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978-0-521-86827-3 - The British Industrial Revolution in Global Perspective
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Excerpt
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1 *The Industrial Revolution and the pre-industrial economy*

> The *general* rule is infallible, that, when by *increase of money, expensive habits of life, and taxes*, the price of labour comes to be advanced in a manufacturing and commercial country, more than in those of its commercial competitors, then that expensive nation will lose its commerce, and go to decay, if it doth not counterbalance the high price of labour, by the seasonable aid of mechanical inventions . . . *Nottingham, Leicester, Birmingham, Sheffield*, &c. must long ago have given up all hopes of foreign commerce, if they had not been constantly counteracting the advancing price of manual labour, by adopting every ingenious improvement the human mind could invent.
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> T. Bentley, *Letters on the Utility . . . of . . . Machines to Shorten Labour*, 1780

This book is about a historical problem: why did the Industrial Revolution happen in Britain, in the eighteenth century? Theories of economic development emphasize technological change as the immediate cause of growth, and that was surely the case for industrializing Britain. The steam engine, the cotton spinning machinery, and the manufacture of iron with coal and coke deserve their renown, for invention on this scale was unprecedented, and it inaugurated an era of industrial expansion and further technological innovation that changed the world. Other features of the Industrial Revolution (rapid urbanization, capital accumulation, increases in agricultural productivity, the growth of income) were consequences of the improvements in technology. Explaining the technological breakthroughs of the eighteenth century is, therefore, the key to explaining the Industrial Revolution, and it is the first objective of this book.

My explanation proceeds in two stages. Part I of this book analyzes the expansion of the early modern (i.e. 1500–1750) economy and shows that it generated a unique structure of wages and prices in eighteenth-century Britain: Wages were remarkably high, and energy was remarkably cheap. In Part II, I show that the steam engine, the water frame, the spinning jenny and the coke blast furnace increased the use of coal and capital relative to labour. They were adopted in Britain because labour was expensive and coal was cheap, and they were not used elsewhere because wages were low and energy dear. Invention was governed by the same considerations, for why go to the expense of developing a new machine if it was not going to be used? The Industrial Revolution, in short, was invented in Britain in the eighteenth century because it paid to invent it there, while it would not have been profitable in other times and places. The prices that governed these profitability considerations were the result of Britain's success in the global economy after 1500, so the Industrial Revolution can be seen as the sequel to that first phase of globalization.

This book is also about the end of the Industrial Revolution. That is usually dated to 1830 or 1850 when new industries – first the railroad and the steamship and then novel manufactures like Bessemer steel – appeared on the scene. I also date the end of the Industrial Revolution to the second third of the nineteenth century, but for a different reason that is the culmination of its origins. The cotton mill and the coke blast furnace were invented in Britain because they saved inputs that were scarce in Britain and increased the use of inputs that were abundant and cheap. For that reason, these techniques were not immediately adopted on the continent or anywhere else in the world. Landes (1969) characterized the period up to 1850 as one of 'continental emulation' because the French, Germans and Belgians were only beginning to use British techniques and pre-industrial practices remained dominant. The 'closing of the gap' only occurred between 1850 and 1873, when modern technology displaced traditional methods, and European industry could compete on an equal footing with British. The slow adoption of British technology on the continent had less to do with war, institutions and culture than with the economics of the new technology, which was not profitable to adopt outside Britain.

This situation did not persist, however – thanks to British efforts. British engineers studied the steam engine and the blast furnace and improved them in order to lower costs. Inputs were saved indiscriminately, including those that were cheap in Britain and expensive elsewhere. The coal consumed per horsepower-hour by a steam engine, for instance, dropped from 45 pounds to 2 pounds. This made it profitable to use steam engines anywhere – even where coal was dear. Britain's success in the early Industrial Revolution was based on inventing technology that was tailored to its circumstances and useless elsewhere. By the middle of the nineteenth century, the genius of British engineering had improved the technologies, thereby eliminating the competitive advantage they had given Britain. The cotton mill, the steam engine and the coke blast furnace were now globally appropriate technologies, and their use quickly spread outside Britain. Global diffusion marked the end of the Industrial Revolution, and it was determined by the life-story of technology. This theme will be developed in the second part of this book. In the first part, we begin with the origins of the Industrial Revolution.

Explaining the Industrial Revolution

The explanation offered here differs from most others. Indeed, explaining the Industrial Revolution has been a long-standing problem in social science and has generated all manner of theories (Hartwell 1967, Jones 1981, Blaut 1993, Goldstone 2002, Bruland 2004). Most approaches fall under the headings of social structure, constitution and property rights, science, and culture.

