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.

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
The Industrial Revolution and the pre-industrial economy

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.
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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
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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. ‘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
did they have any contact with the leading scientists of the day. Jacob and Mokyr suggest that top-level science seeped down to the hoi polloi through provincial ‘scientific societies, academies, Masonic lodges, coffee house lectures’ and similar venues.

The cultural interpretation of the Scientific Revolution receives equivocal support from historians of popular culture. Culture in the eighteenth century was very different from medieval culture. There were ‘two gradual but important changes in popular attitudes’ between 1500 and 1800. ‘They may be summed up in two clumsy but useful abstractions: secularisation and politicisation’ (Burke 2006, pp. 257–8). Most people became more concerned with creating a better life in this world than with the possibilities in a spiritual sequel. ‘Wealth and status’ were pursued ‘as a sign of salvation or even in place of salvation’. This was, of course, Weber’s view. It is also disputable in view of the religious enthusiasm of much of the population and the success of preachers like John Wesley in attracting a large following. Why, in any event, did people become more worldly? Was it the result of elite science trickling down to the masses? The most that Sharpe (2007, p. 330) could claim about the impact of Newton on English society was: ‘Popular scepticism about magic, and popular receptiveness to Newtonian science, are problems which are in urgent need of further research.’ In other words – case not proven!

**Culture and the economy: cause or effect?**

We are on firmer ground with three other aspects of cultural evolution that also happened to have roots in the economic changes of the time. These developments included the spread of literacy and numeracy, the emergence of consumerism as a motive for work, and the postponement or deferral of marriages when it was economically inconvenient. The full ramifications of these were, of course, not fully realized before the Industrial Revolution. Nevertheless, these cultural shifts were big steps in the emergence of modern men and women. The new culture and the economy evolved together, each supporting the other.

The growth of literacy led to profound changes in knowledge and outlook, and the spread of reading was related to economic developments in several ways. Cities, rural industry and commerce required skills that agriculture had not demanded. As a result, literacy rates in medieval Europe were much higher in cities than in the countryside,
The Industrial Revolution and the pre-industrial economy

so literacy rose with urbanization. Commercial prosperity also made it easier for people to pay for education and knowledge. Beyond that, the invention of printing sharply reduced the price of books, leading to much more reading for both useful knowledge and pleasure (van Zanden 2004a, 2004b, Reis 2005). In England, the proportion of the population who could sign their name rose from about 6 per cent in 1500 to 53 per cent in 1800. A reading public of this size was unprecedented in world history and led to new ways of thinking in many areas.

Numeracy also increased in early modern England, although its spread is harder to measure. Commercial developments were the primary cause. While many people wanted to read as an aid to devotion or for simple pleasure, very few people learned long division for fun. Arithmetic was studied for its utility (Thomas 1987). Knowledge of arithmetic and geometry was important to keep accounts and navigate ships. The much greater level of human capital in the eighteenth century than in the middle ages is an important reason why the Industrial Revolution did not happen earlier.

Consumerism and hard work

The evolution of the economy also increased the incentive to work hard. This was a theme of eighteenth-century writers, who contended that the availability of new consumer goods – both English manufactures like books and clocks and imports like sugar and tea – gave people the desire to earn income. Sir James Steuart developed the argument in his Inquiry into the Principles of Political Economy (1767, pp. 53–4, 58, 199, 229). ‘Where industry is made to flourish, the free hands . . . will be employed in useful manufactures, which, being refined upon by the ingenious, will determine what is called the standard of taste; this taste will increase consumption.’ Why? ‘Let any man make an experiment of this nature upon himself by entering into the first shop. He will nowhere so quickly discover his wants as there. Every thing he sees appears either necessary, or at least highly convenient; and he begins to wonder (especially if he be rich) how he could have been so long without that which the ingenuity of the workman alone had invented.’ To buy these goods, people needed income, and that required them to work more. In the ancient world, ‘men were . . . forced to labour because they were slaves to others; men are now
forced to labour because they are slaves to their own wants’. As a result, ‘in a trading nation every man must turn his talents to account, or he will undoubtedly be left behind in this universal emulation, in which the most industrious, the most ingenious, and the most frugal will constantly carry off the prize’.

