1 The British industrial revolution in a European mirror

BRIAN A'HEARN

CONTENTS

INTRODUCTION

Mid-Victorian Britain was a wonder: the workshop of the world, the hegemon behind the *Pax Britannica*, the manager of the international monetary system. The average Briton lived in a city, earned a living as an industrial or service sector employee, and would see her children enjoy living standards that marked a decisive break with the past in terms of health, education, consumption and leisure. Britain had come a long way from its early modern position as a peripheral, backward country. This chapter explores the evolution of the economy from 1700 to 1870, during which it passed through the decisive phase of the industrial revolution. The first section sketches a macroeconomic outline of developments in the period. This is followed by an effort to set these achievements in a comparative perspective, emphasising what was distinctive about Britain's experience. A third section further exploits international data to evaluate several hypotheses about the causes of the industrial revolution that have featured in recent debates. The final section offers a summary and conclusions.

1700–1870: A MACROECONOMIC OVERVIEW

Gross domestic product (GDP) measures a country's annual production of goods and services. Expressed in per capita terms, it is an indicator of the economy's productivity and its ability to meet the needs of its people. Figure 1.1 plots two estimates of inflation-adjusted ('real') British GDP per person. The first is based on the estimates of Crafts and Harley (1992); the second is a new annual series calculated by Broadberry et al. (2011a). Both show a dramatic increase over the period under study. Output per person more than doubled between 1700 and 1870, reaching 2.4 times its initial level. A sharp acceleration is evident around 1830, when the growth rate jumped from 0.3% to 1.1% per annum.

Only by today's standards might this sort of growth be judged slow; historically it was unprecedented. From the late fourteenth century to the early seventeenth, there had been no period of sustained growth at anything like these rates. To be sure, growth was robust in the later seventeenth century, as Figure 1.1 illustrates. But this was a period of falling population, which reduced pressure on resources. From 1700 to 1870, by contrast, British population grew at an accelerating rate, ultimately quadrupling from 6.7 to 26.4 million (Tables 1.5, 1.9). The combination of rapid population growth and steadily rising output per person over a long period makes the post-1700 period unique.

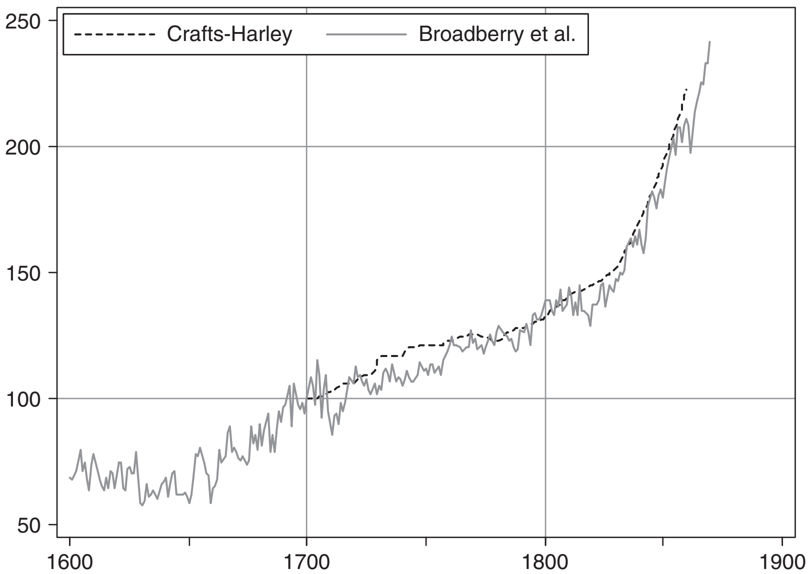

Figure 1.1 Real GDP per capita in Britain

Notes: Broadberry et al. series refers to England only before 1700; Crafts and Harley series derived from published growth rate estimates; GDP divided by annual population estimates from Broadberry et al. (2011a) in both cases. Both GDP series based on estimates of output; for an alternative based on incomes, see Clark (2010).