Social structure

Marxist theories of economic development stress the importance of social structure. Society evolved through stages defined by their property and labour relations: primitive communism (i.e. hunting and gathering), slavery (as in ancient Greece and Rome), serfdom (medieval Europe) and capitalism. Capitalism was the key to growth, for capitalism is characterized by free markets and by a landless proletariat. Markets are necessary to guide economic activity, and the bulk of the population must lose its medieval property rights so that it is willing to move to the cities and for agricultural productivity to grow.

Marx wrote a century and a half ago, and, since then, historians have discovered much about the medieval world including many modern features. Studies of grain prices show that markets were widespread and as efficient as they were in the eighteenth century (Persson 1999, Bateman 2007). The economy of cities and towns was vibrant and commercial (Britnell 1993). Even agriculture no longer appears to have slumbered under a blanket of tradition. Instead, cropping patterns were responsive to environmental and commercial opportunities, and productivity was much higher than once believed (Campbell 2000). An extreme formulation of this upbeat reassessment of the middle ages is Clark (2007), who claims that medieval institutions were almost perfect for economic development.

One can reach an optimistic conclusion about medieval institutions only by glossing over their most characteristic forms – e.g. serfdom (Brenner 1976). For most of the middle ages, a majority of the English were serfs and held land in villeinage (servile tenure). While the free population could defend its ownership of land in the royal common law courts, the serfs could only litigate in the thousands of manorial courts presided over by their lords. They had no recourse to royal courts if the lords violated their rights. They could also not secure public protection for their persons against violence by their lords. They were subject to a variety of assessments that reduced economic incentives. Why improve the quality of your livestock when the lord could take the best beast when the holding was inherited? Land could not be conveyed without arbitrary fines being levied on the transaction. These controls produced a markedly more egalitarian distribution of land-holding than obtained among freehold property not controlled by the lords. Labour mobility was inhibited, since a serf could not leave the estate without permission and that was not lightly given since a distant serf could disappear. Lords could impose arbitrary assessments on their peasants. Tallage is a case in point. Initially, it was an assessment levied for a special purpose – to ransom the lord, for instance, if he were captured on crusade. Tallage was such a convenient and elastic revenue source, however, that it became routine (Allen 1992, pp. 58–66). It is hard to believe that these arrangements did not check the growth of the medieval economy or that the response to the possibilities of globalization after 1492 would have been weaker, had half of the population remained serfs. The emergence of capitalist institutions was a necessary, if not a sufficient, condition for modern economic growth.

Constitution and property rights

While Marxists are concerned with the decline of serfdom and the rise of capitalism, liberals are vexed by despotism and favour 'minimal government' – parliamentary checks on the executive, the security of property rights, the flexibility of the legal system. According to the liberal view, the Industrial Revolution can be traced back to the Glorious Revolution of 1688 that consolidated parliamentary ascendancy, limited royal prerogatives and secured private property. Supposedly, these legal changes created a favourable climate for investment that made the Industrial Revolution possible (North and Weingast 1989, De Long and Schleifer 1993, LaPorta *et al*. 1998, Acemoglu, Johnson and Robinson 2005, Greif 2006, Menard and Shirley 2005).

This interpretation, however, has some weaknesses. Studies of banking and interest rates fail to detect any structural break after 1688, so the improved investment climate was not manifest in anything financial (Clark 1996, Epstein 2000, Quinn 2001, Goldstone 2003). Property rights were at least as secure in France – possibly also in China for that matter – as in England (Bogart 2005a, Bogart 2005b, Hoffman, Postel-Vinay and Rosenthal 2000, Pomeranz 2000). Indeed, one could argue that France suffered because property was too secure: profitable irrigation projects were not undertaken in Provence because France had no counterpart to the private acts of the British parliament that overrode property owners opposed to the enclosure of their land or the construction of canals or turnpikes across it (Rosenthal 1990, Innes 1992, 1998, Hoppit, Innes and Styles 1994). These projects were only undertaken after the French Revolution destroyed local liberties and concentrated power in the national assembly. The English had got there first, however, for the Glorious Revolution meant that 'despotic power was only available intermittently before 1688, but was always available thereafter' (Hoppit 1996, p. 126). Finally, taxes were higher in Britain than across the Channel (Mathias and O'Brien 1976, 1978, Hoffman and Norberg 1994, Bonney 1999). In any event, it was a long stretch from the excise tax on beer or the cost of foreclosing on a defaulting mortgagor (not actually a cheap process in eighteenth-century England) to Watt's invention of the separate condenser. An explanation of the technological breakthroughs has to be more focused on technology than is usual in constitutional discussions. And, what the study of steam engines and spinning jennies shows is that it would not have been profitable to invent the Industrial Revolution in France no matter how good were French institutions. It was the prices that were wrong in France.

The Scientific Revolution

The Industrial Revolution was preceded by the Scientific Revolution of the seventeenth century. It started in Italy with Galileo and ended in England with Newton – a parallel to the reversal in economic leadership that occurred at the same time. Did modern science precipitate modern industry?

