4 Manufacturing and technological change

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Contents

THE SHAPE AND COURSE OF BRITISH MANUFACTURING

The global economic leadership that Britain enjoyed in the nineteenth century had its foundations in the nation's unprecedented industrial capability. To many Victorians and Edwardians this was a fact of life; it followed almost inexorably that should the uniqueness of that capability ever be lost, Britain's international pre-eminence would also be forfeited and decline ensue. The progress of manufacturing was seen as pivotal to Britain's economic fate.

To a large extent, this is also how Britain's decline has been cast in much of the economic history literature, where industrial decline and economic decline are taken as synonymous. As the manufacturing sector was a major employer that provided the vast majority of Britain's exports and was where the full brunt of the growing international competition was felt, it seems a reasonable focal point for the historical analysis of Britain's relative economic decline.

To some, the significance of manufacturing, because of its dynamic properties and integral place in the process of technological change, goes

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well beyond the size of its static contribution to national product. In this view, both economic growth and productivity are seen to be crucially determined by the expansion of the manufacturing sector (Kaldor 1966). Whether such a relationship applies in the late Victorian and Edwardian period is investigated later in the chapter, but it should be noted here that, despite the growing foreign challenge, manufacturing's place in the British economy was not in fact contracting. Rather, as Table 4.1 illustrates, its share of national output and the capital stock actually grew over the second half of the nineteenth century, while its share of employment remained constant. With around a quarter of the nation's output and a third of its employees in 1913, manufacturing's importance in the economy was stronger than ever. The sector also grew steadily over the period; by 1913 its output was more than two-and-a-half times greater than it had been in 1870. This progress was achieved, moreover, without substantial fluctuation. Between 1873 and 1913, growth rates rarely deviated markedly from the long-term trend of 2 per cent. This continuity of growth and general absence of instability in this period raises serious doubts about the existence of an industrial growth climacteric prior to the First World War. However, as Table 4.2 makes clear, the sector's annual average growth rate did decline dramatically in the transwar period between 1913 and 1920 when it fell to around 0.2 per cent. To a large extent this was a consequence of the war, a shock to the economy that saw the manufacturing sector contract at an average rate of 3.8 per cent each year between 1913 and 1918.

Table 4.1 Manufacturing's place in the economy, 1856–1913 (%)

	1856	1873	1913
Output (constant prices)	22.2	24.6	26.6
Employment	32.5	33.5	32.1
Capital stock	12.9	14.6	18.5

Source: Matthews *et al.* 1982: 222.

Table 4.2 Output and fixed capital growth in manufacturing, 1873–1924 (annual percentage growth rates)

Period	Output	Fixed capital stock
1873–82	2.3	2.3
1882–9	1.9	1.6
1889–99	2.3	2.8
1899–1907	1.6	2.7
1907–13	2.0	
1913–20	0.2	
1873–1913	2.0	2.6
1913–24	1.2	

Sources: Matthews *et al.* 1982: 228, 281, 381 and 378; Feinstein 1972: Table 51.

Inputs

The growth of manufacturing was paralleled by an expansion of employment in the sector. Between 1873 and 1913, employment grew on average at 0.8 per cent per annum (Matthews *et al.* 1982: 378), meaning that in 1913 around 30 per cent more workers were being employed in manufacturing than was the case in 1870. As Tables 4.2 and 4.3 show, capital accumulation in the sector also progressed strongly, especially after 1889, growing at an annual average rate of 2.6 per cent between 1873 and 1913. This had an impact on the capital intensity of work. Capital per unit of

Table 4.3 Gross reproducible capital, employment and capital per worker in manufacturing, 1869–1919 (1913 = 100)

	Gross reproducible capital stock	Employment	Capital per worker
1869	37.2	65.5	56.8
1875	44.4	70.7	62.7
1882	52.9	74.3	71.2
1889	56.7	80.6	70.4
1899	66.3	88.6	74.7
1909	90.1	90.4	99.6
1913	100.0	100.0	100.0
1919	125.3	97.4	128.8

Note: 1919 employment figure is an estimate calculated from the 1920 figure on the basis of the growth of output in that year.

Sources: Feinstein 1972: Tables 59 and 60; Feinstein 1988: Table XI.

output rose by 0.6 per cent per annum over the same period, while capital per worker more than doubled between 1869 and 1919.

Placed in a comparative perspective, however, this growth of capital intensity in British manufacturing was somewhat less than spectacular. In 1879 capital per unit of labour in British manufacturing was around 10 per cent higher than in the USA and almost 30 per cent higher than in Germany. By 1900, however, US manufacturing was nearly 90 per cent more capital intensive than British, while German capital intensity was almost on a par with Britain's (Broadberry 1997c: 106–7). Given the heavy focus in the literature on America's much greater capital intensity throughout the nineteenth century, a British lead in these regards up to as late as perhaps 1889 is somewhat surprising (Rostas 1948; Frankel 1957; Habakkuk 1962). Yet, as Broadberry (1997c: 108) points out, such a lead is not necessarily inconsistent with the view that the USA was indeed a much more machine-intensive manufacturer than Britain prior to 1889. Since machinery was in fact only one relatively minor component of each nation's capital stock at the time (Field 1985), it could well be that British manufacturers chose to invest more heavily in other forms of capital, such as structures, than their American counterparts.

There are alternative measures of capital. One such alternative is the quantity of energy consumed in manufacturing, a measure that in any case is potentially more revealing about machine usage, as capital equipment typically absorbed most of the sector's energy. Between 1870 and 1907 there was a massive growth of energy consumption in British manufacturing from approximately 1 million to 6 million horsepower, a rate of growth consistent with what is known about capital accumulation (Musson 1978: 166–70). The energy data, however, also lend support to the notion of the greater machine-intensity of American manufacturing throughout the latter half of the nineteenth century. In 1907/9, when the first reliable comparison can be made, horsepower per worker in American manufacturing was running at more than double the level of British manufacturing. Per capita energy use in German manufacturing by contrast was of the same order as British, whereas in France it was three-quarters of the British level (Broadberry 1997c: 108–9). These figures suggest that British, and indeed European, manufacturing before the First World War was significantly less mechanised than American. As will be seen later, this had important consequences for the relative levels of labour productivity found in each country.

Sectoral composition

The manufacturing sector was composed of a diverse collection of industries fabricating a wide range of products for the British and international marketplace. The first disaggregated data on the composition of the sector comes from the 1907 *Census of Production*, which supplied information on output and employment within the sector. This information, along with the comparable data compiled by the 1924 *Census of Production*, is given in Table 4.4. Despite the diversity of British manufacturing, it is immediately apparent from Table 4.4 that the textiles and clothing & footwear industries hold important places in the pattern of British manufacturing. Other prominent branches of the sector in 1907 and 1924 included food, drink & tobacco, mechanical engineering, metal manufacture and paper, printing & publishing. Overall, however, the majority of British manufacturing was located in the lighter industries, such as boot making, brewing and board making, which typically produced small or 'light' articles with relatively less capital-intensive production technologies. Thus, despite the emphasis placed in the literature on the heavy industries, such as chemicals production, engineering and the manufacture of metal goods, neither in 1907 nor in 1924 did these industries account for more than 40 per cent of the sector's workforce or net output.