Sources: Broadberry et al. (2011a), Crafts (1985), Crafts and Harley (1992), Harley (1999).

What of the *level* of GDP per capita? Comparisons across distant countries or time periods are perilous, but it may not be too misleading to note that Britain's output per person in 1700 was already above that of the poorest developing countries of today (Maddison 2001). By 1870 it was on a par with India in the 2000s. Yet output per person was not yet even close to the values that would be achieved by the twenty-first century. Having increased by a factor of 2.4 over the 170 years from 1700, it would grow by a factor of 7.4 in the roughly 130 years from 1870 to 2008.

As aggregate expenditure grew, its composition changed. Consumption fell as a share of total output, investment and export shares rose, while government purchases varied with military exigencies but had no long-run trend (Table 1.1). Despite these changes, in 1870 the economy still had a long way to travel on its path to the twenty-first century. Investment, and more especially government purchases, would grow to take a much larger share of output by the late twentieth century, while private consumption would fall. In the case of exports, by contrast, Britain was precociously modern by 1870. An export share of one quarter of GDP shows a remarkable dependence on foreign markets. With the world's largest merchant marine, Britain was a major exporter of services, which generated several per cent of GDP in the mid-nineteenth century. And prodigious exports of manufactured goods – amounting to perhaps 40% of total world trade in manufactures around 1870 and probably more in earlier years (Harley 1994: 303) – earned the country the title 'workshop of the world'.

Output per head of population tells us about the availability of goods and services, but nothing about their distribution. It can be misleading as an indicator of the living standards of ordinary people. It is similarly uninformative about the amount of effort required in its production, i.e. labour productivity. For both reasons real wages are an important complementary indicator. Figure 1.2 plots

Table 1.1 Composition of aggregate expenditure

	1700	1760	1800	1840	1870	1990–2009
Consumption	93	74	77	80	81	64
Investment	4	6	8	11	9	17
Government	5	13	15	8	5	20
Net exports	–2	7	0	1	5	–2
Exports	*8*	*15*	*16*	*17*	*25*	*27*

Notes: Figures are percentage shares. Export share in 1840 is the average of 1831 and 1851; 1870 export share based on net exports of 5% and the O'Rourke et al. (2010) openness estimate of 44%. Net exports are derived as a residual, i.e. 100-C-I-G.

Sources: Crafts (1985: 62–3, 73, 95, 131), Hills et al. (2010).

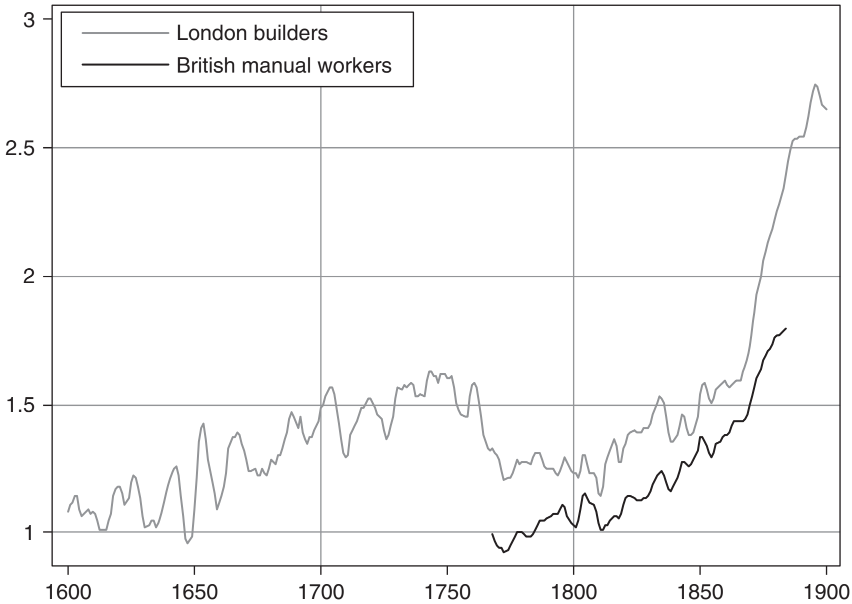

Figure 1.2 Real earnings of British workers

Note: London builder earnings measured in subsistence consumption baskets; British manual worker earnings measured as an index with 1778–82 = 1; units both measured on left axis but not comparable. Five-year moving averages of the two series are plotted.