This is a favourite theme of university presidents and vice chancellors, and, indeed, has been argued by proponents of scientific research since the seventeenth century (Inkster 1991). In 1671, Robert Boyle claimed that 'Inventions of ingenious heads doe, when once grown into request, set many Mechanical hands a worke, and supply Tradesmen with new meanes of getting a liveleyhood or even inriching themselves'. 'Naturalists' could benefit the economy by inventing new products (e.g. the pendulum clock) and by solving production problems (e.g. the invention of Turkey red dye by Cornelius Drebbel). What particularly excited Boyle, however, were the possibilities of inventing 'engines' to mechanize production. 'When we see that Timber is sawd by Windmills and Files cut by slight Instruments; and even Silk-stockings woven by an Engine . . . we may be tempted to ask, what handy work it is, that Mechanicall contrivances may not enable men to performe by Engines.' Boyle thought that there were more possibilities here 'than either Shopmen or Book men seem to have imagined' and experimental scientists would discover them (Boyle 1671, Essay 4, pp. 10, 20).

Was Boyle right? The impact of scientific discovery on technology was explored thoroughly in the 1960s – and dismissed by most historians (Musson and Robinson 1969, Landes 1969, pp. 113–14, 323, Mathias 1972, Hall 1974). However, there is a good case that these historians went too far, and that scientific discoveries underpinned important technology in the Industrial Revolution. The reason that Hall, for instance, could find no link between scientific discovery and new technology was because he only analyzed the period 1760–1830. In the case of Watt, Hall concluded – correctly – that the theory of latent heat contributed nothing important to the invention of the separate condenser. The trouble with this argument is that the scientific discoveries that mattered for the Industrial Revolution were made before 1700 and not after 1760.

The most important scientific discoveries related to atmospheric pressure, namely, the findings that the atmosphere had weight and that steam could be condensed to form a vacuum (Landes 1969, p. 104, Cohen 2004). How these ideas were discovered is a great story that involved many of the leading figures of seventeenth-century science – Galileo, Toricelli, Otto von Guericke, Robert Boyle, Robert Hooke, Christiaan Huygens and Denis Papin – and we will discuss it in Chapter 7. The culmination of these inquiries was Thomas Savery's steam pump invented in 1698 and Thomas Newcomen's steam engine of 1712. It was the technological wonder of the age, and one of the first examples of industrial technology derived from science.

The discoveries of seventeenth-century physics were necessary conditions for the invention of the steam engine, but they were not sufficient. Much of the science was done on the continent, but the steam engine was invented in Britain. Why? Turning the scientific knowledge into working technology was an expensive proposition, and it was a worthwhile investment only in Britain where the large coal industry created a high demand for drainage and an unlimited supply of virtually free fuel. Without Britain's unusual wage and price structure, the R&D would not have been profitable, and Newton would have done as little for the English economy as Galileo did for the Italian.

Superior rationality?

The rise of the West has also been explained by cultural evolution. This has many dimensions, two of which run back to Max Weber. His first argument is that modern people are characterized by their superior rationality. In one of his most famous works, *The Protestant Ethic and the Spirit of Capitalism* (1904–5), he advanced the theory that the Reformation led to modern Western rationality. It caused the great divergence between the West and the Rest.

Historians have not been kind to *The Protestant Ethic*. Its empirical support was limited to a transitory correlation between Protestantism and high incomes – a correlation which did not obtain in the sixteenth century and which does not obtain today. Weber overstated the differences between Calvinism and contemporaneous strands of Catholic theology (Tawney 1938, Trevor-Roper 1967, Blaut 1993, Lehmann and Roth 1995).

Economists have also been unenthusiastic about Weber's views on rationality. His ideas had a major impact on development policy in the 1950s and 1960s since they indicated that agricultural productivity was low in less developed countries because peasant farmers were 'irrational' (Rogers 1962, McClelland 1961, Hagen 1962). Widespread irrationality was rejected by most agricultural economists beginning with Schultz (1964). Tests of the rationality of peasant cultivators considered their response to changes in agricultural prices and their willingness to adopt new techniques. The results of these studies indicate that small-scale farmers in developing countries are as 'rational' as their counterparts in advanced countries (Berry and Cline 1979, Booth and Sundrum 1985, Mellor and Mudahar 1992).

Economic historians have pursued parallel questions for medieval and early modern cultivators. Once serfdom was ended and peasants acquired *de facto* title to land, the open fields, that were supposed to have embodied the traditionalism of medieval England, became the basis of an agricultural revolution. Peasant farmers in England pushed up their productivity in the same way as their counterparts in developing countries (Allen 1992). These findings have called into question the view that the non-Western or pre-modern economy was held back by irrationality.