What is more, across the transwar period, there is no significant shift in the sectoral composition of manufacturing. The dominant position of textiles and clothing remains, though it shows signs of erosion. These industries had in fact been declining as a proportion of the manufacturing sector's labour force since at least the 1870s. At the same time, other light industries, particularly food, drink & tobacco and paper, printing & publishing were becoming steadily more important; by 1924 they together were contributing almost as much to the sector's output as textiles and clothing. This development reflected the growing strength of the light industries in British manufacturing. By contrast, metals and engineering, which had been expanding prior to the First World War, contracted slightly over the transwar period, when the only growing branches of these industries were electrical engineering and vehicle manufacture.

Table 4.4 Sectoral composition of manufacturing in 1907 and 1924 (%)

	Employment		Net output	
	1907	1924	1907	1924
Chemicals	2.6	2.9	4.5	5.0
Coal and petroleum products	0.2	0.6	0.5	1.1
Metal manufacture	6.9	6.7	8.4	6.6
Mechanical engineering	8.4	7.8	9.6	7.0
Instrument engineering	0.4	0.4	0.4	0.4
Electrical engineering	1.3	2.9	1.4	2.9
Shipbuilding	4.3	4.4	4.4	3.4
Vehicles	6.6	8.4	5.6	7.7
Other metal goods	5.6	5.1	5.2	4.3
Textiles	25.0	22.5	19.8	18.1
Leather and fur	1.2	1.2	1.2	1.3
Clothing and footwear	12.4	10.9	8.3	7.9
Food, drink and tobacco	8.8	9.5	14.7	16.2
Brick, pottery, glass and cement	4.1	4.0	3.5	3.9
Timber and furniture	3.5	3.4	3.1	3.1
Paper, printing and publishing	6.3	6.5	6.8	8.2
Other manufacturing	2.4	2.8	2.6	2.9
Heavy industries	36.3	39.2	40.0	38.4
'New' industries	10.5	14.2	11.5	15.6

Source: Broadberry 1997c: 32–3.

A common criticism of British manufacturing since 1870 has been that the sector was slow to move into the new growth industries of the second industrial revolution, such as pharmaceuticals, automobiles and electrical equipment (Landes 1969; Kennedy 1987). A crude measure of the scale of these 'new' industries in 1907 and 1924 is given in Table 4.4, which is calculated by adding together the shares of the three industries most likely to encompass the new areas emerging: electrical engineering, chemicals and vehicle production. In 1907, these 'new' industries accounted for a small, though hardly negligible, 10 per cent of employment and output in manufacturing. Growth in these industries was in fact faster than in other branches of manufacturing, a fact that suggests that Britain's relative overcommitment to the old staples may have reduced the sector's overall rate of expansion. Between 1900 and 1913, the new industries grew at an annual rate of 3.8 per cent, whereas the sector as a whole grew at just 2 per cent. The contrast was even starker in the transwar period when between 1913 and 1924 the new industries grew at an average of 4 per cent every year, while manufacturing as a whole could only manage a relatively poor 0.7 per cent (Matthews *et al.* 1982: 257–8).

To what extent was the apparent failure to embrace the new industries due to underinvestment? It is often claimed that British investors had little interest or money for domestic industry, preferring instead to place their capital with projects initiated by overseas governments and enterprises (Kennedy 1987). This contention is taken up by Ross in chapter 15 below, but it is worth noting here that there is in fact little evidence to suggest that British investment projects were finding it difficult to raise capital at the time. Even new industries seemed able to secure the necessary funds when sought. If in fact insufficient resources were being devoted to new industries prior to the First World War, then, institutional impediments aside, this was chiefly due to demand-side rather than supply-side constraints.

Organisation

Another common criticism of British manufacturing is based on the perceived nexus between business organisation and economic performance. According to Chandler (1990), by the end of the nineteenth century competitiveness in manufacturing hinged crucially on the development of multi-unit, vertically integrated and professionally managed firms, a form of organisation uniquely adept at tapping into the economies of both scale and scope. Such firms, it is contended, were rare in Britain in the late Victorian and Edwardian period, at least relative to America and Germany. Indeed, in Britain, the small, family firm remained the norm well into the twentieth century. The dominant feature of British manufacturing, therefore, was its vertical specialisation and intense competition.

According to Elbaum and Lazonick (1986), it was the strictures imposed by this atomistic organisation of production that in fact represented the main constraint on the viability of British manufacturing going into the twentieth century.

There is no doubt that Elbaum and Lazonick are correct in claiming that the family-owned and family-run factory was the typical form of organisation in British manufacturing before the First World War. In the 1880s less than 10 per cent of the manufacturing sector was accounted for by the 100 largest concerns, a figure which had risen to just 16 per cent by 1909. This degree of concentration was slightly below the American figure of 22 per cent, though above the French figure of 12 per cent. Most industrial markets in Britain, therefore, were catered for by a large number of small price-taking firms. Competition in the manufacturing sector, consequently, was generally intense (Hannah 1983: 13, 23, 180).

Yet it would be wrong to assume from this that the British firm was necessarily inflexible, inefficient or amateurish. British marketing techniques, for example, often lambasted in the literature for their backwardness (Landes 1969: 337; Kirby 1981: 8), prove on closer analysis to be creative and adaptive (Nicholas 1984). In industrial districts, such as Lancashire or London, where competition was fierce, small and vertically specialised firms located in close proximity to downstream (or upstream) firms could prove as technically efficient as the vertically integrated firm (Godley 1996; Johnson 1996; Leunig 2001). The family firm Alfred Herbert Limited, for example, one of the most important companies in the machine tool industry, had an excellent record of profitability and innovation before 1914 and in the interwar period (Arnold 1999). Family firms in Germany at the time also proved remarkably adaptable and viable bases upon which to construct more efficient managerial forms (Schumann 1999).

Nor can it be said that British manufacturing firms were exceptionally small by international standards. The largest American firms certainly tended to be bigger than their British counterparts. In 1912, US Steel had a market capitalisation of issued equity stock more than double that of the largest British company, the textile firm, J & P Coats. J & P Coats, however, was more than twice the size of Krupps, the largest German firm at the time. Average capitalisation values similarly show the leading British firms lying between the Americans and Germans in terms of scale (Schmitz 1995: 23–7). Employment data add further weight to this picture. In 1906–13, the average manufacturing establishment in Britain employed sixty-four people compared to sixty-seven in the USA, fourteen in Germany and twenty-six in France. In certain industries, such as textiles, paper & printing, foods, ceramics and chemicals, the average scale of enterprises in Britain, at least as measured by employee numbers, was as large as, if not larger than, in both Germany and America. The largest British chemical firm in 1903, United Alkali, employed over a thousand more

workers than BASF, Germany's biggest manufacturer of the time. It was only in the heavy industries, such as iron and steel, that British plant was comparatively small (Kinghorn and Nye 1996: 97–104). Indeed, the largest British firms were disproportionately located in traditional light industries, such as food, drink & tobacco and textiles, a reflection of the importance of these industries in British manufacturing (Schmitz 1995: 29).