These ideas have been developed by Mathias (1979) and de Vries (1993, 1994, 2003, 2008), who coined the term ‘industrious revolution’ for the changes that Steuart was describing. Historians of consumption have studied how new goods transformed spending patterns (McKendrick, Brewer and Plumb 1982, Brewer and Porter 1993, Berg 1998, 2002, 2004, 2005, Berg and Clifford 1999, Fairchilds 1993, Lemire 1991, 1997, Styles 2007, Weatherill 1996), and Voth (2000) has found evidence of the predicted increase in work intensity. England and the Low Countries were the heartlands of the Consumer and Industrious Revolutions, although similar patterns have also been observed in Paris and in other capital cities. Although the new consumerism was not sufficient to explain economic progress, it was necessary: the frenetic pursuit of income to buy novel consumer goods, many imported from abroad as the economy globalized in the seventeenth century, was a cultural basis of the Industrial Revolution.

Marriage and children

Northwestern Europe also developed a distinctive pattern of marriage that contributed to high living standards and a broader sphere of personal independence than prevailed in many societies. Hajnal (1965) found that early-twentieth-century censuses showed two patterns of marriage in the world. East and south of a line from St Petersburg to Trieste, virtually all women married, and many of them married in their teens. West and north of that line, as many as one-fifth of women never married, and most of those who did marry waited until their twenties. These tendencies were most pronounced in northwestern Europe. The first marriage pattern led to high fertility and low living standards. The second, which Hajnal called the European marriage pattern, implies a lower level of fertility and one that responded to economic conditions through shifts in the proportion of women marrying and the average age of women at first marriage. The European marriage pattern implied a persistently higher standard of living for the mass of the population, and that high standard facilitated savings and economic growth (Jones
Malthus believed that the standard of living of most people was higher in England than in China because the English deferred marriage when incomes were low, while the Chinese did not.

What explains the European marriage pattern? In a paper evocatively called ‘Girl Power’, De Moor and van Zanden (2005) have traced it back to England and the Low Countries in the late middle ages. While developments in religious doctrine that emphasized the role of personal (rather than family) choice of marriage partner played a background role, the decisive factor was the high wage economy following the Black Death. High wages and the corresponding strong demand for labour meant that young people – and young women in particular – could support themselves apart from their parents and control their lives and marriages. Women put off marriage until it suited them, and they found the right partner. The wage decline of the sixteenth century threatened this independence, but the high wage economy of northwestern Europe guaranteed its existence, and, indeed, marriages in that part of Europe were the most independent from parental influence and exhibited the characteristics of the European pattern most fully. We should not overestimate the freedom enjoyed by women in the eighteenth century. Nevertheless, personal autonomy was promoted in the long run by the high wage economy.

The emergence of modern culture

The popular culture of England and northwestern Europe generally was transformed in the centuries leading up to the Industrial Revolution. Culture possibly became more secular and more concerned with economic success. People could read and calculate. They chased after new products and worked to get the money to buy them. They refrained from marriage and limited their families when they were not economically appropriate. While the eighteenth century was not the same as the twenty-first, modern attitudes and attributes were ascendant. Many had economic roots, and they furthered the growth of the economy.

An economic approach to the Industrial Revolution

The modern culture facilitated the Industrial Revolution, but it was not enough to bring it about. Like capitalism, minimal government and the Scientific Revolution, modern culture has a fatal weakness as an
explanation. These developments may have been necessary conditions for the Industrial Revolution, but they were not sufficient. Getting the institutions right, increasing knowledge of the natural world, and focusing people’s minds on an empirical approach to production may have increased the supply of technology, but they would have had little impact on invention without a demand for new techniques. This book explores how Britain’s high wages and cheap energy increased the demand for technology by giving British businesses an exceptional incentive to invent techniques that substituted capital and energy for labour. I do not ignore supply-side developments like the growth of scientific knowledge or the spread of scientific culture. However, I emphasize other factors increasing the supply of technology that have not received their due, in particular the high real wage. It meant that the population at large was better placed to buy education and training than their counterparts elsewhere in the world. The resulting high rates of literacy and numeracy contributed to invention and innovation. Since high wages and cheap energy were consequences of Britain’s success in the global economy, the Industrial Revolution can be traced back to prior economic success.

My view of Britain in the eighteenth century is reminiscent of Habakkuk’s (1962) analysis of technical progress in nineteenth-century America. American inventions had a labour-saving bias that accelerated the growth in output per worker. Habakkuk attributed the labour-saving bias to high American wages, which led inventors to economize on labour. High wages, in turn, were the result of the abundance of land and natural resources. In this book, I argue that Britain’s extensive coal fields played a similar role in the eighteenth century. Cheap energy made it possible for businesses to pay high wages and remain competitive. High wages and cheap energy made it profitable to invent technologies that substituted capital and energy for labour. Eighteenth-century Britain was, thus, the prequel to nineteenth-century America.2

Britain’s unique wage and price structure was the pivot around which the Industrial Revolution turned. Logically, the next question,
therefore, is how to explain Britain’s wages and prices. They turn out to have been the result of the country’s great success in the international economy in the early modern period. This success was partly due to changes in factor endowments and partly to commercial policy. These themes will be developed in Part I of the book. Here is a thumbnail sketch of what happened.