Sources: Allen (2001), Feinstein (1998).

two estimated earnings series. The darker line is Feinstein's (1998) index of the real weekly earnings of British manual workers, covering agricultural and service sectors as well as industrial workers, and including both sexes. The index, which is expressed relative to the average for 1778–82, shows hardly any improvement from the 1770s to the 1810s, while its growth in the following decades was probably offset by factors such as increasing unemployment and a higher dependency ratio; a significant increase in family living standards was probably not achieved before the 1850s. (Chapter 4 describes corroborating evidence from family budgets.) The grey line represents Allen's (2001) estimate of the annual earnings of a London construction labourer, assuming 250 days employment per year, expressed relative to minimal consumption needs for a family of four. These earnings were comfortably above subsistence needs in 1700, but declined from about 1760 and failed to show any net improvement before the mid-nineteenth century. It is only after 1850 that both series grew rapidly and reached new highs.

The contrast between stagnant wages and growing output per person over much of the eighteenth and early nineteenth centuries suggests growing inequality. That impression is reinforced by estimates of the real rates of return to other factors of production (land and capital), incomes from which accrued almost exclusively to the upper classes. Both rose from the mid-eighteenth to the mid-nineteenth century, the rate of profit doubling according to Allen's (2009b) recent estimates. This resulted in capital's share of income rising from approximately 20% in the 1770s and '80s to more than 45% in the 1860s. More direct evidence on inequality can be derived from social tables compiled by contemporaries. This evidence is not without its ambiguities, but does indicate an increase in inequality between the mid-eighteenth and mid-nineteenth centuries. For example, the share of income earned by the top 5% of households rose from 35% in 1759 to 41% in 1867, a figure well above twentieth-century shares estimated from tax records (Lindert 2000). However, Chapter 7 presents estimates of inequality based on an alternative method, which suggest little change.

Productivity growth

What explains the growth of output per head of population shown in Figure 1.1? It cannot be attributed to greater labour input per person, which probably did not change significantly. On the one hand, female labour force participation probably declined between the eighteenth and nineteenth centuries, while accelerating population growth meant a larger share of the population were below working age. On the other, Voth (2001) has argued for an increase in annual hours of work per employed person. It must then be growth in labour productivity – output per worker – that explains GDP per capita growth.

Labour productivity can increase in two ways. Workers can use more of the other factors of production such as land and capital (i.e. equipment and infrastructure), or they can take advantage of new techniques that are more efficient or yield superior products. Growth accounting is a method of decomposing observed productivity growth into these components. The basic intuition is straightforward. Suppose that the economy is characterised by constant returns to scale. This means that a doubling of all inputs, including labour, results in a doubling of output. Any extra growth in output, beyond a doubling, would be attributable to an improvement in technology. Of course, the factors of production do not typically increase by the same proportion, so we must consider a weighted sum of their growth rates, using weights that reflect the elasticity of output with respect to each input.