The growing size of British firms over the latter half of the nineteenth century was accelerated by the increasing merger activity of the period. Driven by scale-intensive technologies, overproduction and a capital market which looked favourably upon larger concerns, the merger movement reached its peak between 1894 and 1903, when more than a thousand firms valued at £73.9 million disappeared. This, however, paled in comparison with the feverish activity taking place in the USA where in 1899 alone 979 firms with a value of over £400 million were merged. A second surge of merger activity in Britain, larger in terms of value, occurred across the transwar period as firms like Vickers and Nobel attempted to strengthen their peacetime positions by diversifying into non-military products (Hannah 1983: 17–29).

On the whole, then, the Chandlerian model does not fit terribly well with the British experience. British firms were small only relative to their American counterparts and even then the difference on average was not very large. Family firms were not incapable of efficiency. Industrial concentration levels were not exceptionally low. Most troubling of all for the model's explanatory power is that German industry, typically lauded for the relatively large size of its firms, in fact conforms even less to the ideal. Firm size is not a good predictor of industrial performance. British business organisation differed from the American, but this does not mean that it was necessarily inferior. Rather, the pattern of British business could just as easily be seen as a rational response to its unique environment. The relative abundance of skilled shopfloor workers and the legacy of craft control in Britain for one thing made it less profitable for British manufacturers to adopt the labour-replacing technology and managerial practices central to mass-production (Harley 1974).

British demand conditions also militated against the adoption of American practice. In 1860 America's population was already one-and-a-half times larger than Britain's; by the turn of the century it had grown to close on two-and-a-half times that of the British.

Protected by tariff walls and opened up by the railroads, the American market was thus far larger than the British home market and hence offered greater opportunities for mass-production. Yet, as we have seen, the average manufacturing establishment in Britain in terms of employee numbers was at least comparable to the American, a finding that suggests that the British market was clearly capable of supporting firms operating at levels of production obtained by the larger American manufacturers

(Rostas 1948). Where the difference between the countries lay was in the nature of the demand. In the nineteenth and early twentieth centuries standardised products were more marketable in the USA than in Britain, a fact that facilitated the adoption of mass-production techniques in that country (Hounsell 1984). There are number of reasons for this greater acceptance of standardisation in America. First, the greater income inequality and class distinctions of Britain created there a relatively small group of consumers, many of whom insisted upon high-quality, customised products (Rothbarth 1946; Williamson 1991). Secondly, the lower levels of income per capita in Britain also acted as a barrier to standardised production, especially in the more expensive consumer durables (Tolliday 1987; Bowden 1991). Finally, the growing orientation from the 1870s of the British exporter towards Empire markets that were spread over different continents and subject to varying cultures and income levels was hardly conducive to standardised production (Broadberry 1997c: 97). Whatever its sources, the very different demand patterns experienced by British producers made less standardised, flexible production technologies far more appealing than their American alternatives.

Table 4.5 National shares of world manufacturing output, 1860–1928

	1860	1880	1900	1913	1928
UK	19.9	22.9	18.5	13.6	9.9
France	7.9	7.8	6.8	6.1	6.0
Germany	4.9	8.5	13.2	14.8	11.6
Italy	2.5	2.5	2.5	2.4	2.7
Japan	2.6	2.4	2.4	2.7	3.3
USA	7.2	14.7	23.6	32.0	39.3

Source: Bairoch 1982: 296 and 304.

Table 4.6 Industrial growth in leading manufacturing countries, 1870–1913 (annual percentage growth rates)

	UK	USA	Germany	France
1870–80	2.3	5.7	5.9	2.6
1880–90	2.5	5.6	4.6	1.9
1890–1900	2.1	3.1	3.9	2.3
1900–13	2.1	5.4	4.4	3.3

Source: Lewis 1978: 148–50.

BRITISH MANUFACTURING IN INTERNATIONAL PERSPECTIVE

Relative scale and growth

As we have seen, British manufacturing exhibited strong and stable growth across the late Victorian and Edwardian era. This fact, however, did little to alleviate the concerns of many at the time and since who felt that the sector was in the process of losing its dominance. Comparative data, such at those given in Tables 4.5 and 4.6, have thus typically lain at the heart of the criticism of British performance after 1870. Yet such data are not entirely negative about British performance. Table 4.5, for example, confirms Britain's status as the world's largest manufacturer in the nineteenth century. In 1880 more than one fifth of all manufactured products in the world originated in Britain. From that point, however,

Britain's relative position did begin to slide; by 1913 it had fallen to third place behind the USA and Germany. This transition in industrial leadership is also reflected in the growth data presented in Table 4.6. The concern of observers of the time that Britain was losing its place in the world was thus not entirely without justification. Interpreting this loss, however, is no straightforward matter. Britain's relatively poor growth performance may indicate a failure, but also could just as well be the product of the evolution of the international economy as new industrial producers, often with large natural markets like those of America and Germany, emerged on the scene and as rising British wealth and living standards induced resources to be shifted out of manufacturing and into the service sector.

The slower growth of demand in Britain did, however, have consequences for the rate of technological change, by affecting the rate at which machinery was replaced. Investment theory shows that if an industry grows faster than another, it will, *ceteris paribus*, have on average a younger capital stock; and if, in turn, technological change is largely embodied in new capital equipment, this newer capital will be more efficient, granting the rapidly growing industry a lower cost structure (Solow 1960). Slower demand growth, therefore, accounts for the frequently reported reluctance of British manufacturers to discard their old machinery with the same relish as their American competitors. To the extent that protective tariffs also barred British exports from most of the rapidly expanding markets of Europe and North America, limitations of demand – both in terms of scale and nature – effectively reduced the capacity of British manufacturing to modernise at the same rate as the Americans and Germans. Such limitations were factors in the performance of the British steel and paper industries (Temin 1966; Tolliday 1991; Magee 1997b: 199–206).

Exports

As an island nation, Britain has always looked beyond its shores for markets and inspiration. In this regard, British manufacturing was no different. In 1913, 45 per cent of the sector's output was destined for foreign consumers. The corresponding percentages for Germany and the USA were 31 and 5 respectively (Maizel 1963: 223). The international trade in manufactured goods in the latter half of the nineteenth century was important both in terms of value and international pride. In 1913, it accounted for 36.7 per cent of all world trade and was larger in value than the trade in food (Alford 1996: 43). Furthermore, it was a rapidly expanding trade, whose volume tripled between 1880 and 1913 (Bairoch 1982: 296). Britain held a commanding position in this trade. In the early 1880s, British producers were responsible for 43 per cent of world trade in manufactured goods, a leading role that it was able to hold on to,

despite growing competition from the USA, right up until 1929. For most of the nineteenth and early twentieth centuries, then, as Table 4.7 demonstrates, there is real substance to the claim that Britain was indeed the workshop of the world. It was, however, a workshop whose foundations were steadily being eroded. As Table 4.8 illustrates, British export growth was significantly slower than that of other leading industrial nations, especially in the 1880s. Furthermore, between 1913 and 1929, a period in which the volume of world trade in manufactures was expanding at an annual rate of 2.9 per cent, the exports of British manufactured goods actually contracted each year on average by 0.5 per cent (Matthews *et al.* 1982: 467). Not surprisingly, this period is characterised by a significant decline in Britain's share of world trade.

