbol. 'Men "live" their ideologies,' Althusser writes, *'not at all as a form of consciousness, but as an object of their "world"* – as their "*world*" itself.'[101] The ideology is immanent in the very act of looking at the fire. If we add to Althusser some insights from the opposite corner of Marxist theories of ideology – the reification school founded by Lukács – we may well locate interpellation in the very act of consumption, after the purchase. The commodity masks the relation between people; it parades, invigorates, swaggers and chatters as though there were a human voice inside it. Such reification tends 'to cover the whole surface of phenomena,' since the production of relative surplus-value – synonymous with the perpetual increase in productivity – 'requires the production of new consumption; requires that *the consuming circle within circulation expands*'.[102] Subjects are drawn into spiralling consumption because the sphere of production has to dump its growing mountains of goods onto buyers.

The historical tendency of fossil capital is to spew out *more* products with an F in them for *more* people. In an advanced fossil economy – the one that has to be abolished – the transactions containing the formula C – M – C(F) are so innumerable as to permeate 'every expression of life,' with Lukács. Hardly any subject can be formed without material ingestion of the F. Invisible and silent, the stock is present in the most mundane errand and the most exclusive teaser, in the most concrete existence of people, 'in their work, daily lives, acts, commitments, hesitations, doubts, and sense of what is most self-evident,' with Althusser.[103] Whether a party animal or a progressive academic, you need to take that flight to maintain your subjectivity and be the person you are. While sitting in the plane, the window, the seat, the attendant and the view of the clouds below hail you without uttering a word: 'Hey, you there!' – you are a subject of the fossil economy, and since you repeat the act frequently – ISAs are always built on reiterations – you cannot imagine *not* flying: the F has constituted the subject, who cannot see himself outside of it and who rarely reflects upon, let alone articulates, the ideological affiliation. It is just there, in the veins of material life.

So why would the fossil subject rise up to slake the fire? He could lose himself in the process. The fire looks at him so cheerily from the bars. We have here a provisional explanation for why resignation to the fate of global warming deepens with its acceleration: 'Just as the capitalist system continuously produces and reproduces itself economically on higher and higher levels, the structure of reification progressively sinks more deeply, more fatefully and more definitively into the consciousness of man.'[104] But the circles are concentric. On the outer rings of the fossil economy, the bonds to the fire are looser. Indeed, it follows from all of the above that *the subjects most thoroughly constituted by fossil use-values and therefore resistant to climate change mitigation are the richest consumers*. Someone poor, who might pay her utility bill but

never flies to the beach, would have far less of her subjectivity invested in the stock and little if anything to lose from a transition. Insofar as class divides are deepening in fossil economies, the differences are widening. The explanatory power of a theory of fossil consumption as an ISA correlates with affluence; it might have some bearing on middle strata, the intelligentsia and certain privileged segments of the working class, but not on the truly subaltern classes in a warming world.

Much of climate politics is preoccupied with hailing consumers: Hey, you there!, buy something different!, something with a green label or lower footprint, something locally produced or, even better, nothing at all. While this seems to match the ideological weight of fossil consumption, we can see clearly why the focus constitutes a double strategic mistake. First, it speaks to the well-off; the efficacy of such counter-interpellation stands in direct proportion to purchasing power. Second, it deflects attention away from production, the active moment determining business-as-usual as a whole *including* the widening circle of consumption. Any progressive climate politics must, to be sure, confront the magnetism of the fire and come up with alternative interpellations, but as a general compass, the targeting of the consumer leads into the classical blind alley of Western environmentalism. In *Reason in a Dark Time: Why the Struggle against Climate Change Failed and What It Means for Our Future,* moral philosopher Dale Jamieson unknowingly begins with an exact rendition of the human fate under reification, as theorised by Lukács: 'Human action is the driver, but it seems that things, not people, are in control. Our corporations, governments, technologies, institutions, and economic systems seem to have lives of their own.'[105] Only if people were to break out of the stupor of consumption and start acting on *this* level could any real change come about.

CHAPTER 15

A Return to the Flow? Obstacles to the Transition

Woes of the *Gratisnaturkraft*

Our best hope now is an immediate return to the flow. CO_2 emissions have to be brought close to zero: some sources that do not produce any emissions bathe the earth in an untapped glow. The sun strikes the planet with more energy in a single hour than humans consume in a year. Put differently, the rate at which the earth intercepts sunlight is nearly 10,000 times greater than the entire energy flux humans currently muster – a purely theoretical potential, of course, but even if unsuitable locations – oceans, wetlands, steep mountains – are excluded, there remains a flow of solar energy a thousand times larger than the annual consumption of the stock.[1] Wind alone can also power the world. It has nothing like the overwhelming capacity of direct solar radiation, but estimates of the technically available supply range from one to twenty-four times total current energy demand. Pessimists have warned that a massive deployment of turbines would slow down the wind itself to the point where one more wind farm would add no more electricity, but such Ricardian concerns have been put to rest by recent research: it is physically impossible to exhaust the currents of the air.[2] Other renewable sources – geothermal, tidal, wave, water – can make significant contributions, but fall short of the promises of solar and wind. If running water constituted the main stream of the flow before the fossil economy, light and air may do so after it. Fuel scarcity is not the issue this time around either.

How fast could a transition to the flow be implemented? In the most comprehensive study to date – a sort of global Thom report – American researchers Mark Z. Jacobson and Mark A. Delucchi suggest that all new energy could come from wind, solar, geothermal, tidal and hydroelectric installations by 2030; reorienting manufacturing capabilities towards their needs, the world would not have to build one more coal-fired – or even nuclear – power plant, gasworks, internal combustion engine or petrol station. After another two decades, all old equipment based on the stock could be taken off-line, so that by 2050, the entire world economy – manufacturing, transportation, heating: everything – would run on renewable electricity, roughly 90 percent of which the sun and the wind would provide. The job could be done by technologies already developed. In an inquiry with higher resolution, Jacobson, Delucchi and their colleagues have demonstrated how the same conversion of New York State might be fully accomplished by 2030.[3] Others have sketched even more sanguine scenarios: within twenty-five

years, all fossil fuel consumption in the world could be replaced with solar energy; it would take the US and New Zealand no more than a decade to generate 100 percent of their electricity from renewables; wind and solar could – surely the most optimistic proposition – replace every little piece of the stock as soon as 2024.[4]

In the real world, the flow does seem to be undergoing something of a boom, output of wind and solar growing exponentially year after year. Despite the financial crisis, global wind-power capacity increased by 32 percent in 2009; for photovoltaics – popularly known as solar panels – the figure reached 53 percent.[5] In the eighteen months ending in April 2014, more solar power was adopted in the US than in the previous thirty years; in 2013, 100 percent of the fresh electricity in Massachusetts and Vermont came from the sun, while China installed more photovoltaics than any country had ever done before in a single year. Kenya drew up plans for how to generate half of its electricity from solar by 2016. Haiti opened the world's largest hospital, California the biggest power plant fuelled by the sun. Yet the flow remained a drop in the fossil bucket, evidently doing nothing to dampen the emissions explosion. Between 1990 and 2008 – from the first to the fourth IPCC report – fifty-seven times more fossil than renewable energy came online in the world economy; by 2008, wind represented a trifling 1.1 percent and photovoltaics a microscopic 0.06 percent of primary energy supply; excluding hydropower, renewable sources generated a mere 3 percent of the electricity. In 2013, more energy entered the world economy from coal than from any other fuel.[6] How can this be? Why is humanity not running for life out of the fossil economy towards one based on the flow? What impediments block its way? We cannot, obviously, reach anything like exhaustive answers to these questions here, only put up some signposts for further investigations.

A prime suspect is price: fossil fuels simply remain cheaper. And indeed, one decade into the millennium, renewable sources still cost more on average than the conventional incumbents.[7] But the gap narrowed fast. In many parts of the US, onshore wind was already neck and neck with fossil energy, the price of turbines having fallen by 5 percent per annum for thirty years. Photovoltaics crashed at double that speed. In 2014, after a fall of 60 percent in only three years, solar panels cost one-hundredth of what they did in 1975. In nineteen regional and national markets, they had attained 'grid parity,' meaning that they matched or undercut conventional sources without the support of subsidies: in California, Spain, Turkey, even Germany for residential power; in Mexico and China for industrial. Had it not been for state subsidies to *fossil* energy – six times larger than those to renewables in 2013 and showing no signs of decreasing – sun and wind might have had significantly lower relative prices, not the least in developing countries such as Egypt and Brazil. Had the costs of climate change, air pollution, lethal accidents and other 'externalities' been included in the market price of fossil fuels, they would not have stood a chance – and neither would steam power in the nineteenth century – but that remains an academic debate.[8]

The ongoing collapse in the prices of the flow is, at bottom, a function of its profile: the fuel is already there, free for the taking, a 'gift of nature' or *Gratisnaturkraft,* to speak with Marx.[9] The only thing that has exchange-value is the *technology* for capturing, converting and storing the energy of the fuel, and like all technologies, it is subject to economies of scale: mass production slashes the costs of panels and turbines. Every time the cumulative volume of photovoltaic installations has doubled, their market prices have declined by roughly 20 percent. Moreover, there are numerous potentials for increasing performance and further cutting costs: the silicon wafer of a panel can be thinned or replaced with a material better at converting sunlight into

kilowatts, such as the mineral crystal structure known as 'perovskite' which now promises triple efficiency; batteries can be improved; other methods for storage are under development. In what is perhaps the only subfield of the climate debate bristling with optimism and near utopian zeal, experts predict that both solar and wind will be generally cheaper than fossil fuels sometime before 2025. There is talk of approaching 'peak fossil fuels,' beyond which coal, oil and gas will be left in the ground simply because they cost so much more than their clean alternatives.[10]

Now, it is easy to imagine that falling prices must be an unadulterated blessing for solar and wind. Alas, the outcome is not so straightforward. In the early twenty-first century, two of the largest players in the solar industry were BP and Shell, both of which used their newfound inclinations to great PR effect, BP rebranding itself 'Beyond Petroleum' and Shell printing double-page adverts on its faith in a 'new energy future'. For a time, these oil giants were the second- and fourth-largest manufacturers of solar panels in the world, apparently determined to throw their humongous resources into the sector: exactly what it needed for expansion. But in 2006, Shell sold its solar subsidiary. In 2008, it pulled out of the London Array, slated to become the largest offshore wind farm in the world, and the following year, the corporation announced its complete exit: there would be no more investment in solar or wind. Why? 'They continue to struggle to compete with the other investments in our portfolio' – oil and gas, that is – said spokesperson Linda Cook.[11] BP gradually closed down its panel factories, complained in 2011 that it 'can't make any money' on the sun and, two years later, followed Shell's lead: 'We have thrown in the towel on solar. *Not that solar energy isn't a viable energy source,* but we worked at it for 35 years, *and we really never made money,*' CEO Bob Dudley explained, going on to sell off the company's entire US wind business for good measure.[12]

More specifically, both corporations attributed their pullouts from the sun to the plummeting prices on panels. Since they could not extract the fuel and sell it on the market, the only thing amenable to self-expanding value would be manufacturing the technology; the margins were squeezed year after year, however, until little if any profit remained – a tendency with no equivalent in their core business. 'BP couldn't make it [solar] profitable. They couldn't keep pace with the industry, and didn't like the capital allocation required. *When oil is $100 per barrel, the board wants to stay focused on what they do to maximize earnings,*' a former strategist at BP Alternative Energy recalled as the reasoning behind the decision: for someone who is in it to make a profit, a high and stable price is better than a low and falling one. 'In the oil market, the prices are going up and down in cycles. The solar price is just going one way – it's going down,' lamented one former executive at the defunct Shell Solar, restating the case for eternal fixed capital based on the stock: 'Oil companies invest in plants that should work for thirty years, whereas an investment in a solar manufacturing plant can be uncompetitive in five years. That kills the enthusiasm of oil companies.'[13]

But not only inveterate oil companies seem to shun a flow on the way to becoming cheap to ultra-cheap. In 2012, Siemens said it would bury its solar interests due to the plunging prices; Bosch headed in the same direction; Solon, the first publicly traded solar company in Germany, went bankrupt.[14] A more highly publicised death was that of Solyndra, a California solar company, whose factory couldn't withstand the competition from panel manufacturers in China: first stimulated by the German market, then by state credits in the wake of the financial crisis, Chinese panel factories excelling in mass production developed *overcapacity*. This would sound like another blessing for a species that needs solar power now more than ever, but it rattled the industry, set off a string of bankruptcies – including in China itself, where the head of one

defaulting company leapt to his death – and prompted the EU to impose import tariffs, destroying the appetite of capitalists of all hues.[15]

From a peak in 2011 to the year of 2013, global investments in renewable energy *fell by 23 percent*. In Europe, the figure was a stunning 44 percent. Solar tumbled; wind proved more resilient; venture capital and private equity steered clear of the razor-thin margins, their involvement in the sector reduced to 2005 levels. Had it not been for government spending – still rising, but just barely – the fall would have been even steeper. Due to the prices of photovoltaics and turbines dropping even more quickly, these years nonetheless saw growing volumes of actually installed capacity, but that offered scant solace to an actor like Bloomberg New Energy Finance: 'The decline in investment was disappointing for the industry and those hoping to see investors and financiers increasing their dollar commitments to the decarbonisation of the energy system.'[16] In other words, capital did not engage in the transition as many had expected it would, largely *because energy from the flow lost so much of its exchange-value* at the very same time that its social use-value – slowing down climate change – rose towards priceless heights.