$$\dot{Y} = \alpha\dot{K} + \beta\dot{T} + \gamma\dot{L} + \dot{A} \tag{1}$$

In Equation 1, $\dot{Y}$ is the growth rate of output, $\dot{K}$, $\dot{T}$ and $\dot{L}$ the growth rates of capital, land and labour, which can be estimated from historical data. $\dot{A}$ is the rate of economy-wide technical progress, or total factor productivity (TFP) growth, which cannot be observed directly. α, β and γ are the elasticities of output with respect to K, T and L. Under constant returns to scale, these are fractions that sum to one. A doubling of any individual input, then, increases output by only a fraction of that growth. (In principle there could also be an output elasticity with respect to technology, but in practice we cannot distinguish it from the rate of technical progress.) If we assume competitive factor markets, in which the price of an input equals its incremental contribution to output, or marginal product, then α, β and γ equal the factors' shares of national income. Thus, if historical evidence indicates that wages, salaries and self-employment income made up 50% of national income, we can infer $\alpha = \frac{1}{2}$. This allows us to calculate the rate of technical change as residual, unexplained growth since (rearranging the terms) $\dot{A} = \dot{Y} - \alpha\dot{K} + \beta\dot{T} + \gamma\dot{L}$. Further assumptions about the production process, concerning the possibilities for substitution among the factors of production for example, ensure that the residual will be an accurate measure of TFP growth, and that the output elasticities are constant over time. (See Allen 2009b for a critical view.) Equation 1 can also be written to express the rate of growth of productivity (output per worker) in terms of the rates of growth of the capital–labour ratio, the land–labour ratio, and TFP.

$$\dot{Y} - \dot{L} = \alpha(\dot{K} - \dot{L}) + \beta(\dot{T} - \dot{L}) + \dot{A} \tag{2}$$

Table 1.2 presents a growth accounting exercise based on Equation 2. Column 1 ('gr(Y/L)') shows that the growth of output per worker mirrored that of output per head of population: slow and steady over a long period from 1700 to 1830, then sharply accelerating. An inelastic supply of agricultural land meant that labour force growth drove the land–labour ratio down at an accelerating rate, exerting a depressing influence on productivity (Col. 3). As Table 1.1 indicated, investment more than doubled as a share of national output over time. In the face of accelerating population growth this permitted only slow growth in the capital–labour ratio before 1830 – barely sufficient to offset the decline in natural resources per worker (Col. 2). (*Human*

Table 1.2 Growth accounting for Britain, 1700–1860

	gr(Y/L)	gr(K/L)	gr(T/L)	gr(TFP)
1700–60	0.32	0.32	−0.08	0.22
1760–1800	0.33	0.16	−0.33	0.33
1800–30	0.28	0.36	−1.25	0.34
1830–60	0.96	1.10	−1.25	0.76

Notes: GDP growth rates between five-year centred averages. Pre-1800 labour force growth assumed equal to (English) population growth. Pre-1760 capital growth assumed equal to output growth. Land in 1760 by personal communication from R. Allen. Output elasticities with respect to land, labour and capital set at 0.15, 0.50 and 0.35, respectively. Columns 2 and 3 show growth rates of the capital- and land-labour ratios, not contributions to output per worker growth.

Sources: GDP – Broadberry et al. (2011a); labour – Deane and Cole (1962: 143), Wrigley (2004: 64); net fixed capital stock – Feinstein and Pollard (1988: 441); arable and pasture land (England and Wales) – Allen (2004: 104).

Table 1.3 Occupational structure of adult employment

	1710	1817	1851	1871
Primary	48.7	34.6	27.7	21.3
Secondary	37.9	41.3	42.6	43.5
Tertiary	13.4	24.2	29.7	35.2

Notes: The primary sector includes mining; the secondary sector includes construction; the data refer to England and Wales and to adults aged 20 and above.

Source: Table 2.6.

capital is omitted from these calculations, as there is little evidence of a change in investment in education during the period; schooling was not compulsory, and literacy rates stagnated across the central decades of the industrial revolution (Table 1.13)).

It is left to TFP growth to account for most of productivity growth – all of it in the years before 1830 (Col. 4). The acceleration in productivity growth from 1830 is attributable primarily to the acceleration of technical progress, which contributed 0.42% (i.e. 0.76–0.34) of the 0.68% increase. The contribution of more intense capital accumulation was smaller, at 0.26% (i.e. 0.35 × (1.10–0.36)). TFP growth was slower during the industrial revolution, even after 1830, than in recent times, when it averaged 1.2% from 1950 to 1999 (Oulton 2001).