Table 4.7 National shares of world trade in manufacturing exports, 1881–1929

	UK	USA	Germany	Japan
1881/5	43.0	6.0	16.0	0.0
1899	34.5	12.1	16.6	1.6
1913	31.8	13.7	19.9	2.5
1929	23.8	21.7	15.5	4.1

Source: Matthews *et al.* 1982: 435.

Table 4.8 Growth of manufactured exports in selected countries, 1871–1913 (annual percentage growth rates)

	UK	USA	Germany	France
1871/5–1881/5	2.1	7.1		2.2
1881/5–1891/5	0.4	2.7	1.7	1.2
1891/5–1901/5	1.7	9.1	4.3	2.5
1901/5–1913	3.6	6.1	3.3	5.0
1871/5–1913	2.0	6.2		2.3
1881/5–1913			3.7	

Source: Hilgerdt 1945: 158–61.

Apart from the appearance of new foreign producers, Britain's relatively poor export performance had its origins to some extent in its waning price competitiveness from at least the early 1880s. This can be seen in the movements of the relative export price of UK and US manufactured products between 1879 and 1913, which show British prices slowly but fairly steadily drifting up by around 25 per cent vis-à-vis those of its main industrial competitor. In the early part of the 1890s, in particular, there is in a matter of a few years a sharp rise of some 15 per cent, which neatly corresponds with a surge in American exports (Greasley and Oxley 1996: 95).

A further factor affecting Britain's ability to export was the limits to free trade imposed by the commercial policies of different nations. Many industries appear to have been deleteriously affected by tariffs. The introduction of the McKinley Tariff by the American Congress in 1890, for example, is said to have had a major impact on the tinplate and iron and steel industries of Britain (Pollard 1989: 53). In 1890 the ratio of customs duties to imports, a measure of the degree of protection in place, stood at 29.6 per cent in the USA, 8.8 per cent in Germany and 4.8 per cent in the UK. Although all of these percentages subsequently fell in the years leading up to the First World War, they none the less illustrate the significant tariff barriers that British exporters faced in Europe and North America (Broadberry 1997c: 139–41). Despite these barriers, Britain remained a major exporter of manufactured goods throughout this period. Its main

Table 4.9 Main exports (excluding re-exports) of the United Kingdom (share of total), 1881–1913

	1881–90	1891–1910	1910–13
Coal	5.0	6.5	9.4
Iron and steel	11.3	9.8	11.3
Machinery	5.3	6.8	7.1
Electrical goods		0.7	0.8
Vehicles		0.08	0.6
Shipbuilding		0.8	1.9
Non-ferrous metals products	2.3	2.3	2.3
Cotton goods	31.4	27.8	25.7
Wool goods	10.1	8.8	6.7
Chemicals	4.6	4.9	4.3

Source: Alford 1996: 34.

comparative advantages lay in the unskilled labour-intensive commodities of the old staple industries. As Table 4.9 shows, textiles and iron & steel held the dominant place in the British export trade. Together these industries accounted for over a half of all British exports in the 1880s. In the following three decades, however, the share of the textile industry declined. In part this was due to the faster export growth of other industries; in part due to Britain's exclusion from the wealthy markets of Europe and America for all but the highest-quality cloth; and in part due to the resurgence of textile production in Asia (Crouzet 1982: 350). Britain's export data also reveal its lack of comparative advantage in most of the high-technology, human-capital-rich sectors of the period. The one exception was industrial equipment and machinery, though even this advantage had disappeared by 1929. By contrast, these emerging, technologically progressive sectors figured prominently among both American and German manufactured exports, a finding that suggests that Britain's human capital endowment may not have been sufficiently abundant for her to be competitive in these industries (Crafts and Thomas 1986; Crafts 1989b).

Productivity

To arrive at a rounded conclusion about the performance of British manufacturing, the sector must also be examined from the perspective of actual and potential development. One way to do this is to look at the comparative productivities of countries across time. Estimates of labour productivity in British manufacturing are given in Table 4.10. Apart from a plateau in the second half of the 1870s, output per worker in manufacturing increased steadily throughout, growing at an average rate of 1.3 per cent per annum between 1869 and 1913. During the war, however, labour productivity levels regressed and did not show growth again until after 1920. Over this entire period, British labour productivity in manufacturing remained approximately comparable to German, but consistently below American levels. As Table 4.10 demonstrates, the average American manufacturing worker tended to be twice as productive as his or her counterpart in Britain, with the lead, if anything, broadening over the Edwardian and transwar eras.

There was, of course, considerable variation in productivity levels within the sector. They were at their poorest in Britain in the heavy

Table 4.10 Labour productivity in manufacturing in the UK, USA and Germany, 1869–1925

	UK labour productivity (1913 = 100)	USA/UK labour productivity	Germany/UK labour productivity
1869	55.6	203.8	
1871	62.0		92.6
1875	65.0		100.0
1879	64.8	187.8	
1882	74.1		83.6
1889	77.5	195.4	94.7
1899	88.3	194.8	99.0
1909	91.0	208.5	117.8
1913	100.0	212.9	119.0
1919	94.8		
1920	93.9	222.8	
1925	119.6		95.2

Source: Broadberry 1997c: 42, 43, 48, 49, 127.

industries that were subject to significant economies of scale. In the automobile, copper, tinplate and iron & steel industries in particular, labour productivity in Britain in 1907/9 was between a quarter and a third of American levels. Poorer than average performance was also exhibited in the manufacture of soaps, detergents, hosiery, paper and board.

Yet it is important to realise that relatively low labour productivity need not necessarily imply failure. The case of the paper industry is instructive in that the roots of its lower productivity for most of the nineteenth century lay in its unique, yet rational, use of a raw material that required a more labour-intensive form of production. As the first nation to mechanise the process of making paper, Britain held a lead in the industry, both in terms of technology and market share, that was to be unchallenged at least until the 1860s when competition from German and American producers grew more marked. Despite the advent of these rivals, the industry remained innovative, with the average running speeds of British paper machines, an acknowledged industry gauge for technological progress, increasing at least as fast as the American until the 1890s. British paper makers also played a major role in the search for a solution to the industry's greatest problem of the late Victorian and Edwardian era: the urgent need for a new source of cellulose, the key ingredient of all paper and board. Traditionally paper had been made out of rags, but by the latter half of the nineteenth century, manufacturers were finding it difficult to obtain sufficient quantities of rag to meet the rapidly rising demand for paper. The ensuing search for a replacement for rag spanned the world and many of the leading British firms invested heavily in locating and testing the paper making properties of new materials such as bamboo and straw. In particular, British paper makers were

instrumental in the development of a process to use esparto, a grass grown in North Africa and Spain, which proved itself capable of producing good-quality paper. As a result, esparto became the main substitute for rag in Britain until the turn of the century by which time the superiority of wood pulp, a material whose popularity had been growing in America since the Civil War, had become apparent. This British preference for esparto in the latter half of the nineteenth century had important implications for productivity. Because the conversion of esparto into cellulose required significantly more hands than was the case with wood pulp, its use reduced British labour productivity in the industry to levels significantly below American, even though British technology for most of this time was at least on a par with that on the other side of the Atlantic (Magee 1997b).