It is too early to tell if these trends will persist, but we do here discern the contours of a version of the 'Lauderdale paradox': the less exchange-value that is attached to a necessity of life – such as light or air – the less interest capital will have in producing it as a commodity for the market.[17] Or, the more the price of energy from the flow approaches the zero cost of the fuel, the smaller the prospects of making profit and the more deficient the private investments will be. If this is correct, a realisation of the potential of solar and wind on the basis of capitalist property relations would, at some point, become another self-undermining, involuting enterprise. It remains to be seen if the data bear out such a prediction or if capital comes running back to the panels and turbines – perhaps a decelerating productivity race would protect factories from devaluation and entice more spending (which would, however, itself undercut prices). One thing seems certain, though. The spatiotemporal profile of the flow does not allow for anything as lucrative as the primitive accumulation of fossil capital: since the fuel is not hidden away in a separate chamber, but rather hangs like a fruit for anyone to pick, there is little surplus-value to extract in its production – no gap between the location of the energy source and that of the consumers in which the chasm between capital and labour could be reproduced. To some, res communes remain off-putting.

But if prices fall low enough, will not the *consumers* of energy step up to the plate, the suppliers respond to their demand and the two, moving in dynamic equilibrium, carve out a progressively greater space for the flow? We shall return to that possibility. At the time of writing, the collapsing prices of photovoltaics in particular do appear to be a mixed blessing for the transition. Is it further delayed by shortages of the materials required? Jacobson and Delucchi contend that their global 100 percent scenario faces no major constraints from the substrata; all the panels, turbines and plants will devour concrete, steel, copper, aluminium – much of which could be recycled from the retired fossil infrastructure – but apart from a few rare earth minerals, which need to be used frugally and preferably replaced, there is enough to be had for everyone.[18] Solar, wind and their auxiliaries would not occupy much land either. *Biofuels* would, which is one reason why Jacobson and Delucchi and other serious proponents of a renewable world economy exclude them from their schemes, another being the net positive CO_2 emissions when forests and grassland are converted to fields for inter alia corn for ethanol.[19] From flow to stock or back, the Ricardian-Malthusian paradigm has little bearing on the transitions.

Two other, familiar disadvantages are more frequently held against renewable energy. It is not

present everywhere, and not all the time. Strong wind and shining sun are found in greatest quantities on certain spots, which might not be so favourable in other respects. In a major survey of the opportunities for 'scaling up alternative energy' in 2010, *Science* quoted an ecological economist drawing attention to the fact that 'many of the windiest and sunniest regions in the world are virtually uninhabited.' The wind may fall; the sun is guaranteed to be absent at least half of the day: 'The energy they deliver is often intermittent and hard to store.'[20] Concrete space and concrete time are still seen as nuisances of the flow. Let us deal with each in turn.

A Flow against the Tendency of Things

A solar panel in Arizona generates 60 percent more electricity than an identical panel in Maine. The total technical potential of solar energy in the Middle East and North Africa is twelve times that in Western Europe and seventy-two times that in Central and Eastern Europe. Some of the most powerful winds blow over the tip of the Southern Cone, the island of Tasmania and the coasts of the North Sea, while much of Asia is comparatively poor in such endowments. Ever embedded in the landscape, the flow dispenses its energies unevenly in space; no other factor does more to determine variations in kilowatt prices.[21] Consider a photovoltaic array, whose cell converts incident light directly into an electrical current. It is nothing outside the local column of rays from the sun; it cannot be powered by radiation ferried from the other side of the planet; it is utterly hostage to conditions on the spot. Coal can be sent to whatever place capital currently favours for production. So can oil and natural gas, from Alberta or Alaska, Gaza or Ghana, but energy from sun, wind, wave and water can only travel over limited distances: sunshine from Algeria cannot be dispatched to Bangladesh.

Some enthusiasts see only virtues in this localism. Herman Scheer, probably the most influential European ideologist of renewable energy, the architect of the German transition project known as *Energiewende,* has constructed an entire vision for the rejuvenation of modern civilisation around it. In *The Solar Economy,* he sings the praises of the short or nonexistent 'supply chains' of renewables: finally, energy can – nay, must – be generated, harnessed and used in the very same place. Source and consumer will be hand in glove, their local bond unbreakable. The emblem or 'prima donna' of this novel era is precisely the solar panel, fixed on a rooftop and sending the current straight down into the bathroom, kitchen and garage. If power plants running on solar energy are necessary as well, these ought to serve cities in the 'immediate vicinity – for example, Cairo's power needs could be supplied by a plant located in the nearby desert.'[22] Transportation of renewables is neither necessary nor possible, and this is all for the better: Scheer envisions closed loops of energy, goods and services inside local communities, with no trucks or high-voltage cables crisscrossing the earth. Energy consumers will have to adapt to 'the intensity of insolation, strength of the prevailing winds, presence or absence of hydropower potential' in situ. A readjusting process of 'industrial relocation' will ensue, in compliance with the distribution of energy supplies.[23] Factories will besprinkle the globe. There will be no centres.

Echoing *phalanstères* and 'small is beautiful,' Scheer's vision might correspond to an unmodified profile of the flow, but it lacks any appreciation of what is at stake here. 'The fact that supply chains for solar power are short,' he writes, 'really does beg the question of why generations of scientists and technicians have refused to accept it as an alternative' – as though

the forces at work were inscrutable.[24] Their negation of Scheer's ideal is absolute. Globalisation has produced the greatest separation between energy production and consumption in documented history, the chains often taking fossil fuels from deposits in one country to combustion in another, where commodities are manufactured for sale in a third; every year, more carbon – solid and embodied – is shuffled across borders. In times of globalised production, capital flies past all fences to reach the greenest grass, moving restlessly between places in disregard of their intrinsic qualities, more intolerant than ever of tethers; the vision that rules the day is rather that of Jack Welch, the CEO of General Electric who famously proclaimed that 'ideally, you'd have every plant you own on a barge.'[25] If Scheer is correct about the ramifications of a transition to the flow, it stands in antagonistic contradiction to the logic of global capital, for *the means of production would have to be shackled to communities formed around energy nuclei*. The formula that once brought steam to ascendancy would have to be inverted. Capital would need to carry the people to the power, rather than placing the power amongst the people as it has been doing for the past two centuries, and never with greater vigour than in the current stage of abstract space.

'When the nature of the work is such that it is not possible to remove it,' we have seen Babbage explain, 'the proprietors are more exposed to injury from combinations among the workmen.' Globalised production is built on that hard-learnt lesson. Scheer elegantly suggests that 'comprehensive use of renewable energy would take the wind from the sails of an economic globalization and industrial concentration process,' but does not realise what this would mean: disarming capital of the weapon it has used so effectively to prevail in the struggle against labour. It is unlikely to let go of it easily. *Other* classes might have little to lose: *workers* would have if not a world, then at least a slightly safer future to win from chaining the means of production to the sun, wind or water, so that they can no longer suddenly depart. But few are the devotees of renewable localism or regionalism who make such a class alignment. Scheer, for one, entertains the hope of a 'widely distributed capital accumulation,' a castle in the air with zero relation to the actual spatial dynamics of capitalist property relations.[26]

Equally starry-eyed is his rejoinder to the second objection to renewables: 'The correct response to the argument that you can't dry your laundry if the wind doesn't blow is that you can dry it when it does blow.' Sure, if use-value were the purpose of labour. But in advanced capitalist economies, the reign of abstract time has penetrated every moment of existence with round-the-clock appliances, from the refrigerator to the conveyor belt, the data server to the charging station, fostering a general allergy to break-offs. 'It has,' Crary writes in *24/7,* 'become intolerable for there to be waiting time while something loads or connects': there is a 'profound incompatibility of anything resembling reverie with the priorities of efficiency, functionality, and speed'.[27] Not the most propitious historical moment to tell people to give the weather some time. In industry, the equivalents of the cultural malaise diagnosed by Crary as '24/7' are the doctrines of 'lean production' and 'just-in-time': a fanatical war against the remaining pores in the labour process, profoundly incompatible with anything resembling intermittency. Can capital be forced to rely on an inherently fluctuating flow? Its resistance to the thought has probably never been firmer than now.

Critics of Jacobson and Delucchi have aimed for the temporal chink in their armour, pointing to winter weeks when the European skies have been both cloudy and calm and stressing that mismatches with peak demand are 'not acceptable in our modern economy'.[28] In 2008, a climate initiative under the auspices of Google presented a plan for weaning the US off coal by 2030,

replacing the black stone with a medley of wind, solar, nuclear and other sources. 'Absolutely impossible,' the CEO of American Electrical Power scoffed at the idea: 'If you can make the wind blow 24/7 that would be good. Maybe Google's got a plan for that.' Privately owned, profit-oriented utilities in the US abstain from renewables in fear of weather variability, currently causing interannual variations in revenues by 15 to 20 percent for wind farms and 5 percent for solar projects (not to speak of the swings from one month or week to another). 'The tendency of things,' we have seen William Stanley Jevons observe in the 1860s, 'is such that we are likely to find coal a source of sunlight [rather] than sunlight a competitor of coal'; today, in time as well as in space, the tendency is a progressive reification, an 'ever-increasing remoteness from the qualitative and material essence of the "things"', to speak with Lukács.[29] Having incorporated the stock as its very marrow, capital moves ever further from the nature of the flow.

A Catch-22 of the Transition

When all of this is said, however, a field of different possibilities opens up. There might be methods to engineer a more abstract profile of the flow. Solar power technologies, for instance, come in forms other than photovoltaics: a forest of self-acting mirrors may be planted on the ground to track the sun's rays and redirect them onto a single focal point, such as a tower, where the resulting temperatures may range from 200°C to 1000°C; the burning heat can than be used to produce steam – the old idea on which Jevons commented – and drive a turbine as in any conventional power plant. Whereas a panel converts sunlight directly into electricity, 'concentrated solar power' or CSP takes the detour through heat but collects a much denser current, which can be transmitted across long distances – currently up to 2,000 km – through high-voltage overhead lines, into centres of population and industry. For wind, an analogous option is to place giant farms offshore, where the winds are speedy and steady, unhampered by mountains and buildings, and lead the haul onto land.[30] Photovoltaic arrays and onshore turbines can, of course, also be connected to grids, but CSP and offshore farms have a special ability to capture the flow *in the places where it is most abundant* – deserts, straits, bays – from whence it can be carried to the people. But there is one major catch to such solutions: they require advanced planning and coordination.

By far the most intensely hyped scheme in this genre is 'Desertec': a string of mega-CSP-plants in the northern Sahara exporting electricity to Europe via underwater cables. In 2009, a consortium of financial and industrial concerns launched the Desertec Industrial Initiative (DII) to mobilise capital for the project, with the aim of supplying at least 15 percent of European electricity needs by 2050. 'The idea that renewable electricity should be produced in areas with optimal resources and exported to regions with high demand has become known as the Desertec vision,' the DII pronounced in 2012, updated maps showing a thick web of high-voltage lines covering the most densely populated parts of Europe with energy from CSP, photovoltaic and wind installations in the Middle East and North Africa; the project, a confident Initiative reassured the public, 'can be realized by market players and investors'.[31] But two years later, it lay in shambles. Unconvinced of the financial benefits, the heavyweights of the consortium – E.ON, Bosch, Siemens – had pulled out; the nonprofit Desertec Foundation had split with the Initiative; the plan to deliver electricity across the Mediterranean had been put on the shelf, European utilities arguing that it was 'incompatible with current levels of grid interconnectivity' – plus, their markets already suffered from an *excess* of renewable energy.[32] One study

concluded that Desertec was perfectly feasible in technological terms: but 'adequate political frame conditions that would allow for the necessary large investments are not yet available.'[33] There was no plan in place to hold together the atoms of capital.

The Desertec vision travelled to other quarters, however; deserts are gold mines of sunlight waiting to be unlocked for the benefit of the hives and workshops of the world, such as China: hence the idea of 'Gobitec'. The Gobi desert might be the planet's single most favourable habitat for solar power generation. Covering 3 percent of its area with panels would suffice to produce more electricity than the world consumed in 2008; combining large-scale photovoltaics with CSP, mighty currents could be sent through China to the FDI coast in the south, as well as through the Korean peninsula and all the way to Tokyo in the east. Like its European model, Gobitec has yet to leave the drawing board. No private investors have stepped forth. Another familiar problem bedevils the project:

> The cooperation between Asian countries envisioned by Gobitec's proponents overlooks how private market participants may have different agendas than their participating governments. *Competition among private investors may be incompatible with state-based diplomacy,*

as two researchers put it, going on to quote an anonymous informant: 'Getting countries to work together is difficult enough. But energy security is *a money-making exercise; so private firms are reluctant to cooperate*. They want to dominate.' But the involved countries could also be expected to behave like profit-maximisers: if one of them 'loses money, but the others do not, resentment could result'.[34] And that is where the matter stands.

Solutions to the problem of variability tend to point in the same direction: away from the narrow locality, towards 'super grids' of integrated sources, based on the principle that when the wind is still in one place the sun probably shines in another. Jacobson and Delucchi have responded to their critics by suggesting that interconnected wind farms in North Africa, Russia and west Asia would safeguard against barren European winter weeks; the point is to treat renewables in *bundles,* not as enclaves of impossible autarky. Geothermal, tidal and hydroelectric installations provide more constant energy than solar and wind, and so have a critical role to play as buffers.[35] Desertec is – or was – designed to offer the same balancing services (the sun always shines in Arabia). Another idea is to refurbish Norway as the 'green battery of Europe,' charged by surpluses of the flow from neighbouring countries: when the wind is strong in Germany or the UK, some of it can be sent to pump water up into reservoirs in the Norwegian mountain; when the wind slackens, the water can be released and the favour returned. We have seen an 'Ayrshire gentleman' propose the exact same solution for the British industry of the 1820s.