The transformation of the European economy, 1500–1750

Between 1500 and 1750, the economy of Europe was transformed. The manufacturing and commercial centre of Europe in the middle ages had been the Mediterranean with a small offshoot in what is now Belgium. Most of the British population lived in the countryside, and most depended on agriculture. Productivity and incomes were low. Much of the rest of Europe was similarly backward. By the eighteenth century, the economic centre of gravity shifted to the North Sea. The Mediterranean economies were in serious decline, and the Belgian economy was slipping. In the sixteenth and seventeenth centuries, the Dutch Republic pulled ahead and became the economic wonder of the age. British advance was slower but steady. By the seventeenth century, British incomes pushed past those of its chief continental rivals – France and the Habsburg Empire. By the eighteenth century, Britain extended its lead and overtook the Dutch. The Industrial Revolution was the capstone to this advance.

The reconfiguration of the European economy was precipitated by an increase in international trade. In the sixteenth and seventeenth centuries, greater market integration led to a shift in the location of cloth production from the Mediterranean to the North Sea. In the seventeenth and eighteenth centuries, intercontinental trade expanded. The great gainers were the English and the Dutch, who established world empires that fuelled their manufacturing and commerce. At first, the Spanish looked like the biggest winners due to the Latin American silver they acquired, but it proved their undoing for it unleashed inflation that rendered their manufacturing and agriculture uncompetitive (Drelichman 2005).

Success and failure in the early modern economy show up dramatically in economic structure. Table 1.1 divides the populations of the leading economies of Europe into three groups: agricultural, urban, and rural non-agricultural. Countries are defined in terms of modern
boundaries. This is necessary because of data availability, and it is desirable to investigate the effect of policies and constitutions, but it is also artificial since many of these countries were fragmented.

In 1500, most Europeans lived in backward economies. This is indicated, in the first instance, by the fraction of the population engaged in agriculture. About three-quarters of the people were agricultural in England, Austria–Hungary, Germany, France and Poland. This proportion was also characteristic of the less developed countries of Asia, Africa, Latin America and eastern Europe early in the twentieth century (Kuznets 1971, pp. 203, 249–55). In terms of economic

Table 1.1 Percentage distribution of the population, 1500–1800

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<th>1500</th>
<th>1800</th>
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<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
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<tr>
<td>Most successful over the period</td>
<td></td>
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</tr>
<tr>
<td>England</td>
<td>7%</td>
<td>18%</td>
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<tr>
<td>Moderately successful over the period</td>
<td></td>
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</tr>
<tr>
<td>Netherlands</td>
<td>30%</td>
<td>14%</td>
</tr>
<tr>
<td>Belgium</td>
<td>28%</td>
<td>14%</td>
</tr>
<tr>
<td>Small advance over the period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>8%</td>
<td>18%</td>
</tr>
<tr>
<td>France</td>
<td>9%</td>
<td>18%</td>
</tr>
<tr>
<td>Austria/Hungary</td>
<td>5%</td>
<td>19%</td>
</tr>
<tr>
<td>Poland</td>
<td>6%</td>
<td>19%</td>
</tr>
<tr>
<td>Little change over the period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>22%</td>
<td>16%</td>
</tr>
<tr>
<td>Spain</td>
<td>19%</td>
<td>16%</td>
</tr>
</tbody>
</table>

Notes: The first thing to notice in this table are the percentages of the population in agriculture. In 1500, many were about 75 per cent, which was also the share of the population in agriculture in less-developed countries early in the twentieth century. Notice which countries had lower shares in 1500 and how the shares decreased between 1500 and 1800. England had the biggest drop and Spain the least. Then notice how the urban and rural non-agricultural shares take up the slack. England had the biggest urban revolution between 1500 and 1800 and, next to Poland, the biggest increase in rural, non-agricultural share.

Source: Allen (2000, pp. 8–9).
structure, western Europe was at a similar – low – level of development at the end of the middle ages.

The counterpart of a large fraction of the population in agriculture was small cities that included less than 10 per cent of the population. In 1500, for instance, only 50,000 people lived in London; other English cities were little more than market towns. Non-agricultural employment in the countryside was also limited, especially in comparison to later developments.