The labour productivity gap between the two countries, indicated in Table 4.10, also tended to be less extreme in the lighter industries, especially those associated with textiles, clothing and food processing where standardised mass-production either faced no demand-side constraints in Britain, afforded little competitive advantage or simply could not be easily applied. The tobacco industry provides a good illustration of a market that was sufficiently large for British producers to embrace standardised, capital-intensive methods of production. Between 1870 and 1914, the consumption of tobacco products, especially cigarettes, grew rapidly both in Britain and elsewhere. Major export markets opened up for British producers, most notably in the Empire. At the forefront of this expansion of the industry was the Bristol-based firm W.D. & H.O. Wills. Its exceptional success in this period was based on a twin-pronged strategy of using the latest technologies and pioneering the techniques of mass-marketing. In 1880 it acquired the exclusive rights to a mechanical packing machine; this was followed in 1886 by its adoption of Williamson's air-tight tin. The most important technological advance for the industry, however, came with the invention of the Bonsack cigarette machine in 1881. Wills, realising the potential, purchased the exclusive British rights to this technology in 1883, a move that, by placing the firm at the cutting edge of production technology, strengthened its position in the market significantly. As a result, by 1900 just over 10 per cent of the domestic market and nearly a half of all British cigarettes exported were manufactured by Wills. Around this time, however, serious competition from the American Tobacco Company began to be felt in the home market. To counter this, in 1901 Wills merged with other major British firms to form what was to become for a while Britain's largest company, the Imperial Tobacco Company. It proved a successful strategy and helped the British industry to remain internationally competitive well into the twentieth century (Alford 1973).

There were other successes as well. Indeed, in a handful of cases, such as in seed-crushing, the manufacture of lead and zinc and shipbuilding,

British labour productivity levels actually exceeded American in 1907/9. Of these, the success of the shipbuilding industry in this period is particularly noteworthy. More than 80 per cent of all new tonnage built in 1892 had its origins in British yards, a figure that, despite the growing protection afforded to many of its foreign competitors, still stood at more than 60 per cent in 1911. As the iron steamship was one of the technological wonders of the age, such a dominance of the world market by Britain represented a significant achievement. In this instance, the secret of British success, however, lay not in its adoption of mass-production, but rather in the flexibility and efficiency of its craft-based production system. In particular, British firms benefited from the fact that in shipbuilding the profitability of capital-intensive forms of production was severely limited by a demand that was highly cyclical and volatile by nature. A high proportion of fixed costs therefore exposed producers to exceptionally large losses during downturns. By substituting traditionally trained skilled labour, which was available in abundance, for machinery, British shipbuilders were to a large extent able to cushion themselves from such demand shocks while retaining their ability to produce efficiently. The concentration of shipyards on the Tyne, Wear, Tees and Clyde also encouraged the development of local economies that were tightly geared to servicing the specific needs of the shipbuilders. Thus, in the vicinity of yards, one could find some of the world's leading manufacturers of shipyard machinery, marine engineers and architects as well as a wide variety of multi-skilled craftsmen, the so-called 'amphibians' who could find work both in the shipyards and on land. The establishment of linkages between shipbuilders and shipping lines further helped by mitigating the impact of cyclical downturns in demand. Such external economies of scale greatly augmented the flexibility of British shipbuilding, helping it in turn to maintain its high productivity levels right up to the First World War (Pollard and Robertson 1979).

Labour productivity calculations, however, have their weaknesses, not the least being that they are only partial measures of productivity. They do not, for example, make allowances for changes in capital stock or energy use (Rostas 1948). An arguably better way of examining how efficiently an industry is using all the resources available to it is to calculate its total factor productivity growth (TFP). This technique measures the rate of growth of output not accounted for by the growth of all inputs (Brown 1966). Estimates of TFP are presented in Table 4.11. These estimates show TFP in manufacturing increasing on average by 0.6 per cent each year between 1873 and 1913. Such growth in the productivity of the sector accounted for 30 per cent of all manufacturing growth and 35.5 per cent of all TFP growth in the British economy in this entire period (Matthews *et al.* 1982: 228). Table 4.11 also lends further support to the notion of an Edwardian slowdown in productivity. Between 1899 and 1913, the rate of productivity growth fell to a third of what it had been in the last quarter

Table 4.11 Total factor productivity growth in manufacturing in the UK, USA and Germany, 1873–1925

	UK (%)		USA/UK (UK = 100)	Germany/UK (UK = 100)
1873–82	1.1	1869	204.9	
1882–9	0.4	1875		116.4
1889–99	1.1	1879	189.7	
1899–1907	0.1	1889	174.0	104.9
1907–13	0.3	1899	166.8	99.8
		1909	179.7	118.5
1873–99	0.9	1913		117.2
1899–1913	0.3	1919	179.5	
1873–1913	0.6	1925		110.5

Sources: Feinstein *et al.* 1982: 178; Broadberry 1993.

of the nineteenth century. Up to 1907 TFP showed virtually no improvement at all. It picked up slightly in the years leading to the war, but still grew at what was a comparatively low rate of 0.3 per cent per annum.

Relative to the USA and Germany, Britain's TFP performance in manufacturing was once again not impressive. TFP in America in 1869 stood at twice the British level, but unlike the labour productivity gap at least the TFP levels converged somewhat up until 1899. German TFP by contrast tended to operate at a level on average about 10 per cent above the British throughout the period in question. It is worth noting that against both countries, British TFP lost ground in the first decade of the twentieth century. In the following section, technology and other factors influencing this relatively poor productivity performance are discussed.

TECHNOLOGICAL CHANGE

The ability to create, develop and implement new technologies is generally held to be central to the attainment of long-term industrial competitiveness (Pavitt and Soete 1981: 106). Not surprisingly, then, most theories of Britain's industrial decline in some way touch, if not actually focus, on the process of technological change. As Mokyr (1990: 266) succinctly puts it, for many the failure of late Victorian Britain 'was not an economic failure, but a technological and scientific one'.