After the transition, Jevons imagined how coal could be made entirely redundant by some intelligent planning:

> The most perfect conceivable system of machine labour might be founded on hydraulic power. Imagine an indefinite number of windmills, tidal-mills, and water-mills employed to pump water into a few immense reservoirs near our factory towns. Water power might thence be distributed and sold as water is now sold for domestic purposes. Not only all large machines, but every crane, every lathe, every tool might be worked by water from a supply pipe, and in our houses a multitude of domestic operations, such as ventilation, washing, the turning of the spit, might be facilitated by water power.[36]

We know on what blocks such ideas stumbled. Now, as then, the required technologies are fully

mature, but a spirit of mutual concession and accommodation among the parties is rarely met with: Norwegian electricity companies do not expect profits large enough to motivate investment; it remains unclear who will pay for the infrastructure; some outdoor enthusiasts oppose the overhead lines for aesthetic reasons.[37] In the meantime, companies continue to pump Norwegian oil and dig German coal, without coordination.

There is no reason to assume a priori that these obstacles are insurmountable. Other options for managing swings are at hand: oversized generation capacities, storage in batteries, weather forecasting, even – the daring thought – demand regulation.[38] But there appears to be a general catch-22 freezing the transition (or, as it is often and appropriately referred to, the *exit*). On the one hand, a return to the concrete fold of the flow would tear apart abstract spatiotemporality. On the other hand, an attempt to create the most abstract possible space and time out of the concrete flow would demand comprehensive planning. There is an emergency, and if some integral aspects of capitalist property relations keep closed the exit gate to the left, we bump into others to the right. Robert Thom, of course, got stuck in the same catch: with long aqueducts, multiple reservoirs and state-of-the-art sluices, he promised to 'convey water from the most remote and inaccessible places' and make it 'work with the same accuracy as a piece of clock-work'. Except capital could not agree upon it. Ready to sacrifice neither spatial mobility and temporal uniformity nor the anarchy of competition, it rather entered upon the construction of a fossil economy; trying to get out of the structure today, the fire alarm ringing, we seem to face doors locked with the same keys. Should we manage to get out in either direction, relations would seem to *have* to move in a more communal direction – in line with the concrete profile or the communist tendency of the flow.[39]

The res communes of water, light and air are still in a 'state of continual motion and ceaseless change,' with Blackstone; 'of a vague and fugitive nature,' in the words of a French legal scholar.[40] The capture of their forces appears technically viable on condition of planning and coordination on a level unknown today, sweeping industries, nations, several continents under the wings of Irwell commissioners for the twenty-first century. But the tendency of things is for the stock to continue to circulate in motionless submission.

Towards a Planned Economy for Power?

Herman Scheer wants to go the local way, without understanding what he would have to grapple with. In *The Energy Imperative,* published posthumously in 2012, he fumes over Desertec, the Norwegian battery and all proposed super grids as betrayals of the *geist* of renewable energy, which 'is, by its very nature, decentralized'. Instead of taking the light and the air for what they are, such schemes seek to squeeze them into the Procrustean bed of fossil structures; worse still, they would lend new prerogatives to the state. The idea of a continental super grid 'has the character of *a planned economy for European power',* Scheer whines.[41] Let us assume he is right. If post-fossil economies are not to splinter into self-contained local or regional spheres – where the means of production would be in detention, to the benefit of labour and the detriment of exchange-value – they will have to be planned. How deep would such planning have to go? Could it not stay on a surface of cables linked with wires, much as the state furnishes any other infrastructure to capital without meddling in its truly internal affairs?

The first thing to keep in mind here is that any transition, and particularly one in the abstract

key, requires investments on a scale out of the ordinary. But capital is not rising to the occasion. From the first plants in California in the 1980s until the moment of this writing, not a single CSP installation has seen the light of the day without considerable public funding; there seems to be no way to get the ball of a Desertec or Gobitec rolling unless states throw their full weight behind it; offshore farms – still accounting for a mere 2 percent of global wind capacity – pose the same challenge, as do the transmission systems tying them all together. While they might yield cheaper electricity in the long run, technologies for concentrating the flow can only be put into operation at high initial costs.[42] Numbers fly around – the International Energy Agency (IEA) says the world should spend 1 trillion dollars per year until 2050 to shift to renewables – but however one counts, it is evident that the investments needed are colossal and that *only a fraction has so far materialised*. Total spending in 2012 amounted to one-third of the level posited by the IEA. If the decisions remain in the hands of private agents, all indications are that too little will happen too late. There is something pathetic about the UN climate chief Christina Figueres *begging* financial institutions to please pour some money into 'green infrastructure': they hold the keys – not she, nor any elected or intergovernmental body – but they just won't open the doors.[43]

Not that there is a lack of money: the financial players of the world have hundreds of trillions of dollars at their disposal. Not that they shun risky projects: they are willing to gamble their fortunes on the most hazardous speculation. Instead, as Swedish researchers Robin and Staffan Jacobsson argue, the dynamics of financialisation have made private investors utterly unfit to bankroll a transition, the chase for instant profit taking them ever further from a super grid or an offshore farm. When the average stock is owned for a mere twenty-two seconds, why would they underwrite a long-term project for exploiting the flow with little in the way of guaranteed revenues?[44] Abandoning the illusions, Jacobsson and Jacobsson recommend that the states pick up two sledgehammers: a complete restructuring of the financial sector and the founding of public investment banks with massive lending capacity. Then the infrastructure could be built from the ground up.

If states alone are fit to commit to the investments, so only states and other public authorities can make the imperative decisions. The City of Los Angeles has one of the more farsighted energy policies in the US: terminating all contracts for coal-fired power, investing heavily in wind, establishing utility-scale photovoltaics in the desert, linking up with wind and solar in seven western states, it is well on its way to generating a third of its electricity from renewables by 2020, replacing in the course of a decade 70 percent of a power infrastructure built over a century. What makes such a comparatively bold venture possible? In a piece for *Nature Climate Change,* Democratic mayor Antonio R. Villaraigosa and two collaborating scientists point out the decisive factor: the city has retained full ownership and control of its utility. Procurement, generation, transmission and grid integration fall under the responsibility of one and the same department, ruled by elected officials *who can take the measures needed to stay on target*.[45]

But grids and utilities across the world are now undergoing privatisation. Once they end up behind the fences of private property, a public authority cannot simply enjoin them to switch to the flow – unless it trespasses onto that property. A private energy company will, as Naomi Klein underscores in her magnificent *This Changes Everything: Capitalism vs. the Climate,* turn to renewables only on the condition that it is profitable. It can attend to no other bottom line. Even if it were to voluntarily set its own targets for higher efficiency or a larger share of renewables, experience suggests that such gains will – Jevons's paradox once more – be outstripped by the growing size of businesses. But states and their municipalities can have other goals than profit

and are under no compulsion to expand like capital. Not only in American cities but in the world as a whole – and particularly on the critical continent of Asia – they simply have to take charge of the transition if there is to be anything of the kind.[46]

That would mean engaging in destruction as much as in creation. Expressing a common credulity, Scheer writes that 'every single investment in renewable energy is synonymous with CO_2 avoidance': if you erect a wind turbine on the hill, it will automatically replace a proportionate quantum of coal. But that is not how a capitalist economy works. Environmental sociologist Richard York analysed data from nearly all the countries in the world for the period 1960–2009 and found that 1 kilowatt-hour of non-fossil electricity replaced an average of 0.1 kilowatt-hour of fossil electricity. Rather than displacing the coal and avoiding the CO_2, a wind turbine adds another slice to an ever-growing energy pie; merely building the flow infrastructure will accomplish a tenth of a transition, unless there is a simultaneous *'direct suppression of fossil-fuel use*'.[47] This is one reason for the perverse situation of overcapacity and excess of renewable energy technologies: from a human point of view, there is of course *too little* of them, but as long as the markets are overflowing with fossil fuels, they will remain just another brimful niche. It would be foolhardy, then, to trust in demand and supply as the mechanisms of the transition. If solar and wind were to become radically cheaper than fossil fuels, demand for the latter might fall – only to induce a corresponding fall in their prices, reviving demand and reestablishing an equilibrium of profligacy.[48]

Invest, decide, suppress: not the behavioural pattern of your average neoliberal state. As Klein maps out in detail, the entire logic of neoliberalism runs counter to the basic requirements of the transition: instead of resources for investment, we get ever more famished public coffers; the opposite of intervention, states have systematically deregulated markets; loathing the mere thought of extending their influence, they give up one sector after another to private agents. The fact that scientists awakened to the magnitude of global warming and called for a drastic change of course just as governments, under neoliberal hypnosis, surrendered the very idea of interfering with the self-driving market is indeed – another key aspect of climate temporality – an 'epic case of bad historical timing'.[49] These insights are shared by less radical thinkers. A U-turn to renewables can be realised solely by means of 'concerted social and political efforts beyond the traditional sorts of economic incentives,' in the restrained words of Jacobson and Delucchi. Even Anthony Giddens, who can hardly be accused of communist sympathies, recognises that the powers of the state 'have to be invoked if a serious impact on global warming is to be made': there must be a 'return to planning, in some guise or other'. In the Soviet Union, the five-year plans often missed their targets; we need plans that do not. There is no alternative: planning is 'inevitable'.[50] It has to cut far deeper into our economies than any prevailing paradigm permits, and even deeper once the signal dimension of climate change – time – is fully taken on board.

The more CO_2 that has been released into the atmosphere, the smaller the scope remains for limiting global warming. Consider the 2 degrees target, not as a threshold to dangerous global warming – we are well within its field of force – but rather as a demarcation between the dangerous and the extremely dangerous, beyond which positive feedback mechanisms might run amok. To have at least a reasonable chance of maintaining an orderly civilisation, we should keep the rise in average temperature below that line; the emissions explosion of the early twenty-first century, however, has pushed the climate system perilously close to it. The carbon budget for 2 degrees is in the process of being consumed: if global emissions remain at 2014 levels, it

will be entirely exhausted within thirty years. But emissions are, of course, *growing fast;* current projections suggest a continued growth of upwards of 3 percent throughout the second decade of the twenty-first century. Only a narrow field for a war of manoeuvre is still there. According to the latest scientific consensus, global emissions would have to peak before 2020 and then decrease by *at least* 3 percent per year – the same pace at which they currently increase, the explosion inverted into a flood of cuts, business-as-usual completely reversed.[51] What if the peak occured after 2020, perhaps ten or twenty years later? Then the emissions would have to be slashed even more brutally, if anyone then still dares to aim for 2 degrees. Such is the subversive, immutable arithmetic of climate change.

It tightens the screws on Marxists as much as on everyone else. Any argument along the lines of 'one solution – revolution' or, less abbreviated, 'socialist property relations are necessary to combat climate change' is now untenable. The experiences of the past two centuries indicate that socialism is an excruciatingly difficult condition to achieve; any proposal to build it on a world scale before 2020 and *then* start cutting emissions would be not only laughable, but reckless.[52] At this moment in time, the purpose of an inquiry into the climatic destructivity of capitalist property relations can only be *a realistic assessment of the obstacles* to the transition. They grow higher by the day. If the temporality of climate change compels revolutionaries to be a little pragmatic, it obliges others to start pondering revolutionary measures. Had the dismantling of the fossil economy begun, say, after the UNFCCC was signed in 1992, when the CO_2 concentration in the atmosphere was 355 parts per million rather than the current 400, the trick might have at least hypothetically been made with some gentle nudging of the market – a little tax here, a little tariff there, some discounts for electric vehicles – but the longer the postponement, the more dramatic the demolition must be when it starts.[53]

Hermann Scheer thinks individuals and households can do it. He opposes mandatory emissions reductions, 'set quotas and deadlines,' anything that smells of 'technocratic planning'; if only the powers of the sun are set free, the shift will be completed spontaneously, from below. Let self-interest rule and people will realise that 'small is profitable.' Adhering to the odd German ideology known as 'ordoliberalism' – a putative third way between neoliberalism and Keynesianism, not retreating from nor intervening in the market but actively midwifing its innately benevolent forces – he champions feed-in tariffs as the panacea of the transition: guarantee producers a revenue when they feed renewable electricity onto the grid and they will do it. The point is to conceive of solar technologies 'in such a way that, like the steam-engine before them, they will become an unstoppable economic force'.[54] A lot could be said about this programme; suffice it to conclude that it belongs to circa the mid-1980s and has no aid to offer climate politics in a millennium when the traditions of the dead breathe ever heavier down the necks of the living and the not-yet-born.