Structural change

Economy-wide TFP growth can result from technical change in individual sectors or industries, or from movements of resources between them, i.e. structural change. The best available estimates of occupational structure are those of the Cambridge Group for the History of Population and Social Structure, which are discussed in detail in Chapter 2. As explained there, accurate data from 1851 onwards are available from the census, while earlier figures are derived from baptismal records for men and informed conjectures for women.

Several features of the estimates in Table 1.3 are particularly striking. The first is the starting point in 1710, when most employment was already in the secondary and tertiary sectors; considerable structural change must have *preceded* the industrial revolution. The second is the dramatic decline of primary sector employment, which occurs despite a gain of several percentage points in mining. The third is the rise of service sector employment. Indeed, Table 1.3 gives the impression of a services revolution more than an industrial revolution. In every sub-period services gain more workers than industry. The rise of industrial employment was too limited and too gradual (just 3.2 points over the century from 1710 to 1817) to generate significant productivity growth through pure reallocation of resources. Moreover, sectoral income per worker in industry appears to have been slowly falling from above to below the economy-wide average over this period (Crafts 1985: 61–4; Broadberry et al. 2011b: Table 7).

The service sector, by contrast, both grew more rapidly and maintained an advantage in income per worker. An upper-bound estimate by Wrigley (2010: 127–35) suggests that the (relative) shift of resources out of agriculture into industry and services could have explained half or more of growth in GDP per capita over the eighteenth century. The estimate is an upper bound in a mechanical sense because it assumes that a reallocation of labour induces no change in either the within-sector composition of employment or the between-sector income differences. At a more fundamental level, it implicitly underestimates the significance of technological progress by assuming that major structural shifts would have been profitable even without it. This is analogous to the assumption in growth accounting that capital-deepening at observed rates would have been worthwhile even without technical change. At a minimum, then, pure (within-sector) technological progress explains half of economy-wide TFP growth.

Technical change

What was the nature of this technical progress? A cluster of famous inventions in the later eighteenth century are justly celebrated as transforming their industries. Ready examples can be drawn from cotton spinning (Hargreaves' jenny, 1764; Arkwright's spinning frame, 1769, and the Cromford mill, 1771; Crompton's mule, 1779), iron refining (Cort's puddling and rolling process, 1784), and steam-power generation (Watt's separate condenser, 1769). The TFP growth estimate for the cotton industry in Table 10.1 illustrates how important such new technologies could be, not only for their own sector but also in contributing to economy-wide productivity growth.

Yet the timing of these well-known inventions means that they cannot explain the slow but cumulatively significant TFP growth from 1700 to 1760. Nor does the timing fit naturally with the acceleration in technical progress that developed later, from the 1830s. In part this delay is explained by the small starting size of the revolutionised industries, which limited their contribution to the aggregate. In part it has to do with the slow process of refining general purpose technologies like steam-power and adapting them to different uses, which could take decades. But it is also because technical progress in Britain, though uneven, was widespread. The pervasive nature of technical progress, even in the absence of spectacular changes, is seen in the histories of unheralded industries such as candle- and hat-making, as recounted in Chapter 10. And the TFP growth estimates of Table 10.1 indicate that technological change was not confined to industry. Technical change in services too could be near the economy-wide average (shipping) or in excess of it (canals and railways). In agriculture, TFP growth was as high as 0.7% from the late eighteenth to the mid-nineteenth century (Allen 2004: 107; Table 10.1). Technical progress would have been measurably slower without the iconic inventions of the industrial revolution, but it would have continued just the same, gradually raising productivity and living standards.

Towns and factories

If the rise of industry's share of employment was limited and slow between 1700 and 1870, changes in the nature and location of industrial jobs were more dramatic. The share of the population in cities with a population of at least 10,000 more than tripled, from 12 to 42% (Table 1.4). For comparison, the analogous share for 2001 (based on a different definition of cities) was 80%. Together Tables 1.3 and 1.4 tell us that in the early eighteenth century the vast majority of industrial employment must have been rural, while in 1870 a majority must have been in cities.