This failure, of course, related to not just the generation of ideas, but also technical choice: the seeming inability or unwillingness of British manufacturers to adopt cutting-edge equipment when it became available. The cotton industry's failure to adopt ring spinning and automatic looms, the dyestuff manufacturers' reluctance to capitalise on Perkin's synthesising aniline, and the alkali manufacturers' clinging on to the

Leblanc process, are just the better-known instances of this phenomenon. Proponents of the entrepreneurial failure thesis claim that this has steadily eroded British industrial competitiveness since the latter half of the nineteenth century. While the specific question of the quality of British entrepreneurship is considered in chapter 9 below, it is worth noting here that most of these alleged irrational choices in fact tend to make perfect sense once allowance has been made for factor costs, demand conditions and the state of knowledge (McCloskey and Sandberg 1971). Thus, it was the cotton industry's emphasis on the finer grades of cloth combined with the relative abundance of skilled labour and dense co-location of spinning and weaving firms in Lancashire towns – and not irrationality – that explained the cotton manufacturers much-debated predilection for mule spindles (Sandberg 1974; Leunig 1997). Similarly, the paper makers' apparently peculiar preference for esparto grass over wood pulp as a source of cellulose at the turn of the century becomes more understandable when due consideration is given to the sources, timing and flow of new information about the competing raw materials available at the time (Magee 1997b). Indeed, the only failure that is widely accepted in the literature was the soda manufacturers' retention of the Leblanc process long after the superior profitability of the alternative Solvay process had been established; this is a somewhat atypical example in that it occurred in a heavily cartelised industry largely sheltered from foreign competition (Lindert and Trace 1971). Where competition was stronger, the application of sufficient entrepreneurial vigour (Magee 1997a) to technical choice does not appear to have been a major problem.

The soundness of British invention and innovation, however, is less easy to establish. The late nineteenth and early twentieth centuries were a period of major technological transformation, an era in which *inter alia* the internal combustion engine, electricity, synthetic dyes, aspirin, telephony, the automobile and the wireless radio came of age. To what extent was Britain in the van of these technological revolutions? One problem in addressing this question is that there is no unambiguous index of a nation's technological performance. There are, however, a number of measures, which might serve as a proxy. Streit (1949), for example, provides a list of 1,012 major inventions made between 1750 and 1950 and their countries of origin. To the extent that these inventions constitute a meaningful sample of inventive activity, the list, summarised in Table 4.12, sheds some light on the changing location of technological leadership over this period. It shows that the relative contributions of Britain and America to the first industrial revolution (1776–1825) are almost exactly reversed in the second

Table 4.12 Major inventions by country of origin, 1776–1926 (percentage of total)

	Total	Britain	USA	Germany	France
1776–1825	163	43.6	11.7	9.8	26.4
1826–75	292	22.6	24.0	21.2	21.6
1876–1926	343	14.0	43.7	17.5	14.0

Source: Streit 1949.

Table 4.13 Foreign patents granted in the USA by country of origin, 1883–1929 (%)

	1883	1890	1900	1913	1929
Austria	2.6	3.4	3.4	4.0	2.5
Belgium	1.6	0.9	1.4	1.3	1.3
France	14.2	8.5	9.8	8.1	9.8
Germany	18.7	21.5	30.7	34.0	32.4
Sweden	1.0	1.5	1.3	2.1	3.2
Switzerland	1.8	2.7	2.3	3.1	4.5
UK	34.6	36.2	30.5	23.3	22.2

Source: Pavitt and Soete 1981: 109.

(1875–1926). Britain's inventive dominance is steadily lost over the course of the nineteenth century, so that by 1875 it is just one of the sources, albeit still an important one, of new technological ideas. This impression is supported by the patent data from the USA presented in Table 4.13. It confirms both the massive scale and the relative decline of British inventive and innovative activities at the turn of the century. Table 4.13 also shows the growing capacity of Germany, which by 1900 was rivalling Britain. The relative rise of German capability is more starkly seen in per capita terms: whereas the average Briton was patenting more than twice as frequently in America as the average German in 1886–90, by 1910–15, the gap had narrowed to just 17 per cent (Edgerton 1996: 64).

Moreover, the composition of British patenting in the USA between 1890 and 1912 provides further ground for concern. British inventors and firms tended to patent disproportionately in technologies associated with traditional industries, which offered fewer opportunities for rapid change. In the twenty-five years leading up to the First World War, Britain's greatest technological strengths still lay predominantly in industrial engines and turbines; rubber, coal and petroleum products; shipbuilding; soaps, detergents and fertilisers; textiles; and radio and telegraphic equipment. By contrast, German patenting was characterised by a much stronger commitment to the new industries of the second industrial revolution: chemicals, especially dyestuff and paints; pharmaceuticals; lighting and wiring; radio receivers; and electrical operating systems (Cantwell 1991: 46–7). It is clear that Britain was not at the forefront of the new wave of technologies breaking at the end of the nineteenth century.

What accounts for Britain's relative technological decline after 1870? One feature of British manufacturing that has constantly cropped up throughout this chapter is the sector's somewhat limited engagement with the new industries and technologies of the period. That these industries tended on the whole to be more scientifically orientated has prompted claims that the British worker and manager was simply inadequately trained to meet the challenges of the new technologies (Crafts 1989b: 135). Yet, as the discussion of human capital in chapter 3 above demonstrates, such claims have tended to be overstated. Technical education in Britain was not non-existent, as often asserted, but simply different with a greater emphasis on intermediate level skills than was the case in the USA.

In evaluating the strengths of Britain's technological system, it is also important to bear in mind that, in the late Victorian and Edwardian

period, innovative activity was still largely the preserve of the independent inventor. Research and development (R&D) was typically carried out on the shop floor in a rather *ad hoc* manner with little direct application of scientific expertise. Admittedly, consulting chemists and engineers did exist, but when engaged they tended to undertake specific tasks rather than initiate systematic R&D programmes (Saul 1968: 117–18; Magee, 1997b: 38–9). To an extent, the existence of a relatively sophisticated international market for technological ideas obviated the need for more in-house research. By acquiring machinery from specialised capital good producers or through the patent system, the immediate technological needs of most firms could be easily met without incurring the significant costs of doing in-house R&D (Magee 1999, 2000). Indeed, costs were a real consideration for firms since in most instances such activity would have had to have been funded out of retained profits and, hence, be paid up front. Nor did the state offer much by way of relief. Other than providing indirect support through the funding of universities, museums and other institutions such as the National Physical Laboratory established in 1900, the state's engagement in Britain's R&D effort in this period was almost entirely restricted to purely defence-related matters (Edgerton 1996: 42).

The contribution of Britain's higher education sector was also limited. Unlike the situation that was emerging in the USA, where by the first decade of the twentieth century tertiary institutions such as Massachusetts Institute of Technology (MIT) were already involved in commercially funded research in electrical and chemical engineering, the research links between British industry and universities were comparatively weak and rare (Mowery and Rosenberg 1998: 23–5, 82). British tertiary education was also seemingly less focused on technical and scientific subjects than American. In 1870, only nineteen students graduated with degrees in science, mathematics or technology in England. In that year neither Oxford nor Cambridge offered courses in these fields. While thirty years later the situation had improved somewhat, England still only managed to produce just 677 science, mathematics and technology graduates in 1900, a small minority of the students who graduated in that year (Edgerton 1996: 20). The contrasts with Germany are striking. In 1872, there were fewer students reading for degrees or engaged in research in chemistry in England than there were at the University of Munich alone. This situation had not changed dramatically by 1908 when there were still fewer than 300 students enrolled in applied science courses in the entire country; at this time German universities were churning out over 400 graduate degrees in chemistry alone each year. The story is much the same in engineering. Between 1900 and 1910, German *Technische Hochschulen* were producing on average around 1,000 graduate engineers each academic year; the corresponding figure for Britain was about 400 (Sanderson, 1972: 271; Aldcroft 1975: 293; Fox and Guagnini

1993: 80). The implication of these figures is that, relative to its competitors, British industry may have been starved of scientifically trained personnel capable of working with the cutting-edge technology of the time.