If global emissions are to contract by 3 percent a year, those of rich nations might have to shrink by 5 or 10 percent or even more to give developing countries some space. According to Kevin Anderson, distinguished expert on mitigation scenarios, humanity might retain a 50 percent chance of staying below 2 degrees if emissions hit zero before 2045, but then 'flying, driving, heating our homes, using our appliances, basically everything we do, would need to be zero carbon – and note, zero carbon means zero carbon.' Cuts of this magnitude have no historical precedent. The collapse of the Soviet Union set the record, with emissions dropping by 5 percent for a couple of years in the 1990s. How, then, could such a last-ditch effort possibly succeed? Anderson states the obvious: the market cannot do it. 'Conventional market economics

is premised on understanding and making small (marginal) changes. But with climate change, we are not talking about small changes; we are dealing with a world of very large changes, outside the realm of standard market theory.' The alternative? 'Planned economic recession,' claim Anderson and his colleague Alice Bows.[55] They do not say it loud, but a planned economic recession would of course objectively constitute a war against capital. The politics of climate change mitigation follow a tragic historical timeline, running via Eduard Bernstein to Leon Trotsky: 'Comrades, we stand face to face with a very difficult period, perhaps the most difficult period of all. To difficult periods in the life of peoples and classes there correspond harsh measures,' as Trotsky wrote in *Terrorism and Communism* in the *annus terribilis* 1920. Or, with Walter Benjamin: 'To the process of rescue belongs the firm, seemingly brutal grasp.'[56]

A more popular analogy than war communism is that of the Second World War. In one of the most clear-sighted papers on climate politics so far, Australian researchers Laurence L. Delina and Mark Diesendorf lay out the case for wartime mobilisation as a model for rapid abatement of climate change: conjuring up an enormous defence budget after Pearl Harbor, the American state planned and enforced the production of everything from airplanes to ammunition. The executive branch of the government directed the resources of the nation, summoned labour, requisitioned properties, forced manufacturers to accept contracts, terminated the production of certain goods – notably private cars – and, in short, mobilised the economy in toto for the sole aim of defeating the enemy. When the task is to cut emissions by some 10 percent per year, nothing less is required than a similar centralisation of power under 'a special Ministry for Transition to a Low-Carbon Future'.[57] Given exceptional prerogatives, that ministry would raise funds, redirect labour, speed up R & D, sequester fixed capital based on the stock, organise mass production of everything from buses to CSP mirrors and roll out the full powers of the flow. Annual emissions cuts of a set quantity could be executed against the will of fossil capital and its representatives. Delina and Diesendorf estimate that such regimes could bring the transition to its zero-carbon conclusion within twenty-five to thirty years in developed countries and perhaps forty in the world as a whole. Four political entities – the US, the EU, China and India – currently account for more than half of all emissions: set up one special ministry in each and we would be on our way.[58]

The Second World War analogy has its limitations, however. Big business had little to lose from entering the war. A zero-hour transition to the flow would have to be imposed by forces antagonistic to the interests of fossil capital: in the absence of a mass movement, 'it seems unlikely that governments will undertake emergency mitigation, even when life-threatening climate disasters occur.'[59] For some forces, a planned economy for power is an absolute abomination. They will fight the idea, come flood or drought, and much prefer the manipulation of a very different entity.

The Last Escape from Planning

The precipice is already in view, but the train of the fossil economy only runs faster in its fixed tracks – so what do we do now? Maybe we could put mirrors in orbit to reflect sunlight back into space. Or we could bleach the clouds, or paint the roofs white, or suck carbon out of the air by artificial trees and pump it underground, or sprinkle the oceans with iron so as to stimulate the production of planktons, whose tiny bodies capture CO_2 through photosynthesis and carry it into

the seabed when they die… Since the scale of the emissions explosion became clear, much interest has been diverted towards these and other methods of *geoengineering,* commonly defined as 'deliberate, large-scale intervention in the climate system designed to counter global warming or offset some of its effects'.[60] Long regarded as the fantasy of some mad scientist, it became a topic of intense and perfectly serious research after Paul Crutzen, fresh from having introduced the Anthropocene concept, published an article in *Climatic Change* in 2006 suggesting that humans should strive to imitate volcanic eruptions. In June 1991, Mount Pinatubo in the Philippines spewed out a plume of sulphur into the stratosphere, blocking some of the incoming solar radiation: the following year, the average temperature on earth fell by half a degree. We could spread sulphate aerosols, intentionally and systematically, like a sunshade around our planet.[61]

Since Crutzen's intervention, there has been a veritable eruption of studies and preparations: workshops, computer simulations, think tank reports, hundreds of scientific papers, theme issues of the main journals in climate science, actual live experiments, start-up companies, patents. Most work focuses on the 'Pinatubo option,' or 'solar radiation management' through sulphate aerosol injection, in the more clinical terms. Of all the colours on the geoengineering palette, this is believed to be the most effective.[62] It could be up in the air within months, a couple of airplanes circling through the stratosphere some 20 km above the earth, spraying sulphates and suspending the effect of two centuries of fossil fuel combustion in the time it takes to build one wind farm. In *A Case for Climate Engineering,* physicist-entrepreneur David Keith stresses how fantastically cheap the operation would be – instant relief 'for the price of a Hollywood blockbuster,' or about one-hundredth of current spending on renewable energy technologies.[63] As CO_2 continues to build up in the atmosphere, and as sulphate aerosols only stay in place for a year before sailing down towards earth, the annual injections would have to grow perpetually; Keith estimates that if we start in 2020, we would need a million tons of sulphate per year and a fleet of a hundred planes by 2070. The chemical is abundant. Existing aircraft can be easily adapted for the job.

Solar radiation management through sulphate aerosol injection is likely to deplete the ozone layer, upset precipitation patterns, possibly shut down the Asian monsoon, disrupt photosynthetic productivity, whiten the sky, tinker with the balance between day and night as well as winter and summer, 'contribute to thousands of air pollution deaths a year' – Keith's words – as the soot comes drizzling down, induce lasting addiction to larger doses, certainly lower the efficiency of solar panels by diluting the sunlight.[64] But let us focus on just one detail. To cancel out the rising CO_2, the shade must thicken each year – but imagine something goes wrong. Imagine some part of the technology breaks down, or an unexpected side effect turns out to be unbearable, or India shoots down the planes or shoots up some counteracting substance because the monsoon has failed, or the companies can no longer agree on the terms – anything that turns the system off. What happens then? Known as the 'termination problem,' the result would be an extreme pulse of sudden warming. As the lid is removed, the radiative forcing of all the accumulated CO_2 would boil over violently: according to the latest research, average temperatures on the land surface might increase by 3 degrees *per decade*. Depending on how long the system has been in operation and how much CO_2 has been emitted in the meantime, the spike might be slightly lower or dramatically higher; some regions could heat up by 15 degrees per decade for a while. Now it is well known that the ability of the ecosystems to adapt is conditioned not only by the

magnitude, but also by the *rate* of the warming. At this rate, without precedent in geological history, they would all fry.[65]

Bill Gates is now the world's number one financial supporter of geo-engineering research. A patron of Keith – the blurb for whose book he penned – and other pioneers, he owns shares in companies developing technologies for delivering the sulphates, brightening the clouds and capturing the carbon. N. Murray Edwards, a Canadian oil magnate knee-deep in the Alberta tar sands, is a generous funder; the American Enterprise Institute and other think tanks of the conservative right – just recently denying climate change – eagerly promote the smart solution; Shell, BP, Exxon, Boeing are on board.[66] Rex Tillerson, the man who wants to drill and make money, has laid out a practical view of global warming: 'It's an engineering problem and there will be an engineering solution.'[67] No special intelligence is needed to decode the interests at work here, but what of the scientists who are clearly genuinely concerned about where business-as-usual is taking us? Had it not been for their involvement, geo-engineering would not have come anywhere near its current position as a centrally placed emergency brake.

Crutzen ended his article with a frank admission: 'The very best would be if emissions of the greenhouse gases could be reduced so much that the stratospheric sulphur release experiment would not need to take place. Currently, this looks like a pious wish.'[68] Keith bases his entire argument on the premise of 'economic inertia. We suffer from the persistent illusion that we can rapidly accomplish the deep structural changes necessary to decarbonize our economy' – some might have wild ideas about intervening in capitalism, but instead we should treasure that system, which has, by the way, made 'enormous progress in managing environmental problems over the last half century' (proof: the US Clean Air Act).[69] Keith would obviously break out in a rash if someone proposed a planned economy for power, but he is more than willing to countenance a biosphere run by 'central planners' who regulate the thermostat, optimise conditions for agriculture, fine-tune the climate for every living being.[70] And here we have the red-hot engine of geoengineering. Analogies with wartime mobilisation appear every now and then in the literature but evoke none of the buzz surrounding the Pinatubo parallel. Planning the economy is the ultimate taboo; planning the climate is worthy of close consideration, an idea cognate with genetic engineering, GPS systems, smart devices, in vitro meat, drone warfare and other natural elements of late capitalist hypermodernity. Fossil capital would die in a transition; geoengineering may give it a new lease on life; what began as real subsumption of labour must end as real subsumption of the biosphere. There is that nagging feeling that a fleet of airplanes packed with sulphur are far more likely to show up than a special Ministry for a Transition to a Low-Carbon Future. It has become easier to imagine deliberate, large-scale intervention in the climate system than in capitalism.

CHAPTER 16

Time to Pull the Plugs: On CO_2 as an Effluent of Power

The Name of the Epoch

In *The God Species,* Mark Lynas builds his narrative around a familiar villain: we, us. 'God's power is now increasingly being exercised by us. We are the creators of life, but we are also its destroyers,' and 'our collective power already threatens or overwhelms most of the major forces of nature,' and 'our detritus gets everywhere,' and 'we are altering the characteristics of the atmosphere in unanticipated ways,' and on and on ad nauseam.[1] This must be one of the most common tropes in climate change discourse. We, all of us, you and I have created this mess together and make it worse each day – and with such an indiscriminate apportioning of blame, no end to the ordeal is in sight. It is perhaps not a coincidence that Paul Crutzen is the spiritual father of both the Anthropocene narrative and the geo-engineering solution, or that Lynas embraces the environmental Kuznets curve, sulphate aerosol injection – 'for me this is a reason for optimism' – and the American view of China as the saboteur of climate politics.[2] If humanity as a whole drives the locomotive, there is no one to depose. A revolt against business-as-usual becomes inconceivable.

Enter Naomi Klein, who bases her call to revolt on the proposition that 'we are stuck because the actions that would give us the best chance of averting catastrophe – and would benefit the vast majority – are extremely threatening to an elite minority.'[3] Upon release of the call, defendants of the mainstream discourse frowned on her. In his review for *The Observer,* philosopher John Gray stated that 'Klein describes the climate crisis as a confrontation between capitalism and the planet. It would be more accurate to describe the crisis as a clash between the expanding demands of *humankind* and a finite world'; in the *London Review of Books,* Paul Kingsnorth, ex-environmentalist and longtime purveyor of the view that collapse is inevitable, argued that 'climate change isn't something that a small group of baddies has foisted on us … In the end, *we are all implicated.*'[4] After denialism, this is emerging as the great divide in the debate on global warming.

Building a sophisticated case for the *we*-view demands a lot of imagination. In two high-profile essays, noted post-colonialist Dipesh Chakrabarty has questioned the utility of historical

materialism for understanding climate change and come down squarely on the side of the Anthropocene narrative: 'Imagine,' he writes,

> the counterfactual reality of a more evenly prosperous and just world made up of the same number of people and based on exploitation of cheap energy sourced from fossil fuel. Such a world would undoubtedly be more egalitarian and just – at least in terms of distribution of income and wealth – but the climate crisis would be worse!

Yes, imagine a planet Earth inhabited by 9 billion human beings, every one of whom owned five houses, three SUVs and a private airplane. Wouldn't we all burn! Indeed, such a world would be physically impossible. From his sci-fi scenario Chakrabarty draws the conclusion that 'the climate crisis is not *inherently* a result of economic inequalities,' when in fact it only reminds us of a stark reality: climate change has come about because a fortunate few have appropriated the bulk of the atmospheric carbon sink through massive emissions *which by definition cannot be extended to humanity as a whole*.[5] If everyone lived like a rich American, guzzling cheap fossil energy, we would be at 6 degrees tomorrow and then no one would live. Logically *and* historically, in the actually existing world, from the rays of steam to the twilight of globalisation, the crisis is inherently a result of some having more than – nay, taking from – others, the accumulation of fossil capital a very negation of universal species-being.

But Chakrabarty insists: 'The poor participate in that shared history of human evolution just as much as the rich do.' Frankly speaking, 'the lurch into the Anthropocene has also been globally the story of some long anticipated social justice, at least in the sphere of consumption. This justice among humans, however, comes at a price.'[6] With this argument, Chakrabarty manages to mistake his invented planet for the one he lives on – truly an impressive feat of the human imagination. Driving it further, he maintains that humanity is unified not only as the source but also as the victim of this crisis. 'Unlike in the crises of capitalism, there are no lifeboats here for the rich and the privileged (witness the drought in Australia or recent fires in the wealthy neighborhoods of California)'; the human species is 'a universal that arises from a shared sense of catastrophe'.[7] But exit Chakrabarty's world of ideas and witness Katrina in black and in white neighbourhoods of New Orleans, Sandy in Haiti and in Manhattan, sea level rise in Bangladesh and in the Netherlands, all the realities of differentiated vulnerability in any impact of climate change, direct or indirect. For the foreseeable future – indeed, as long as there are class societies on earth – there *will* be lifeboats for the rich and privileged, and there will *not* be any shared sense of catastrophe. More than ever, class divisions will become matters of life and death: who gets to drive out of the city when the hurricane approaches; who can pay for seawalls or homes solid enough to withstand the coming flood. The capitalist class is evidently not very worried. Quite a few fractions of it are rather gearing up for some sweet profits from newly available oil resources in the Arctic, desalination plants and floating cities, ownership of ever more precious land, the construction of walls, fire insurances, genetically modified crops to withstand the heat, geoengineering.[8] As in all crises of capitalism, this one presents a welter of opportunities for those in clover, and *après moi, le déluge*.