The leading economies of Europe in 1500 were Italy, Spain and present-day Belgium. The Dutch economy also showed advanced proportions, but its population was so small that its figures are more a portend of the future than an indicator of economic importance at the time. The urban fraction ranged from 19 per cent to 30 per cent in these economies, and those cities housed the great manufacturing industries of the middle ages. The agricultural fraction was correspondingly reduced to about 60 per cent.

The economies of Europe followed a variety of trajectories between 1500 and 1800, and the countries in Table 1.1 are grouped to emphasize these divergences. England was the most successful country by far. The fraction of its population in agriculture dropped to 35 per cent – this was the biggest decline and the lowest value reached in Europe. In 1800, each person in agriculture had to feed almost three people \((2.86 = 1 / 0.35)\), while his predecessor in 1500 had only fed one and a third \((1.35 = 1 / 0.74)\). An agricultural revolution was part of the transformation of the English economy.

The drop in the agricultural share was matched by rises in both the urban and the rural non-agricultural proportions. The latter corresponds to the ‘proto-industrial’ revolution (Mendels 1972, Coleman 1983). This was a phenomenon of the early modern period. In many parts of Europe, manufacturing industries developed in the countryside. Production was carried out either in workshops or in people’s homes. Merchants signed up rural residents as piece rate workers, brought them raw materials and collected the finished products. These were often sold in large market halls to other merchants who shipped them across Europe. Regions were intensely specialized. Woollen cloth industries developed around Norwich and in the West Riding of Yorkshire, metal buttons, fittings and implements were made in Birmingham, stockings were knit in Leicestershire, and blankets were woven near Oxford and shipped to Canada by the Hudson Bay
The Industrial Revolution and the pre-industrial economy

Company. Rural industries were found in many parts of Europe, but they were particularly dense in England.

The expansion of rural industry in northwestern Europe was associated with the emergence of new economic leaders because it came at the expense of established producers. In the middle ages, Italian and Flemish cities produced woollen cloth that was exported across the continent. The English also produced and exported heavy broadcloths made from short staple wool. By the sixteenth century, the English and the Dutch began to imitate the lighter Italian worsteds. These clothes were the ‘new draperies’. They proved so popular that the Italians were driven out of the woollen business in the seventeenth century (Rapp 1975, Harte 1997). England was successful in this competition largely because the fall in the population after the Black Death led to the reversion of much good farmland to pasture. The improved feed supply for sheep meant that their wool was longer and better suited for worsted than the shorter wool of poorly fed medieval sheep. In addition, refugees from the continent brought skills that improved the quality and variety of English products (Goose 2005).

Urbanization was also rapid in early modern England. Some of the urbanization was due to the improvement of agriculture. The state taxed some of the income generated in the countryside and spent it in the capital or in towns like Portsmouth where arsenals and naval dockyards dominated the economy. Cities like Bath were also supported by the agricultural income of landed society. Some of the urban growth was due to manufacturing; London was the centre of English publishing and furniture-making from an early date. Most of the growth of cities, however, was due to trade and commerce. In the seventeenth century, intra-European trade was the basis of London’s expansion. There were close connections to rural manufacturing. The new draperies were woven in East Anglia and exported to the Mediterranean through London. Between 1500 and 1700, the population of London increased ten-fold. The export of new draperies made a significant contribution to that growth (Davis 1978, p. 390, Wrigley 1987, p. 148).

Intercontinental trade became more important in the seventeenth and eighteenth centuries. Portugal was the most successful European power in South Asia in the sixteenth century. It monopolized the spice trade and seized important colonies including the Moluccas, the ‘Spice Islands’ that were the source of cinnamon and nutmeg. The Netherlands, in turn, took these islands from Portugal in the
early seventeenth century and established its Indonesian empire. This imperial success contributed to Amsterdam’s becoming Europe’s wholesaling centre for tropical produce. A vigorous colonial policy, the navigation acts and three wars with the Dutch helped London wrest that trade from Amsterdam. Trade with India added tea and cotton textiles to the list of Asian imports. As the eighteenth century progressed, intercontinental trade loomed larger in England’s international accounts, and the growth of that trade contributed to the growth of Britain’s cities.

The Low Countries were the second most successful economies in the early modern period. Less than half of their populations were engaged in agriculture, and the urban and rural, non-agricultural shares were also very high. Flanders in present-day Belgium had been highly urbanized and a leading manufacturing centre in the middle ages. Its economy failed to grow as rapidly as the leaders in the early modern period, but it still retained a more modern structure and higher incomes in 1800 than most of the continent.