Science as culture

In work published after his death, Weber (1927) advanced a second argument about cultural change and economic development, namely, that a scientific attitude had to replace superstition for technological progress to occur. Weber believed that pre-modern people attributed events in the natural world to the interventions of supernatural beings – deities, spirits or fairies. Control over the natural world, therefore, required the manipulation of the spiritual world. Sometimes, this was accomplished through sacrifices, prayers, or the priestly interventions of temples and churches; sometimes, it was accomplished by witches, wizards and shaman. While there was usually some recognition of empirical regularities or 'laws of nature' that proceeded independently of spiritual actors, the latter were so important in influencing human life that they dominated thinking. This orientation stood in the way of the empirical, scientific outlook necessary for technological and social progress.

The creation of modern society, therefore, required what Max Weber called 'the disenchantment of the world'. Once the world was seen as a material realm unaffected by the spiritual, the attention of people could focus on discovering its empirical regularities and natural laws. Technological development could then proceed rapidly. Weber thought that this process began earlier in the West than elsewhere and explained the rise of the West.

The question is: why did the West give up superstition? Historians of science like Jacob (1997, pp. 1, 2, 6–7) propose that the Scientific Revolution transformed popular culture.[1] 'A new scientific understanding of nature preceded mechanized industry and, most important, assisted in its development.' There was widespread interest in science in the late seventeenth and eighteenth centuries, and exposure to science changed human nature. 'The most important cultural meaning to be extracted from the Scientific Revolution . . . lay in the creation first in Britain by 1750 of a new person.' This person was 'generally but not exclusively a male entrepreneur who approached the productive process mechanically'. He saw it 'as something to be mastered by machines, or on a more abstract level to be conceptualized in terms of weight, motion, and the principles of force and inertia. Work and workers could also be seen in these terms.' The effect of this new way of thinking was the mechanization of production. Manufacturing was done 'by using machines in place of labour'. This new culture was adopted more enthusiastically in Britain than on the continent with the result that 'industrial development occurred first in Britain for reasons that had to do with science and culture, not simply or exclusively with raw materials, capital development, cheap labor, or technological innovation'. Rather, Britain's lead over France was due to 'the marked differences in the scientific cultures found in Britain in comparison to France or the Netherlands' (Jacob 1997, p. 105). The French were supposedly theoretical, while the British were practical.

This contrast between British and French engineering is deeply problematic. It is not clear that there was much difference in inventiveness between eighteenth-century Britain and France (Hilaire-Pérez 2000). There are certainly many examples of the French inventing. Mokyr (2009) highlights 'chemical knowledge, paper, and high-end textiles'. Why do we think the British had a more pragmatic engineering culture than the French? Because it was Brits who first smelted iron with coke, invented the steam engine, and discovered how to spin with machines.

[1] Other works of cultural interpretation include Stewart (1992), Levere and Turner (2002) and Jacob and Stewart (2004).

In Part II of this book, I will show that these differences in behaviour were due to differences between the countries in the profitability of doing R&D. If that argument is accepted, then cultural explanations become superfluous. Indeed, they are circular.

Mokyr (2002, 2009) has advanced an influential variant of the cultural argument in which the Enlightenment connected the Scientific Revolution to the Industrial. He coined the term ‘Industrial Enlightenment’ to describe the essential features. The Industrial Enlightenment emphasized the application of the scientific and experimental methods to the study of technology, the belief in an orderly universe governed by natural laws that could be apprehended by the scientific method, and the expectation that the scientific study of the natural world and technology would improve human life. The Industrial Enlightenment explains ‘why the Industrial Revolution took place in western Europe (although not why it took place in Britain and not in France or the Netherlands)’ (Mokyr 2002, p. 29). Mokyr highlights two factors that made the Industrial Revolution British. First, the Industrial Enlightenment was more fully realized in Britain than on the continent. Communication between *savants* and *fabricants* was easier and more fruitful. Any such difference in behaviour, of course, could also be explained by the higher rate of return to inventing in Britain. Secondly, Britain was more abundantly supplied with skilled mechanical artisans than France, so it was easier for engineers to realize their inventions. In part, this is a claim about human capital, and the British were, indeed, well endowed in the eighteenth century, although perhaps not more so than people across the Channel. In part, this is also a claim that artisans were adopting the Newtonian worldview.

Cultural explanations of the Industrial Revolution contend that the scientific worldview percolated down the social scale and influenced the second and third tiers of inventors, who were critical in elaborating the breakthrough technologies and applying them across a broad range of activities. Jacob (1997, p. 132) thought that even factory operatives had to become Newtonians. ‘Relatively sophisticated mechanical knowledge had to be a part of one’s mental world before such mechanical devices could be invented and, more to the point, effectively exploited. If you were a worker having to work in relation to a machine, understanding it meant coming closer to understanding how your employer might view all of nature, yourself included.’ These people were not members of elite bodies like the Royal Society, nor