If 'the Anthropocene' is an indefensible abstraction at the point of departure as well as the end of the line, might there be a more adequate term for the new geological epoch? Our suspicion that the interests once entering the locomotive are still inside it seems to have been confirmed: accumulation of capital through abstract space, abstract time and anarchic competition runs ever faster away from the flow, demanding a fuel of matching qualities in constantly growing

quantities. Unlikely to gather anything like a consensus behind it, a more scientifically accurate designation, then, would be 'the Capitalocene'. This is the geology not of mankind, but of capital accumulation. To paraphrase Althusser, capitalist time, biochemical time, meteorological time, geological time are being articulated in a novel whole, determined in the last instance by the age of capital, even though it will come to an end long before this epoch does. The long tail of CO_2 from the stock will stretch out for hundreds of thousands of years; a new glacial period might not form for half a million.[9] Little did a cotton master switching to steam in Lancashire or a car manufacturer moving to China suspect that this would be his one gift to eternity. The Capitalocene will outlive them all, like oxygen the stromatolites.

There is, then, another way to measure CO_2: as an effluent of power, of *our* defeats and *their* victories. But this requires a conception of history very different from that established in climate change discourse.

In the State of Emergency

> Where the deep, dark drive of the animal (as countless stories tell) finds a way to avoid the approaching danger, seemingly before it can be seen, this society … stumbles as a blind mass into every danger, even the one lying just around the corner, and the variety of individual goals counts for nothing against the identity of forces dictating developments. Over and over again it has been shown that the way society clings to normal (but already long lost) life is so fierce as to frustrate the truly human use of intellect and foresight, even in the face of drastic danger. The upshot is that society today presents a perfect picture of stupidity: uncertainty, indeed perversion of the instincts so essential to life and importance, not to say decay of the intellect. This is the mood of the bourgeoisie as a whole,

except Walter Benjamin did not write 'the bourgeoisie' but 'Germany's middle class,' and the year was 1928.[10]

The trope of the undifferentiated *we* does violence to the historical record. For E. A. Wrigley, the 'inorganic economy' was always a blessing, up until the very moment when the news of climate change broke: then it suddenly morphed into a curse. 'The benefits which have flowed in the wake of the industrial revolution are great *and universal,*' but now we must ask if the pursuit of 'prosperity for all' has too high a price – the fantasy world, again. This is an act of exoneration. It idealises the history of the fossil economy. A more accurate philosophy of it would depart from Thesis VIII in Benjamin's *On the Concept of History:* 'The tradition of the oppressed teaches us that the "state of emergency" in which we live is not the exception but the rule.'[11] The tradition of the handloom weavers, the cotton spinners, the calico printers, the wool combers and all the other workers trampled underfoot by the steam demon and its iron men teaches us that the state of emergency arrived at dawn, in the land of Britain itself – and then we have not even glanced at the inhabitants of the distant shores where British steam power landed. For them, the losses were of another order of magnitude.

In *The Condition of the Working Class in England,* Engels walks among the ecological ruins of the Industrial Revolution, with particular attentiveness to – not to say obsession with – the atmosphere. 'The atmosphere of the factories is, as a rule, at once damp and warm'; workers 'are drawn into the large cities where they breathe a poorer atmosphere than in the country,' in streets poisoned by 'carbonic acid gas, engendered by respiration and fire,' while the bourgeoisie flees the vitiated air. In the coal mines, CO_2 and CH_4 trigger 'the most terrifying calamities, and these come directly from the selfishness of the bourgeoisie'. At one point, Engels meets a member of

that class in a Manchester street and confronts him with the ubiquitous catastrophes, whereupon the man curtly responds: 'And yet there is a great deal of money made here; good morning, sir.'[12] If I can drill and make money…

From this historical standpoint, climate change is not so much a surprising reversal of fortunes as a *lifting of the veil* on two centuries of fossil capital – which is, of course, the literal meaning of the Greek word *apokalyptein*.[13] The truth has been hidden from view; the present moment reveals the meaning of what has been going on for a long time. Benjamin's angel of history 'sees one single catastrophe, which keeps piling wreckage upon wreckage and hurls it at its feet'; Theodor Adorno concurs – 'normality is death' – but emphasises that the eternity of horror 'manifests itself in the fact that each of its new forms outdoes the old. What is constant is not an invariable quantity of suffering, but its progress towards hell: *that is the meaning of the thesis of the intensification of antagonisms.*'[14] From the very start, at the very smallest scale – in the hot factory, the smoky street, the mine laden with explosives – there emerged a pattern – some swept away by the storm we call progress, others sailing to their fortunes – subsequently magnified and iterated on progressively larger scales, until climate scientists discovered it in the biosphere as a whole, where the self-similar storm now spirals on. Every impact of climate change unfolds a fraction of that hitherto folded past.

Why engage in a lost cause?, sceptics might ask of the struggle against climate change, and not without reason. But fighting from a position of defeat is nothing new: global warming is itself a sum of lost causes. Commoners and Luddites and plug drawers and innumerable other vanquished challengers counsel us to rethink 'the moment of the danger' as extreme and unprecedented *by dint of* being the latest manifestation of the past. Or, in Benjamin's supremely visionary words: 'The only historian capable of fanning the spark of hope in the past is the one who is firmly convinced that *even the dead* will not be safe from the enemy if he is victorious. And this enemy has never ceased to be victorious.'[15] Benjamin's conception of history – his voluntaristic messianism, organised pessimism, revolutionary melancholia – draws its inspiration from the heritage of the oppressed in order to derail the ultimate disaster of the present. And what is needed today, if not some global edition of the Plug Plot Riots? Go and stop the smoke! That might seem like an exceedingly improbable event, but political action can never be based on probability calculations – that would be swimming with the tide or sailing with the storm. At the time of this writing, a global climate movement is gathering momentum.[16] It should be the movement of movements, at the top of the food chain, on a mission to protect the very existence of the terrain on which all others operate, but the question is – as so many have pointed out – whether it can attain that status and amass a social power larger than the enemy's *in the little time that is left*.

But then again, every truly revolutionary movement has faced a similar predicament, as understood by Benjamin. 'Marx says that revolutions are the locomotive of world history. But perhaps it is quite otherwise. Perhaps revolutions are an attempt by the passengers on this train – namely, the human race – to activate the emergency brake.' The prospects are dismal: hence the need to spring into action. As in previous emergencies, but now more than ever, as we soar above 400 ppm, we must 'accept symptoms of collapse as the quintessence of stability and see salvation alone as something so extraordinary as to pass understanding and verge on the miraculous'.[17] The only ones with at least a hypothetical ability to conjure up that miracle are humans.

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Alf Hornborg is my sheikh. More than anyone else, he made me see how thoroughly power and nature have become interfused, how accelerating degradation of the environment must be understood in relation to escalating injustices, how progressive scholars and activists ignore that nexus at their peril. I owe him an immense debt. He supervised my thesis; Stefan Anderberg was my co-supervisor; the LUCID PhD students were my colleagues: I thank them all. Also, many thanks to the Human Ecology Division and the Human Geography Department (special thanks to Karl-Johan Lundquist), as well as to all the human ecology students – particularly at the masters programme Culture, Power and Sustainability – who contribute to making this part of Lund University such a unique environment for radical political ecology.

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List of Abbreviations

BNEF – Bloomberg New Energy Finance
BO – Bradford Observer
CC – Climatic Change
CJE – Cambridge Journal of Economics
CM – Caledonian Mercury
CtB – Circular to Bankers
EE – Ecological Economics
EHR – The Economic History Review
EP – Energy Policy
ER – Edinburgh Review
ERL – Environmental Research Letters
FT – Financial Times
GH – Glasgow Herald
GRL – Geophysical Research Letters
HL – House of Lords Papers
HM – Historical Materialism
HO – Home Office
IAR – Industrial Archaeology Review
ILN – Illustrated London News
IRSH – International Review of Social History
JEH – Journal of Economic History
JEP – Journal of Economic Perspectives
JHC – The Journal of the House of Commons
LT – Leeds Times
MC – Morning Chronicle
MECW – Marx Engels Collected Works
MG – Manchester Guardian
MM – Mechanics' Magazine
NCC – Nature Climate Change
NG – Nature Geoscience
NLR – New Left Review
NS – Northern Star
NSAS – The New Statistical Account of Scotland
NYT – New York Times
PC – Preston Chronicle

PIVRSB – Papers on Irwell Valley Reservoir Schemes (Bolton)
PIVRSP – Papers on Irwell Valley Reservoir Schemes (Preston)
PNAS – Proceedings of the National Academy of Science
PP – Parliamentary Papers (House of Commons)
PTERC – Papers of Turton and Entwistle Reservoir Commissioners
PTRSA – Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences
RFIHYE – 'Report of the Factory Inspectors for the Half-Year Ending…'
RHO/OPBCE – Records of the House of Commons, Opposed Private Bill Committee Evidence
SPCK – Society for Promoting Christian Knowledge
TBNHS – Transactions of the Buteshire Natural History Society
TE – The Economist
TT – The Times
UNCTAD – United Nations Conference on Trade and Development
WR – Westminster Review

Notes

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2. Scarcity, Progress, the Nature of the Human Species

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3. The Long Life of the Flow

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4. 'There Are Mighty Energies in those Masses'

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Kennedy, *Observations;* W. Radcliffe, *Origin of the New System of Manufacture Commonly Called Power-Loom Weaving,* Clifton NJ, 1974 [1828]; D. Bythell, *The Handloom Weavers: A Study in the English Cotton Industry During the Industrial Revolution,* Cambridge, 1969.

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44 PP (1834) X; PP (1835) XIII; Committee, *Letter;* Thompson, *Making,* ch. 9; Bythell, *Handloom*. Quotation from Baines, *History,* 493.

45 Committee, *Letter,* 10. Emphasis added.

46 Baines, *History,* 494–5.

47 PP (1834) X, 400, 478 (Laurence Don); PP (1835) XIII, v. See further e.g. PP (1834) X, 54, 70, 343, 464, 477–8; PP (1835) XIII, 1, 205, 211–14. Attempts to crack down on embezzlement by means of legal prosecution proved fruitless. For closer consideration of this and other aspects of the rise of the power loom, see Malm diss., 220–40.

48 PP (1834) X, 407. See further ibid., 444; PP (1835) XIII, 100; Bythell, *Handloom,* 72.

49 Committee, *Letter,* 15; royal commission quoted in *Westminster Review* [hereafter *WR*], 'The Hand-Loom Inquiry Commission,' July 1841, 68. Emphasis added. On eradication of embezzlement as the chief advantage of the power loom, see also A. Redford, *Labour Migration in England 1800–1850,* Manchester, 1976 [1926], 130; M. Berg, *The Machinery Question and the Making of Political Economy, 1815–1848,* Cambridge, 1980, 241–2; Bythell, *Handloom,* 85–6; von Tunzelmann, *Industrialization,* 197–9.

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5. Puzzles of the Transition

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2 Chapman, *Cotton,* 18, 119. Emphasis added.

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5 The higher productivity of power looms is another matter. Ten power looms requiring 1 hp: Fairbairn's testimony in Records of the House of Commons, Opposed Private Bill Committee Evidence [hereafter RHO/OPBCE], HL/PO/PB/5/9/4, Committee on Bolton Waterworks Bill, 18 May 1843, 124; Ure, *Cotton, Vol. 1,* 304–6; Ure, *Cotton, Vol. 2,* 405.

6 Kanefsky, *Diffusion,* 336–8.

7 Ibid., 349.
8 These figures were collected by the factory inspectors, as reported in *Journal of the Statistical Society of London,* 'Increase of Steam-Power in Lancashire and its Immediate Vicinity,' 1 (1838), 315. See further 'RFIHYE 31 December 1841,' 93; Kanefsky, *Diffusion,* 289–90.
9 Wood's figure for 1835 is 188,000 handloom weavers. Wood, *Wages*, 127. On his figures as low estimates, see Timmins, *Shift,* 24–32. For a fuller statement of the statistical procedure adopted here, see Malm diss., 243–4.
10 Figures calculated through the same procedures as above, with data from Wood, *Wages,* 128; Kanefsky, *Diffusion,* 245–7, 292–4.
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12 Ibid., 259, 256. On 1838 as culmination, see Kanefsky, *Diffusion,* 255.
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15 Landes, *Prometheus,* 42, 54.
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17 Fairbairn, *Treatise Pt 1*, 91.
18 T. Reynolds, *Stronger Than a Hundred Men: A History of the Vertical Water Wheel,* Baltimore, 1983, 319; Hills, *Industrial,* 145, 184; von Tunzelmann, *Aspects,* 133; von Tunzelmann, *Industrialization,* 51–61; Kanefsky, *Diffusion,* 167–9; Hills, *Steam,* 77–8.
19 Sutcliffe, *Treatise*, 251.
20 W. Fairbairn, *The Life of Sir William Fairbairn, Bart: Partly Written by Himself, Edited and Completed by William Pole,* Newton Abbot, 1970 [1877], 122. For a history of the company, see C. Brogan, *James Finlay & Company Limited: Manufacturers and East India Merchants, 1750–1950,* Glasgow, 1951.
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24 First two quotations from Finlay Archive, UGD91/1/5/3/6/3, letter from Mr. Graich, 3 February 1838; third from anonymous and undated, but in all likelihood written by manager Thomas Norton in 1846, UGD91/1/5/3/13/1, 'Brief'. Emphasis in original. On coal prices in Edinburgh and Birmingham at this time, see von Tunzelmann, *Aspects,* 69.
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30 Cooke Taylor, *Notes,* 30; Boyson, *Ashworth,* 14, 47, 62; RHO/OPBCE, Bolton, 17 May 1843, 109.
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36 Kanefsky, *Diffusion,* 172–5.
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6. Fleeing the Flowing Commons

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25 Baines, *History,* 86; Cooke Taylor, *Notes,* 118, 155.

26 *MG* 30 July 1831.

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29 PIVRSP, DDX951/13, plans and sections of proposed reservoirs, undated, c. 1833.