To what extent was this true? While most comparative studies do tend to identify a British shortfall in scientifically trained workers, especially relative to the USA, the scale of the disparity was probably not as stark as has often been supposed. Owens College in Manchester alone, for example, saw seventy-one of its honours graduates in chemistry between 1884 and 1901 find employment in industry. Similarly, between 1870 and 1914, the membership of British engineering institutions rose tenfold from 4,000 to 40,000. These figures suggest that scientific skill was far from absent from British industry. Such skill was also making progress in entering the ranks of management. Between 1875 and 1895, 14 per cent of active partners or executive directors of British steel firms had had formal technical training, a share that rose to 16 per cent between 1905 and 1925. It is noteworthy that in the latter period, around a third of those technically trained managers had acquired their training at Oxbridge (Edgerton 1996: 25–7). How did this situation compare with other countries? Comparable data are sparse, but a number of scholars have argued that a larger proportion of American managers in this period had university qualifications than was the case in Britain (Chandler 1977). Similarly, a study of leading businessmen in Germany and Britain between 1870 and 1914 has found that only 13 per cent of British businessmen had any form of higher education, whereas nearly double the proportion of the Germans, some 24 per cent, had experienced it. Revealingly, though, there was virtually no difference between the countries among those businessmen born after 1860, a finding that indicates that the higher education gap must have progressively narrowed over the period (Berghoff and Moeller 1994).

At the turn of the century, the *ad hoc*, uncoordinated nature of nineteenth-century invention started to change, as an increasing number of firms, cognisant of the strategic need to keep abreast of technological knowledge, took it upon themselves to establish their own independent R&D capability. Although German and American corporations led the way in this process, British firms were also involved. By the first decade of the twentieth century, it has been estimated that around £0.5 million was being expended by British firms on R&D each year; by the 1920s this figure had risen to more than £2 million. The vast majority of this British R&D effort was concentrated in a few large firms manufacturing chemicals and naval shipping (Edgerton 1994; Edgerton and Horrocks 1994). Such levels of spending, however, were almost definitely lower than the amounts being invested in both Germany and the USA. Certainly, in Britain there was nothing to compare to the massive research laboratories that by this time were being operated by the likes of General Electric, Eastman

Kodak and Bell Telephones in America or Bayer in Germany (Mowery and Rosenberg 1989: 101, 107). In relation to its competitors, then, there is certainly some evidence to suggest that late Victorian and Edwardian Britain may have underinvested in R&D and higher-level scientific and technical training, even if the magnitude of the gap between it and its main competitors prior to 1914 was probably not as large as many critics have maintained.

Another distinctive feature of British manufacturing, which may have affected its productivity and technological performance, was its high and increasing rate of unionisation. In 1892, 13 per cent of the manufacturing workforce were paid-up members of a union; by 1911 that percentage had risen to 18.6 per cent. During the war, unionisation, tacitly encouraged by government in order to advance the war effort, increased dramatically, so that by 1925 slightly under a half of the entire manufacturing workforce had been unionised. By contrast, while there were some exceptions (Magee 1997b: 169–73), American manufacturing on the whole appears to have been conspicuously less unionised. Only 4.3 per cent of American manufacturing workers were in unions in 1897, a figure that had risen to just 18.1 per cent by 1920 (Broadberry 1997c: 145–6).

Such a difference in unionisation may have had significance for the very different rates of technological development achieved by each nation, especially after 1890. In fact, a major theme in the literature of the period is the hostility of British unions and workers in general to changes that altered the existing customs and arrangements regarding employment in their industry. Because of regional concentration, vertical specialisation and a traditional emphasis on skill-intensive flexible production methods, British industry in the nineteenth century tended to depend heavily on its craftsmen to co-ordinate production. Manufacturers, thus, typically left the management of the shop floor, from hiring and training of employees right through to setting of work rates and manning ratios, to the most experienced and skilled workers, an arrangement which gave these workers and their organisations considerable industrial power and prestige (Lazonick 1979, 1994).

While such craft control undoubtedly could work and even adapt efficiently within the confines set by nineteenth-century technologies, in the longer term it proved less malleable and tended to impede shopfloor flexibility. Increasingly menaced by the advent of skill-displacing technologies, which threatened to challenge their dominance of the workplace, craft unions used their power on the shop floor to enforce traditional practices in the workplace in terms of the numbers employed, training, routines and piece-rates. Such attempts were more successful in industries, such as shipbuilding and cotton, where skilled craft labour could not be easily replaced and was relatively better organised than its employers. Irrespective of outcome, however, the increasing frequency and pervasiveness of such disputes over shopfloor control as the end of the

century drew nearer only served further to sour relations with management and make the labour force even more defensive about technological change in general: hardly developments likely to spur on innovative effort at the grassroots level. Lewchuck (1987: 221–5) contends that such mistrust between management and labour in the automobile industry produced a sub-optimal outcome in which British manufacturers, fearful of union objections, opted not to pursue the adoption of American mass-production technologies, while workers, suspicious of employers' intentions, chose not to co-operate in shopfloor reorganisation.

But poor technological choice was not the only drawback of such a restive workplace. Given that a significant proportion of technological change in manufacturing originates in the ideas and innovations of those who work in it, matters of industrial relations also clearly play an important part in determining the degree of technological change that is realised. Working in an atmosphere of industrial conflict, characterised by friction between labour and capital and resentment of the owner, a worker may simply have no desire to help the boss out by improving his machinery; at least, not unless something is given in return. Where, however, the benefits of such learning acquired through production were considered important enough, employers could opt for remuneration plans favourable to its employees and the generation of further home-grown innovation. Apart from piece-rates, other incentive-driven remuneration policies that can be employed include profit-sharing plans, bonuses, promotions or even partnerships for those who introduce or suggest innovative ideas.

While there is evidence to suggest that some Victorian and Edwardian manufacturers clearly did explore ways of rewarding and encouraging shopfloor invention, the practice was probably not widespread, at least relative to the USA (Magee 1997b; MacLeod 1999). In fact, it would seem that American manufacturers on the whole appeared to have appreciated, better than British, the necessity of providing a suitable work environment and conditions for their workers, and of instilling them with positive and desirable attitudes to technological change. American firms were certainly more active in experimenting with various fringe benefits for their workers such as free technical education and the establishment of mutual relief and insurance associations. More importantly, a system of giving premiums, bonuses and promotions for improvements and suggestions made by an employee was commonly used in the USA and, apparently, frequently brought beneficial results all round (Hatton 1988a; Magee 1997b: 221–30).