The Dutch economy was the most advanced in Europe in the seventeenth century; indeed, the main question in economic policy was how to emulate the Dutch. Like the English, the Dutch had an agricultural revolution, which facilitated the growth of the urban and manufacturing economies. Trade was critical to the progress of the Netherlands. The new draperies were first established in the Low Countries in villages like Hondschoote. The manufacture of light cloth spread into other rural areas including the Ardennes, but, more significantly, was re-established in the cities like Leyden, Delft, Gouda, Haarlem and Utrecht (Pounds 1990, pp. 235, 293). The Dutch took over the Portuguese empire in Asia, and Amsterdam became the great wholesale market in Europe. Dutch manufacturing and rural industry were also formidable. The English did not overtake the Dutch before the late eighteenth century.

The third group was the rest of continental Europe north of the Alps and Pyrenees. France and Austria were major military powers, Poland was united in 1500 but dismembered in the next three centuries, and Germany remained divided into many states throughout the period. Prussia, however, was an actor on the international stage.

These countries showed modest development in the early modern period. Their agricultural shares dropped to about 60 per cent – rather like Italy and Spain in 1500. This decline was matched by a rise in the
share of people in proto-industry. These countries developed important rural manufacturing industries that rivalled those of the leading economies in terms of the fractions of the population employed. Their urban shares, however, scarcely increased, and that sets them apart from England and the Low Countries. For a time, the French had some valuable colonies, but they were lost in the Seven Years War and the Revolution.

Italy and Spain comprise the final group. What is remarkable about these economies is the absence of structural change between 1500 and 1800. They had larger urban shares and smaller agricultural shares than most of the continent at the end of the middle ages, and these shares hardly budged. A corollary was the absence of growth in rural manufacturing. The proto-industrial revolution did not extend south of the Alps or the Pyrenees. The Italians never had foreign possessions. Spain did, but they did her no good, for they brought inflation that wrecked the peninsular economy rather than stimulating industrial expansion.

From early modern expansion to Industrial Revolution

The Industrial Revolution was the result of a long process of social and economic evolution running back to the late middle ages. The commercial and imperial expansion of Britain was a fundamental feature of this evolution, but not its totality.

The path to the Industrial Revolution began with the Black Death. The population fall increased labour mobility by generating many vacant farms, and that mobility undermined serfdom (Allen 1992, pp. 37–77). The low population also created a high wage economy. The benefits of high consumption were not confined to people: sheep ate better as well, and their longer wool was the basis for England’s early modern worsted industry – the new draperies. The enormous export of these fabrics through the port of London led to rapid growth in the city’s population and the rise of the coal industry to provide the capital with fuel. The trade boom was extended to the Americas and Asia in the seventeenth and eighteenth centuries by England’s mercantilist expansion of trade and acquisition of colonies. More trade led to larger cities, and their growth was an impetus for advances in agricultural productivity. Larger cities sustained a more refined division of labour than smaller towns, so urbanization also led directly to greater efficiency and higher wages (Crafts and Venables 2003).
The expansion of the early modern economy was underpinned by favourable institutional and cultural developments. The end of serfdom and the establishment of a stable legal environment favourable to capitalist enterprise undoubtedly promoted growth. The gradual decline in superstition and medieval religion and the corresponding rise of a scientific attitude inclined more and more people to look for practical solutions to life’s problems rather than trying to solve them by manipulating supernatural agents. The demands of trade and the enormous drop in the price of books spread literacy and numeracy. New products, many obtained from abroad like cotton, tea, sugar and tobacco, enlarged the aspiration to consume and increased the incentive to work and earn high income. Political institutions favourable to capitalist development, as well as the growth of literacy, numeracy and hard work, followed from the expansion of international commerce and cities (Brenner 1993, Hill 1966, Acemoglu, Johnson and Robinson 2005). Urbanization may also have undermined medieval superstition.

The upshot of the commercial expansion of the early modern economy was the unique wage and price structure that Britain enjoyed in the eighteenth century. Wages were high and energy was cheap. These prices led directly to the Industrial Revolution by giving firms strong incentives to invent technologies that substituted capital and coal for labour. The famous technologies of the Industrial Revolution – the steam engine, mechanical spinning and coke smelting – had these characteristics. The evolution of law and culture created a favourable supply response to these incentives. Since the evolution of culture and law had commercial roots, the international expansion of Britain’s economy in the early modern period made a decisive contribution to the Industrial Revolution. These themes define the agenda for the rest of the book.