30 PIVRSP, plans and sections; 'Peter Ewart & Thomas Ashworth's Observations'; figure on Manchester from von Tunzelmann, *Aspects,* 42; Ashworth in *MG* 17 November 1832.

31 *MG* 26 January 1833, 30 July 1831, 3 November 1832.

32 PIVRSB, UWR/6, Irwell Reservoirs Bill, 3–36. Quotations from 20, 22, 26.

33 *JHC* 88 (1833), 209.

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38 *MG* 28 September 1836; RHO/OPBCE, Saddleworth, 1837, 1 May, 81.

39 *MG* 28 September 1836; RHO/OPBC, Saddleworth, 1837, 1 May, 63, 81, 147 (quotation from 147); 3 May, 14; 4 May, 117.

40 RHO/OPBC, Saddleworth, 1837, 3 May, 8, 15, 124.

41 Ibid., 1 May, quotations from 16 (Joseph Ogden), 43 (Phillip Chetham). See further 28 April, 1–125.

42 *JHC* 92 (1837), 124, 152, 167, 298, 305, 366; RHC/OPBCE, Saddleworth, 1837, 28 April, 1 and 4 May. (Like all petitions to the House of Commons before 1951, the actual texts were subsequently destroyed.) For considerations on the role of landowners in opposing reservoir schemes, see the more extensive discussion in Malm diss., 262–310.

43 Albinson Collection, maps and plans, flipside: 'Saddleworth Reservoirs: Case of The Trustees of the late Ellis Fletcher, Esquire', dated 1837.

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7. A Ticket to the Town

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2 Woolrich, 'Engineer', 129–30.
3 J. Russell, *A Treatise on the Steam-Engine,* Edinburgh, 1841, xi; von Tunzelmann, *Industrialization,* 2. Cf. Chapman, 'Cost,' 6; Nuvolari, *Making,* 11.
4 J. Farey Sr, *General View of the Agriculture of Derbyshire, Vol. 3,* London, 1817, 514–15. Emphases in original.
5 Farey, *Treatise,* v.
6 Ibid., 7, 406. Emphases added.
7 McCulloch, 'Babbage,' 323. Emphasis added.
8 *The Circulator of Useful Knowledge, Literature, Amusement, and General Information,* 'Mr. M'Culloch's Lectures on Political Economy, at the London Tavern', 9 April 1825, 230; McCulloch, 'Rise', 16.
9 Fairbairn, *Treatise Pt 1,* 67.
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12 W. Turner, 'The Significance of Water Power in Industrial Location: Some Perthshire Examples,' *Scottish Geographical Magazine* 74 (1958), 101, 106; Chapman, 'Peels,' 65–6; Chapman, 'Cost,' 19; von Tunzelmann, *Industrialization,* 135–6; Reynolds, *Stronger,* 267–8.
13 Advertisement in Derby Mercury, December 1771, quoted in Fitton, *Arkwrights,* 30.
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Journal of Population Economics 10 (1997), 358; R. Langlois, 'The Coevolution of Technology and Organisation in the Transition to the Factory System,' in P. Robertson (ed.), *Authority and Control in Modern Industry: Theoretical and Empirical Perspectives,* London, 1999, 49, 53, 59–60; K. Honeyman, *Child Workers in England, 1780–1820: Parish Apprentices and the Making of the Early Industrial Labour Force,* Farnham, 2007, 143–5.

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20 Finlay Archives, 'Note on origin,' Cf. Brogan, *Finlay,* 68–70.

21 'RFIHYE 31st December 1838', 98. See further PP (1833) XXI, A3.37; Finlay Archive, UGD91/1/5/3/6/2, letter from R. Sterling to J. Smith, 1 April 1837.

22 PP (1833) XX, A1.94.

23 Rose, *Gregs,* 28, 110–4; Collier, *Family,* ch. 5; Owens, *Quarry,* 43.

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50 Cf. B. Lewis, *The Middlemost and the Milltowns: Bourgeois Culture and Politics in Early Industrial England,* Stanford, 2001, 293–4.
51 As quoted in Boyson, *Ashworth,* 96. See further PP (1833) XXI, A3.55; PP (1834) XX, A1.171, D1.149, 280; 'RFIHYE 31st December 1838', 96, 101; HL (1842) XXVII, 338–40; W. Dodd, *The Factory System Illustrated,* Abingdon, 1968 [1842], 92; Cooke Taylor, *Notes,* 32.
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53 L. Faucher, *Manchester in 1844: Its Present Condition and Future Prospects,* London, 1969 [1844], 92.
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55 Boyson, *Ashworth,* 141–4.
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57 Ibid.; Boyson, *Ashworth,* 132, 146–7.
58 PP (1834) XX, D1.281. Profit figures from Boyson, *Ashworth,* 16–18, 147–8.
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60 Chadwick Papers, University College London Special Collections, London, correspondence, box 203, letters from Henry Ashworth to Edwin Chadwick, 26 and 24 December 1836.
61 Quotations from Quarry Bank Mill Archive, 'Memoranda,' 46; Cooke Taylor, *Notes,* 24. On strikes and Chartism in the Ashworth colonies, cf. Boyson, *Ashworth,* 135, 149–50; Lewis, *Middlemost,* 292.
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63 Cooke, *Stanley,* 126–7; *NSAS,* 'Neilston, Renfrewshire,' no. 14, 1837, 338.
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78 PP (1833) XX, E.8; cf. Lee, *Cotton,* 114–15, 117; Collier, *Family,* 15–16.
79 PP (1835) XXV, 350; PP (1835) XIII, 140; PP (1833) XXI, D2.38.
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82 Ibid.
83 W. Scott, *Familial Letters of Sir Walter Scott in Two Volumes, Vol. 2,* Boston, 1893, 78. Emphases added.
84 Leigh, *Preston,* 40–3; Fraser, 'Glasgow', 83–4.
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86 Babbage, *Economy,* 306, 230. Emphasis added.
87 Greg Archive, C5/8: 10–13, 17–23, letters from Robert Hyde Greg to Samuel Greg, 14 May and 29 August 1829. Emphasis in original.
88 Quarry Bank Mill Archive, 'Memoranda,' 8. Emphasis added. See further Rose, *Gregs,* 43–4.
89 PP (1834) XX, D1.184; Rose, *Gregs,* 39, 43, 52–5; Collier, *Family,* 39; Owens, *Quarry,* 74. The factory in Lancaster was acquired in 1822, the one in Lancaster in 1827. Business records for them, and for the two water mills in Caton and Bollington, have not survived.
90 Boyson, *Ashworth*.
91 Finlay Archive, valuation of Catrine, Deanston and Ballindaloch. Emphasis added.
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95 Jevons, *Coal,* 150–51. Emphasis added.
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101 J. McCulloch [unsigned], 'Philosophy of Manufactures,' *ER* 61 (1835), 457.
102 See Unwin, *Oldknow,* particularly chs. 2, 8; cf. Buxton, 'Rise,' 208; Williams, 'Inscribing,' 44–6.
103 Jevons Papers, John Rylands Library, Manchester, JA6/9/168, 'Fuel from the sun,' undated clip from *Express,* and note.
104 von Tunzelmann, *Aspects,* 66–8; von Tunzelmann, *Industrialization,* 63–7, 158; Crafts and Wolf, 'Location', 3, 8.
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106 Ure, *Cotton, Vol. 1,* 205.
107 Balderston, 'Abundance,' 574.
108 R. Holden, 'Water Supplies for Steam-Powered Textile Mills,' *IAR* 21 (1999), 41–51; P. Maw, T. Wyke and A. Kidd, 'Canals, Rivers, and the Industrial City: Manchester's Industrial Waterfront, 1790–1850,' *EHR* 65 (2012), 1495–523.
109 Buxton, 'Rise,' 206.
110 'RFIHYE 30th April 1860,' 36.
111 Farey, *Treatise,* 7. Cf. 296, 502; Fairbairn, *Treatise Pt 1,* 67.
112 Chapman, 'Cost,' 19–20, 26–7; Chapman, *Cotton,* 18–9, 33–4; Hills, *Steam,* 118.

8. A Force to Count On

1 HL (1819), *Minutes of Evidence Taken before the Lords Committee Appointed to Enquire into the State and Condition of Children Employed in the Cotton Manufactories of the United Kingdom,* 299 (Job Bottom); Hunter, *Waterpower,* 122.
2 PP (1834) XX. Greg on D1.301.
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6 PP (1834) XX.
7 Senior, *Letters,* 14.
8 See e.g. PP (1834) XX, D1.6, 94, 303; the discussions in the Political Economy Club in May 1837, related in H. Higgs (ed.), *Political Economy Club: Minutes of Proceedings, 1899–1920, Roll of Members and Questions Discussed, 1821–1920, Vol. VI,* London, 1921, 274; Rose et al., 'Origins,' 96; Horner in 'RFIHYE 31st December 1841,' 27.
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11 Ingle, *Yorkshire,* 34, 247.
12 *GH* 28 August 1826. Emphasis added.
13 RHC/OPBCE, Bolton, 23 May 1843, 193, 198–9; 'Report for the quarter ending 30th September, 1844; and from 1st October, 1844, to 30th April, 1845,' 5 (T. J. Howell).
14 Hulbert, *Memoirs,* 213. See further J. Langdon, 'Water-mills and Windmills in the West Midlands, 1086–1500,' *EHR* 44 (1991), 430; Lucas, *Wind,* 139.
15 PP (1834) XX, A1.14; *Manchester Times* 10 February 1849.
16 PP (1834), XX. Cf. von Tunzelmann, *Industrialization,* 171; Kanefsky, *Diffusion,* 176.
17 PP (1833) XX, C2.65 (Edward Birkett). Emphasis added.
18 Boyson, *Ashworth,* 94–6; PP (1834) XX, A1.170.
19 PP (1833) XX, A2.43 (Robert Mustard); PP (1833) XX, A1.37; PP (1833) XX, D1.100 (Humphrey Dyson).
20 PP (1833) XX, 10.
21 Ibid., D2.31. Emphasis added.
22 For extensive accounts of the movement, see R. Gray, *The Factory Question and Industrial England, 1830–1860,* Cambridge, 1996; J. Ward, *The Factory Movement 1830–1855,* London, 1962.
23 Quotations from Ward, *Factory,* 166, 183, 189. The 'law' in Oastler's outburst (emphasis in original) referred to the Factory Act of 1833, which the mill-owners sought to repeal at this point. See below.
24 PP (1832) XV; PP (1833) XX, D1.17–29; S. Finer, *The Life and Times of Sir Edwin Chadwick,* London, 1952, 50; M. Thomas, *The Early Factory Legislation: A Study in Legislative and Administrative Evolution,* Westport, 1970 [1948], 38; J. Ward, 'The Factory Movement,' in J. Ward (ed.), *Popular Movements c. 1830–1850,* London, 1970, 66–7; Hutchins and Harrison, *Factory,* 33–4, 47–53; Ward, *Factory,* 41–64; Gray, *Factory,* 55.
25 PP (1834) XX, C1.19 (J. Whitaker). Emphases added.
26 PP (1833) XX, D2.31 (Robert Hyde Greg); PP (1834), A1.14. Emphasis added.
27 PP (1833) XX, D2.17. Cf. e.g. PP (1832) XV, 250.
28 E.g. PP (1833) XX, D2.132.
29 PP (1834) XIX, D2.224.
30 H. Ashworth, *Letter to the Right Hon. Lord Ashley on the Cotton Factory Question, and the Ten Hours' Factory Bill,* Manchester, 1833; Greg, *Factory;* K. Finlay, *Letter to the Right Hon. Lord Ashley, on the Cotton Factory System, and the Ten Hours' Factory Bill,* Glasgow, 1833; Boyson, *Ashworth;* Rose, *Gregs,* e.g. 78; Gray, *Factory,* 99–101, 124; Cooke, *Rise,* 194.