Yet, while perhaps inimical to long-run technological performance, this relative absence of higher-level scientific and technical education, R&D and shopfloor incentives for innovation in British manufacturing may have had a rational explanation. The point is best, and most often, made through a comparison of British and American production

technologies. Broadberry (1997c) contends that two factors succinctly explain the divergent paths of British and American manufacturing since 1870: the standardisation of demand and the relative abundance of skilled shopfloor labour. As was seen earlier, in the USA the demand for standardised products was high. Skilled craftsman, however, were in relatively short supply especially in the manufacturing heartlands of the mid-west and eastern seaboard. Almost as compensation for this, though, America was blessed with a richness of resources. This specific combination of shortages and abundances acted as a stimulus to the development and utilisation of labour-saving technology in those branches of manufacturing where skilled labour was particularly important (Ames and Rosenberg 1968; James and Skinner 1985). Such machine-intensive production, coupled with a rich potential for standardised products, provided American manufacturers with fertile ground in which to lay the seeds of mass-production.

The situation in Britain was very different. Demand there tended to be much more fragmented and customised and natural resources less plentiful than was the case in America. Moreover, unlike in America, skilled shopfloor labour was readily available and, hence, comparatively inexpensive in Britain, especially in the industrial regions of the country. Faced, therefore, by a less urgent need to find substitutes for expensive labour and a pattern of demand that did not lend itself to standardisation, most branches of British manufacturing offered little scope for the introduction of mass-production technologies. Instead, they opted for a more flexible form of production, based on general purpose machinery, skilled labour and customised demand; a form much more suited to British conditions.

To the extent that this depiction of British manufacturing is true, it has a number of implications for the interpretation of the sector's pattern of development. First, given that flexible production and craft control of the shop floor was rational in British circumstances, there was less perceived need on the part of manufacturers to provide formal higher-level scientific and technical education for their workers. Traditional workplace training through apprenticeships would suffice. Secondly, because of British manufacturing's abundance of skilled craft labour, it was only natural that the sector's comparative advantage should lie in the old staple industries, such as textiles and iron and steel, where such labour was used most intensively. Since these industries also required less scientific knowledge and understanding, it follows that they had less need for organised R&D capabilities. Thirdly, as most major technological improvements in this era were tied to mass-production, Britain's adherence to more traditional flexible production methods, as well as its slower rate of expansion, meant that it was less capable of achieving as rapid a rate of technological change as was America. Finally, the analysis provides an explanation for why the American manufacturing workforce was twice

as productive as the British throughout the late Victorian and Edwardian era and beyond. Because British demand conditions and factor endowments dictated smaller production runs and greater labour input than in the USA, British manufacturing was significantly less capital intensive by a margin of about two to one in 1900. With less machinery at his or her disposal, the average British worker was not surprisingly less productive.

MANUFACTURING AND THE BRITISH ECONOMY

Between 1870 and 1913, manufacturing was a large and expanding part of the British economy. But was manufacturing's place in the economy more important than the weight of its contribution to national output? At the beginning of the chapter reference was made to the Kaldor (1966) thesis, the view that manufacturing had dynamic properties that made it of special importance to the economy. Central to this hypothesis is an alleged correlation between the sector's rate of expansion and productivity growth. Attempts to test for this supposed relationship in the British economy over the long term provide no clear evidence of its existence (Matthews *et al.* 1982: 277–8; Crafts 1988: xii). Interestingly, though, the alleged correlation is most evident in the period between 1873–99 and 1899–1913, when a fall in the average rate of manufacturing growth from 2.2 to 1.8 per cent coincided with a steep decline in productivity from 0.9 to 0.3 per cent per annum. Yet, while such a finding is certainly consistent with the hypothesis, it is hardly proof of it. After all, factors other than manufacturing's dynamic economies of scale can clearly affect productivity and it may well be these that are of greater importance in the period under investigation. Furthermore, comparisons of growth and TFP rates reveal nothing about the direction of causation. Indeed, it could just as plausibly be that it is faster (slower) productivity growth that leads to an acceleration (deceleration) of output growth, and not vice versa. In an environment like late nineteenth-century Britain, where new productivity-enhancing technologies were being regularly developed and applied, such an explanation would have currency.

The hypothesis that manufacturing held an indispensable position in the economy is also undermined by other factors. A common corollary of this view is that a growing service sector is deleterious to an economy's well-being if its expansion is fuelled by drawing resources away from manufacturing (Baumol 1967). As employment in the service sector grew faster than in manufacturing between 1870 and 1913, this charge could be made for the late Victorian and Edwardian period. It would, however, be an ill-founded one. Manufacturing and services are interdependent, rather than in competition with each other. Banking, insurance, shipping and education, for example, all provide vital services that

facilitate the smooth running of the manufacturing sector. Without a reliable means of bringing cotton from the USA or financial institutions capable of funding such international transactions, Lancashire's cotton industry simply could not have functioned. Moreover, it would seem that as economies become more complex, the need for such services increases. Thus, as Britain moved into science-based industries, it created a demand for greater numbers of scientifically trained workers, a demand that in the long run could only be met by expanding the number of science faculties in the country. The rise of the service sector is not symptomatic of the failure of manufacturing.

A final consideration is the performance of British industry: did late Victorian and Edwardian manufacturing really fail as is often claimed? As this chapter has demonstrated there is certainly reason for concern. After all, relatively slow growth rates and declining market share are usually not taken as signs of economic vitality. Yet such an assessment would ignore the historical context in which these phenomena occurred. By the latter half of the nineteenth century industrialisation, pioneered in Britain, had begun to take root in a growing band of nations in Europe and North America. At the beginning of their industrial revolutions, with large shares of their workforce engaged in agriculture, an abundance of industrial potential to tap into and often imposing tariff walls to protect themselves, these nations had the ingredients necessary for rapid industrial expansion. By contrast, Britain in 1870 was already a mature industrial economy, whose potential for industrial growth was far more limited. Moreover, as the products of these new industrial centres appeared in the marketplace, it was only natural that Britain's share of world manufacturing activity should diminish accordingly. And it did. But this was not a zero-sum-game, as the volume of British manufactured exports continued to grow throughout this period, despite its declining proportion of the world trade. This is, of course, what one would expect in an international economy that was both expanding and integrating at an unprecedented rate.

Assessment of British manufacturing is also clouded by a tendency in the declinist literature to equate the sector's performance with that of a handful of high-profile industries, whose record appears far from impressive in this period. Typically, these were the industries, such as steel, automobile and electrical engineering, where Britain's competitiveness is said to have been undermined by its slowness to adopt the techniques of mass-production. But, as discussed earlier, even these 'failures' can be accounted for by Britain's unique factor endowment and demand conditions, which made mass-production less, and flexible craft-based production more, profitable in Britain than elsewhere, particularly the USA.

The declinist perspective is further weakened when consideration is extended beyond the heavy industries where mass-production came to dominate. In some industries, such as food, drink and tobacco, soaps,

shipbuilding and textile machinery, British performance was distinctly respectable, with high productivity levels, significant technological progress and healthy shares of world exports. When the full diversity of British manufacturing experience is considered it is hard to be adamant about the sector's failure. Indeed, it could be said that on the whole British manufacturers did reasonably well in adapting their industries to the changed and much more competitive international environment after 1870. There is no evidence of widespread entrepreneurial ineptitude. Failure, in the sense of a rapid loss of markets, was an issue in only those industries for which upon reflection it can be seen that the nation was not well suited. Elsewhere British manufacturers appear to have held their own.