31 J. Doherty, *Misrepresentations Exposed in a Letter, Addressed to Lord Ashley, M.P.,* Manchester, 1838, 19–20. On Greg and the apprentices, see 23–5.
32 Ibid., 25; Kirby and Musson, *Voice*, 355, 364, 377, 399; Gray, *Factory,* 126.
33 PP (1834) XX. Quotation from J. Hall & Son, Stockport, D1.46; for the supporter of the bill (Thomas Flintoff of Manchester), see D1.208.
34 PP (1834) XX, D1.196–7, 3. Emphasis added. On this capitalist consensus, see further Ward, *Factory,* 115; B. Martin, 'Leonard Horner: A Portrait of an Inspector of Factories', *International Review of Social History* [hereafter *IRSH]* 14 (1969), 412–43; Thomas, *Factory,* 72–3, 78; Lee, *Cotton,* 130; Howe, *Masters,* 180–2.
35 PP (1833) XX, 32.
36 See PP (1816) III, 116–117, 236, 251; Hansard, 23 February 1818, 583; HL (1819) XVI, 420.
37 Tufnell, *Character,* 28; S. Weaver, 'The Political Ideology of Short Time: England, 1820–1850,' in Gary Cross (ed.), *Worktime and Industrialization: An International History,* Philadelphia, 1988, 77.
38 Quoted in Ward, *Factory,* 105. Cf. 98; Finer, *Chadwick,* 51; Thomas, *Factory,* 61–4, 71.
39 PP (1833) XX, 53.
40 Hutchins and Harrison, *Factory,* 41; Finer, *Chadwick,* 56–63; Ward, *Factory,* 102–13; Thomas, *Factory,* 63–4; Gray, *Factory,* 71–2.
41 L. Horner, *The Factories Regulation Act Explained, with some Remarks on its Origin, Nature, and Tendency,* Glasgow, 1834, 7–8, 11; letter from Horner to Senior, 33 May 1837, in Senior, *Letters,* 30. For the full text of the Act, known as 'An Act to Regulate the Labour of Children and Young Persons in the Mills and Factories of the United Kingdom,' see C. Wing, *Evils of the Factory System: Demonstrated by Parliamentary Evidence,* London, 1967 [1837], 431–41. Silk was subsequently exempted.
42 See paragraphs XVII-XIX, XLIV-XLV in the Act; PP (1833) XX, 68; Horner, *Factories,* 14; P. Bartrip and P. Fenn, 'The Evolution of Regulatory Style in the Nineteenth Century British Factory Inspectorate,' *Journal of Law and Society* 10 (1983), 204.
43 H. Marvel, 'Factory Regulation: A Reinterpretation of Early English Experience,' *Journal of Law and Economics* 20 (1977), 380.
44 The Act as included in Wing, *Evils,* 432. Cf. Horner, *Factories,* 9.
45 Chadwick Papers, correspondence, box 203, letter from H. Ashworth to E. Chadwick, 17 June 1836; Hutchins and Harrison, *Factory,* 58–9; Ward, *Factory,* 132; Martin, 'Horner,' 429–30; Thomas, *Factory,* 85–7, 94, 116; Weaver, 'Ideology', 78; Howe, *Masters,* 180–2.
46 A. Peacock, 'The Successful Prosecution of the Factory Acts, 1833–55,' *EHR* 37 (1984), 199, 206–7; P. Bartrip, 'Success or Failure? The Prosecution of the Early Factory Acts', *EHR* 38 (1985), 425; C. Nardinelli, 'The Successful Prosecution of the Factory Acts: A Suggested Explanation,' *EHR* 38 (1985), 429; Bartrip and Fenn, 'Evolution', 205–6, 217.
47 'Report of the Factory Inspectors, 1 August 1834', 25. Cf. e.g. PP (1840) X, *Reports from the Select Committee on the Act for the Regulation of Mills and Factories,* 1.9. The act added to the burdens of the colonies not merely by curbing overtime, but also by forcing them to replace their youngest hands – those under thirteen – with others, either several sets of children aged nine to thirteen who would work in relays of eight hours or workers above that age. In either case, it exacerbated the problem of labour recruitment, just as Ashworth had feared.
48 PP (1840) X, 1.5; 'RFIHYE 31st December 1842,' 41 (R. J. Saunders); PP (1837) L, *Trade and Navigation; Factories; Post Office; &c,* 16–21. Emphasis in original.
49 See PP (1840) X, 1.1–2, 15, 26, 34; 'RFIHYE 31st December, 1840,' 17; 'RFIHYE 31st December 1841,' 3; 'RFIHYE 31st December, 1842,' 3; 'RFIHYE 30th June, 1843,' 19. Nardinelli concludes: 'It is clear that within a few years after the implementation of the Factory Act the law was generally obeyed.' Nardinelli, *Child,* 107.
50 PP (1840) X, 1.15, 6.16.
51 Marvel, 'Regulation,' 396. Note that these convictions also concerned other violations than excessive overtime, though this probably accounted for the bulk. For full treatment of the rules of the act – inter alia for schooling of children – frequently broken by water mills, see Malm diss., 416–29.
52 Gray, *Factory,* 165–7.
53 PP (1837) L, 26.
54 PP (1840) X, 3.1–2, 21; Boyson, *Ashworth,* 168–9.
55 PP (1840) X, 3.23; Doherty (1838), *Misrepresentations,* 27.
56 See *MG* 27 May 1840; PP (1840) X, 3.46–50, 59–61; Senior, *Letters,* 9; Boyson, *Ashworth,* 170–6.
57 PP (1840) X, 3.18, 27, 59.
58 Greg, *Factory,* 16, 129–30.
59 Marvel, 'Regulation,' 395; Nardinelli, 'Succesful,' 429.

60 Hansard, 17 February 1847, 165 (Mr. Roebuck). Emphasis added. For the very special situation in Scotland, see Malm diss., 430–32, 440–6.
61 'RFIHYE 30th June, 1842,' 8. Cf. 'RFIHYE 30th June, 1843,' 24; von Tunzelmann, *Industrialization,* 172.
62 PP (1833) XX, E7. Emphases added.
63 PP (1833) VI, 686; 'RF/HYE 31st December 1838,' 61.
64 PP (1833) VI, 297 (William Haynes). Emphasis added.
65 J. Choi, 'The English Ten-Hours Act: Official Knowledge and the Collective Interest of the Ruling Class,' *Politics and Society* 13 (1984), 463; Hutchins and Harrison, *Factory,* 59–64; Ward, *Factory,* 158, 167, 190–1, 201–2, 232–4; Ward, 'Factory,' 71; Thomas, *Factory,* 146; Weaver, 'Ideology,' 78, 86, 96.
66 Hansard, 15 April–24 May 1844, 973–4 (William Ferrand).
67 Chadwick papers, correspondence, box 203, letter from E. Ashworth to E. Chadwick, 29 April 1847.
68 'RFIHYE 30th April, 1850,' 4-5; 'RFIHYE 31st October, 1851,' 6; *TT* 30 April 1850, 14 May 1850, 29 May 1850; Hutchins and Harrison, *Factory,* 105–7; Thomas, *Factory,* 295–6, 308–9, 316–27.
69 'Report for the quarter ending 30th September, 1844; and from 1st October, 1844, to 30th April, 1845,' 20–2. Emphases added.
70 'RFIHYE 31st October 1848', 29, 47–8. Emphasis added. For more evidence of the speedup, see e.g. 'RFIHYE 31st October 1848', 36, 45, 50; 'RFIHYE 30th April, 1850', 5; *TT* 13 February 1850; J.J.: 'A factory woman's letter', *The Working Man's Friend and Family Instructor,* 13 April 1850, 54. On prosecution of owners of water mills for illicit overtime under the acts of 1847/1850, see Malm diss., 442–3.
71 'RFIHYE 31st October, 1850', 16; 'RFIHYE 31st October 1856', 20.
72 Russell, *Treatise,* 141. Emphasis added.
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9. 'No Government but Fuel'

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3 *The Tradesman,* 'The History of the Combination of the Journeymen Calico Printers,' 1 January 1809, 32–3; Ure, *Philosophy,* (1835), e.g. 285, 369. See further Anonymous, *Considerations,* 4–6, 18; PP (1835) XIII, 119; Baines, *History,* 265–85; J. Leach, *Stubborn Facts from the Factories,* London, 1844, 46–8, 82–4.
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8 Nasmyth in R. Buchanan and T. Tredgold, *Practical Essays on Mill Work and other Machinery,* London, 1841, 395; J. Nasmyth, *James Nasmyth, Engineer: An Autobiography. Edited by Samuel Smiles,* London, 1883, 199–200.
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10 Fairbairn, *Life,* 112–17, 312. See further A. E. Musson, 'James Nasmyth and the Early Growth of Mechanical Engineering', *EHR* 10 (1957), 123; N. von Tunzelmann, 'Technology in the Early Nineteenth Century,' in R. Floud and D. McCloskey, *The Economic History of Britain since 1700. Second Edition. Volume 1:1700–1860,* Cambridge, 1994, 288–90; C. Freeman and F. Louçã, *As Time Goes By: From the Industrial Revolutions to the Information Revolution,* Oxford, 2002, 188; Musson & Robinson, *Science,* 475–6.
11 Tufnell, *Character,* 29–42, 109–11 (master Samuel Holme). Emphasis added.
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22 C. Turner et al., *Proceedings of the Public Meeting Held at Freemason's Hall on the 18th June, 1824, for Erecting a Monument to the Late James Watt,* London, 1824, 51, 70 (first quotation: James Mackintosh).
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30 SPCK, *Industry,* 60–1.
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44 Ibid., 278–9, 282. For a closer reading of the tensions in Gaskell's work, which set out to *criticise* steam-power, see Malm diss., 511–13.
45 Baines, *History,* 227.
46 Robison, *System,* 390. Emphases added.
47 Senior Papers, National Library of Wales, Aberystwyth, lectures, course 2, lecture 8, 1848, 22–3, 33–4. Emphasis added.
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54 Ibid., 4. Emphasis added.
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63 Ibid., 12.
64 M. Dunn, *An Historical, Geological, and Descriptive View of the Coal Trade of the North of England,* Newcastle-upon-Tyne, 1844, vii; Jevons, *Coal,* 1–2; *CtB* 31 May 1833. Emphasis added. For just two other examples, see E. Binney, 'Observations on the Lancashire and Cheshire coal field, with a section,' *Transactions of the Manchester Geological Society* 1 (1841), 67; T. Twiss, *Two Lectures on Machinery,* Shannon, 1971 [1844], 53.
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69 Hornborg, *Zero-Sum,* 39; R. Boer, 'That Hideous Pagan Idol: Marx, Fetishism and Graven Images,' *Critique* 38 (2010), 114. Emphasis added.
70 Hornborg, *Zero-Sum,* 39.

10. ‘Go and Stop the Smoke!’

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2 *A Collection of the Public General Statutes, Passed in the Seventh and Eighth Year of the Reign of his Majesty King George the Fourth,* London, 1827, cap. XXX.
3 *MG* 12 March 1831.
4 *Coventry Herald and Observer* 30 March 1832; *MG* 16 August 1834; Leigh, *Preston,* 29–31.
5 Frederick Marryat, ‘Diary of a blasé,’ *The Metropolitan Magazine* (May– August 1835), 255–56. Emphases in original.
6 Ibid. Emphasis added.
7 D. Jerrold, ‘The Factory Child,’ in *Heads of the People: Or, Portraits of the English,* London, 1840, 188–9. Emphasis in original. The publication of this story in *The New Moral World:* Berg, *Machinery,* 270.
8 Baines, *History,* 452, 457; *The London and Westminster Review,* ‘Domestic arrangement of the working classes’ (July 1836), 253. Emphasis added. See further Berg, *Machinery,* 276–9, 282–3.
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12 Thompson, *Making,* 826. See further B. Brown, ‘Lancashire Chartism and the Mass Strike of 1842: The Political Economy of Working Class Contention,’ CRSO Working Paper, University of Michigan, 1979, 17–18; R. Sykes, ‘Early Chartism and Trade Unionism in South-East Lancashire,’ in J. Epstein and D. Thompson, *The Chartist Experience: Studies in Working-Class Radicalism and Culture, 1830–60,* London, 1982, 152–93; Thompson, *Chartists,* 112, 179–99, 208–28; Chase, *Early,* 192; Chase, *Chartism,* 211.
13 Quotation from *MG* 23 July 1842. See further Home Office [hereafter HO] 45/269, letters from Colonel T. J. Wemyss, 21 and 22 July 1842; *Northern Star* [hereafter *NS*] 30 July 1842; *PC* 30 July 1842; A. Rose, ‘The Plug Riots of 1842 in Lancashire and Cheshire,’ *Transactions of the Lancashire and Cheshire Antiquarian Society* 68 (1957), 85; R. Fyson, ‘The Crisis of 1842: Chartism, the Colliers’ Strike and the Outbreak in the Potteries,’ in Epstein and Thompson, *Chartist,* 196–200; Jenkins, *General,* 60–1.
14 *Leeds Times* [hereafter *LT*] 6 August 1842. Emphasis added. See further HO 45/266; HO 45/265; *NS* 13 August 1842; *MG* 10 August 1842; Fyson, ‘Crisis,’ 200; Thompson, *Chartists,* 277.
15 Quotation from the final speech by William Muirhouse in F. O’Connor et al., *The Trial of Feargus O’Connor, Esq. (Barrister-at-Law) and Fifty-Eight Others at Lancaster on Charge of Sedition, Conspiracy, Tumult and Riot,* Manchester, 1843, 28. See further Jenkins, *General,* 21, 67–9; Sykes, ‘Early’, 152–3; Thompson, *Chartists,* 283–7.
16 *The Observer* 14 August 1842; HO 45/249, letter from Holme et al., Oldham 8 August 1842; HO 45/268, letter from Major-General W. Warre, 9 August 1842; HO 45/269, letter from Colonel T. Wemyss, 9 August 1842; *MG* 10 August 1842.
17 *MG* 10 August 1842.
18 *NS* 13 August 1842; *MG* 13 and 17 August 1842; *The Manchester Courier and Lancashire General Advertiser* 20 August 1842.
19 *The Observer* 14 August 1842. See further *MG* 13 August 1842.
20 HO 45/268, letter from Major-General W. Warre, 10 August 1842; HO 45/249C, letter from mayor W. Neild, 13 August 1842.
21 *BO* 18 August 1842. Emphasis added.
22 Ibid.; HO 45/242, letter from mill-owners W & J. Bradshaw, 6 September 1842; T. Reid and N. Reid, ‘The 1842 “Plug Plot” in Stockport’, *IRSH* 24 (1979), 64–5.
23 *PC* 20 August 1842; *NS* 20 August 1842. See further HO 45/268, letter from mayor Horrocks et al., 13 August 1842; *MG* 17 August 1842; *The Preston Pilot and County Advertiser* 13 August 1842; Leigh, *Preston,* 45–50.
24 *PC* 20 August 1842; *MG* 7 September 1842; Leigh, *Preston,* 50.
25 HO 45/249, letters from R. Willock, 14 August 1842, and from P. Towneley et al., 15 August 1842.

26 Quotations from *MG* 17 August 1842; *NS* 27 August 1842; HO 45/249, letter from mayor T. Cullen, 16 August 1842. See further HO 45/249, letters from Whitaker and Earnshaw, 16 August 1843; from H. Gaskell, 17 August 1842; from J. Winder, 13 August 1842; *PC* 20 August 1842; *NS* 20 August 1842.
27 HO 45/249, placard announcing the resolutions of 'A meeting of the operative cotton spinners of Bolton and its vicinity'; HO 45/242, letter from mayor T. Stringer, 12 August 1842; *MG* 17 August 1842.
28 HO 45/249C, The Executive of the National Chartist Association, 'To the People!!!'.
29 *BO* 18 August 1842. Further *MC* 18 August 1842; *LT* 20 August 1842; *NS* 20 August 1842.
30 *LT* 20 August 1842. Emphasis in original. See further *BO* 18 and 25 August 1842; *LT* 20 August 1842; *NS* 27 August and 10 September 1842.
31 *NS* 20 August and 3 September 1842.
32 Quotations from *PC* 27 August 1842; *MC* 18 August 1842. See further *Birmingham Gazette* 15 August and 12 September 1842; *MC* 19 August 1842.
33 Quotations from *MG* 20 August 1842; HO 45/261, resolution by the Birmingham Chamber of Commerce, 1 September 1842. See further HO 45/266; *CM* 8, 13 and 25 August 1842; *BO* 25 August 1842; *MG* 7 September 1842. There were, however, reports of factories being attacked and workers turning out en masse in Glasgow as well: see HO 45/266.
34 *MG* 17 August 1842; *Illustrated London News* [hereafter *ILN*] 20 August 1842. See further *BO* 18 August 1842; *MG* 24 August 1842; Mather, 'General,' 116, 118, 130; Jenkins, *General,* 171, 181, 187, 250–2; Royle, *Revolutionary,* 122.
35 *MC* 15 August 1842; *ILN* 20 August 1842; *MG* 13 and 17 August 1842.
36 *LT* 20 August 1842. See further *LT* 27 August 1842; *BO* 18 August 1842; *NS* 20 August 1842; *MG* 14 September 1842; Butterworth, *Historical,* 220–1; Reid and Reid, 'Plug Plot,' 74; Brown, 'Lancashire,' 46-47; Jenkins, *General,* 198–202.
37 *NS*, 27 August, 3 September and 10 September 1842; *MG* 7 September 1842; *BO* 8 September 1842; Jenkins, *General,* ch. 10; E. Yeo, 'Some Practices and Problems of Chartist Democracy,' in Epstein and Thompson, *Chartist,* 366; Royle, *Revolutionary,* 121–2; Chase, *Chartism,* 226.
38 E. Hobsbawm, *Labouring Men: Studies in the History of Labour,* London, 1968 [1964], 8. Emphasis added.
39 See Mitchell, *Carbon Democracy: Political Power in the Age of Oil,* London, 2011.
40 Chase, *Early,* 194, 197.
41 *NS* 22 October 1842.
42 J. Epstein, 'Feargus O'Connor and the Northern Star,' *IRSH* 21 (1976), 51–97; Chase, *Chartism,* 16–17, 44.
43 *NS* 30 January 1841.
44 *NS* 16 March 1839, 21 December 1844. Emphases in original.
45 *NS* 30 March 1844. Emphases in original. Cf. 3 May 1851.
46 *NS* 9 October 1841, 9 April 1842, 4 June 1842.
47 See e.g. *The Operative* 4 November 1838; *The Chartist* 9 February and 23 March 1839; *The Chartist Circular* 6 and 20 March 1841, 17 October 1840; *The Odd Fellow* 30 October and 9 January 1841.
48 *The Odd Fellow* 26 June 1841.
49 M. Sanders, *The Poetry of Chartism: Aesthetics, Politics, History,* Cambridge, 2011, 70–3.
50 *NS* 11 February 1843.
51 *NS* 26 June 1846. Cf. 5 September 1846.
52 *NS* 2 October 1847. Emphasis added. See further e.g. *NS* 27 July 1844; *The Odd Fellow* 11 December 1841.
53 Sanders, *Poetry,* 24–5; Epstein, 'Feargus,' 86. Emphasis in original.
54 Quoted (anonymously) in Chase, *Chartism,* 200.
55 *NS* 16 April, 12 March, 9 July, 23 April 1842. For other leaders expressing similar views, see Leach, *Stubborn,* 5, 20; *MG* 20 March 1844; *PC* 23 October 1841, 22 March 1845. Despite its particularly sharp confrontations with the water barons, the factory movement expressed similar views of steam.
56 Quoted in Thompson, *Chartists,* 298. Last emphasis added, the others in original.
57 James, *Bradford,* 104. Emphasis added.
58 Another highly significant episode was the Chartist Land Plan: for an analysis of its articulation of resistance against (among other things) the environmental depredations of the fossil economy, see Malm diss., 594–600.
59 HL (1819), 280–1 (John Watkins). On the general difference between climate in water and steam mills, cf. Fitton, *Arkwrights,* 165–7; Honeyman, *Child,* 144.
60 PP (1833) XX, A1.70–91, A2.51–7.
61 PP (1833) XXI, D2.64. Further PP (1833) XX, A1.70–91, A2.51–7. See also e.g. PP (1816) III; PP (1832); PP (1834) XX; PP (1840) XX.
62 Quotation from PP (1833) XX, A2.61 (Charles Cleghorn). See further e.g. C. Thackrah, *The Effects of Arts, Trades, and Professions, and of Civic States and Habits of Living, on Health and Longevity,* London, 1832,

136, 144, 154–5; J. Kay Shuttleworth, *The Moral and Physical Condition of the Working Classes Employed in the Cotton Manufacture in Manchester,* London, 1970 [1832], 24; R. Ritchie, *Observations on the Sanatory Arrangements of Factories,* London, 1844, 3.

63 Gaskell, *Artisans,* 161, 227, 229; Partington, *Account,* 244.

64 U. Satish, M. Mendell, K. Shekhar et al., 'Is CO_2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO_2 Concentrations on Human Decision-Making Performance,' *Environmental Health Perspectives* 120 (2012), 1671–7; Ritchie, *Observations,* 24. Emphases in original.

65 Ritchie, *Observations,* 4, 19; Gaskell, *Artisans,* 231. Emphasis in original.

66 Mosley, *Chimney*.

67 Faucher, *Manchester,* 26; Dickens, *Hard,* 65. On the death of flora and fauna, see Mosley, *Chimney,* 36–45.

68 Mosley, *Chimney;* quotation from 144.

69 William Fairbairn, 'On the construction of boilers,' *The Engineer and Machinist* (June 1851), 118.

70 P. Bartrip, 'The State and the Steam-Boiler in Nineteenth-Century Britain,' *IRSH* 25 (1980), 80.

71 'Boiler explosions, and government interference,' *The Engineer and Machinist* (June 1851), 97. Emphasis in original. See further particularly Bartrip, 'State'.

72 J. P. Robson quoted in M. Vicinus, *The Industrial Muse: A Study of Nineteenth Century British Working-Class Literature,* London, 1974, 82. See further Holland, *History,* 247–85; Jevons, *Coal,* 60; Flinn, *Coal,* 128–37, 412–23; Church, *Coal,* 582–99.

73 Cf. Chase, *Chartism,* 21.

11. A Long Trail of Smoke

1 W. Humphrey and J. Stanislaw, 'Economic Growth and Energy Consumption in the UK, 1700–1975,' *EP* 7 (1979), 31–6; B. Mitchell, *Economic Development of the British Coal Industry 1800–1914,* Cambridge, 1984, 1, 12; B. Mitchell, *British Historical Statistics,* Cambridge, 1988, 258; Buxton, *Economic,* 57; Flinn, *Coal,* 213; Church, *Coal,* 24.
2 S. Pollard, 'A New Estimate of British Coal Production, 1750–1850,' *EHR* 33 (1980), 229; A. Taylor, 'The Coal Industry,' in R. Church (ed.), *The Coal and Iron Industries,* Oxford, 1994, 135; Humphrey and Stanislaw, 'Economic,' 38; Mitchell, *Economic,* 3–4, 96; Church, *Coal,* 5.
3 1700–1830: Flinn, *Coal,* 26; 1830–1900: Church, *Coal,* 3.
4 Mitchell, *Economic,* 12. Cf. Mitchell, *British,* 258; Church, *Coal,* 19. On the development of the share of domestic heating in the late eighteenth century, see Flinn, *Coal,* 213, 251. According to Flinn's figures, that share *rose* between 1800 and 1830. Ibid., 252.
5 Turner, 'Significance,' 113–14; Rodgers, 'Lancashire,' 141–2; Musson, 'Motive,' 437–9; Redford, *Labour,* 129; Kanefsky, *Diffusion,* 232, 295, 352–3; Turner, 'Localisation,' 81; Ingle, *Yorkshire,* 42, 243–7; Cooke, *Rise,* 4, 75–6.
6 Fairbairn, *Treatise Pt 1*, 67.
7 von Tunzelmann, *Industrialization,* 110–2; Flinn, *Coal,* 26, 247; Church, *Coal,* 27–8.
8 Buxton, *Economic,* 56–8, 65–6; Humphrey and Stanislaw, 'Economic,' 38; Church, *Coal,* 24, 27, 761; Taylor, 'Coal,' 135.
9 Ashmore, *Industrial,* 25; Foster, *Class,* 118; Pollard, 'Estimate,' 219–20, 229–30; Mitchell, *Economic,* 7, 23–31; Church, *Coal,* 28–9; Berg, *Age*, 44, 97; Kander et al., *Power,* 125.
10 Boden et al., *Global*.
11 Clark and Jacks, 'Coal,' 69.
12 Church, *Coal;* Clark and Jacks, 'Coal'.
13 Boden et al., *Global*.

12. The Myth of the Human Enterprise

1 Wrigley, *Continuity,* 75.
2 Flinn, *Coal,* 212.
3 Mitchell, *British,* 9, 247; Hobsbawm, *Industry,* 20–3.
4 Wrigley, 'Divergence,' 138–9; Wrigley, *Energy,* 193, 191. Emphasis in original.
5 Wilkinson, *Poverty,* 90, 102.
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8 Cf. Kander et al., *Power,* 229–31.
9 Wilkinson, *Poverty,* 173, 176.
10 Wrigley, *Poverty,* 31.
11 Wrigley, *Energy,* 191.
12 Quotation from D. H. Fischer, *Historians' Fallacies: Toward a Logic of Historical Thought,* London, 1971, 169.
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14 Wood, *Origin,* 34. Emphasis added.
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27 N. Diffenbaugh and C. Field, 'Changes in Ecologically Critical Terrestrial Climate Conditions,' *Science* 341 (2013), 489.

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34 G. Lukács, 'Technology and Social Relations,' *NLR*, no. 39 (1966), 29.

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36 *MECW, Vol. 33,* 340–1.

37 Ibid., 395–409, 425–39, 443–7.

38 Ibid., 391–2; Marx, *Capital 1,* 468. Emphasis added.

39 Marx, *Capital 1,* 499.

40 Ibid., 924, 496–7.

41 Ibid., 562–3. Emphasis added.

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13. Fossil Capital

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6 E.g. ibid., 200, 249–50.

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8 PP (1816) III, 362.

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10 Marx, *Capital 1,* 290, 293.

11 Ibid., 133. On this crucial point, see further the excellent A. Schmidt, *The Concept of Nature in Marx,* London, 2009 [1962].

12 K. Marx, *Capital, Vol. 2,* London, 1992 [1885], 109, 132.

13 Marx, *Capital 1,* 288.

14 Marx, *Grundrisse,* 90.

15 Marx, *Capital 2,* 137; Marx, *Grundrisse,* 516.

16 Marx, *Capital 1,* 725–32. Quotation from 727. See further e.g. P. Burkett, *Marx and Nature: A Red and Green Perspective,* London, 1999, 108; P. Burkett, *Marxism and Ecological Economics: Toward a Red and Green Political Economy,* Leiden, 2006, 169; J. Kovel, *The Enemy of Nature: The End of Capitalism or the End of the World?,* London, 2007 [2002], 42; Foster et al., *Ecological,* 39.

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25 Ibid., 19. Absolute growth of GDP – which is what counts for nature, as a proxy for total throughput – shows the same pattern; see e.g. 30, 262.
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28 Cf. K. Marx, *Capital, Vol. 3,* London, 1991 [1894], 373.
29 Marx, *Capital 2,* 208.
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32 Y. Rapoport and I. Shahar, 'Irrigation in the Medieval Islamic Fayyum: Local Control in a Large-Scale Hydraulic System,' *Journal of the Economic and Social History of the Orient* 55 (2012), 1–31.
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41 Brenner, 'Origins,' 37. Emphasis added.
42 Babbage, *Economy,* 203.
43 Marx, *Grundrisse,* 497, 476, 157–8.
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57 Ibid., 307, 101, 120.
58 Smith, *Uneven,* 115, 7.
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117 Nef, *Rise, Vol. 1,* 316. See further 156, 265, 310–16, 343; Nef, *Rise, Vol. 2,* 329–30. Similar conflicts in eighteenth- and nineteenth-century Wales are charted in Osborne, 'Commonlands'.

118 Nef, *Rise, Vol. 1,* 312. See further 308–9, 316–17; Nef, *Rise, Vol. 2,* 14–15; Žmolek, *Rethinking,* 87–8.

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120 Ibid., 277, 286, 303, 310, 313–17.

121 Ibid., 46, 150, 152, 318, 343; Nef, *Rise, Vol. 2,* 72, 210, 330; Osborne, 'Commonlands,' 232; Žmolek, *Rethinking,* 91, 102.

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14. China as Chimney of the World

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16. A Time to Pull the Plugs

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15 Benjamin in Löwy, *Fire,* 42. Emphasis in original.

16 See Klein, *This,* part 3.

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