If London – already huge in 1700 with a population of more than half a million – is excluded from the calculation, the increase in urbanisation is tenfold, from 3 to 30%. Much of this growth was in 'new' cities like Liverpool, Manchester, Birmingham and Leeds, which grew from towns of 5,000–10,000 in 1700 to major cities of 200,000–450,000 by 1861. The growth of these manufacturing centres entailed a geographic redistribution of population. The population of a contiguous swathe of five industrialising counties in the Midlands and North grew by 772% from 1700 to 1871, doubling its share of the English total from 15 to 31% (Table 2.11). Meanwhile, in some southern agricultural counties, a process of de-industrialisation was underway during the eighteenth century. At a regional level, industrialisation wrought real changes.

Many of the new urban manufacturing jobs were in factories – although not all factories were in towns or cities. The decline of artisanal and rural putting out production was anything but steady or universal (Hudson 2004), but larger-scale establishments became increasingly common over time, and with them mechanisation, division of labour, long hours, factory discipline and loss of autonomy. We lack comprehensive statistics on the size of firms or establishments before the

Table 1.4 Urban shares in the British population

	1700	1750	1800	1870
Cities > 10k	11.8	15.6	22.6	42.1
W/out London	*3.1*	*6.6*	*13.6*	*29.8*
Cities > 5k	13.1	21.2	30.9	48.4
W/out London	*4.4*	*12.2*	*22.0*	*36.0*

Source: Malanima (2010).

censuses of production, but partial data provide glimpses into the transition. One example is an 1841 census of the Lancashire cotton industry, carried out by the inspectors tasked with enforcing the Factory Act of 1833 regarding the employment of children. The 975 spinning and weaving firms employed nearly 200,000 people, at least two in five of whom were aged under 18. While small businesses abounded, the average job was in a large concern, and 25 firms employed over a thousand operatives each (Gattrell 1977: 98; Chapman 1904: 112).

Health, mortality and living standards

The new cities and their factories made a deep impression on early nineteenth-century contemporaries. Thinkers as different as Marx and Ruskin wrote about the alienation generated by factory work. Social reformers like the Earl of Shaftesbury launched parliamentary inquiries and introduced legislation to regulate the labour of women and children in factories and mines. Foreign visitors like Engels and Faucher were appalled by living conditions in cities like Manchester. In their search for a quantitative measure of well-being, they paid particular attention to mortality data, which were becoming available through the efforts of early epidemiologists like Chadwick and a nascent government statistical apparatus. Life expectancy at birth ('e_0'), today approximately 80 years in the UK, was in the 1850s barely over 30 in the largest industrial cities: 32 in Manchester, 31 in Liverpool and 30 in Glasgow. This was fully 10 years less than the national figure of 41 (Szreter and Mooney 1998: 88, 90, 96). Infant mortality could exceed one in five in industrial towns. Urbanisation thus explains part of Britain's failure to register much improvement in life expectancy over the long run from 1700 to 1870; e_0 was 38.5 years in the 1700s and 38.4 in the 1790s. Slow progress raised this to 40.7 in the 1830s, but there was no further improvement before the 1870s.

Height is another summary measure of health. As explained in Chapter 4, height reflects the quantity and quality of nutritional intake in the growing years, net of losses due to disease and the demands of physical activity. Investigations conducted in 1833 and 1837 in connection with Factory Act legislation led to the measurement of more than 10,000 working-class children in Manchester and other industrial towns in Lancashire and the West Riding (Tanner 1981: 147–61; Floud et al. 1990: 163–82). Contemporaries were interested in whether factory workers were smaller than other poor children. They were, though the difference was small. But what strikes an observer today is that average heights among all poor children were at about the *third percentile* of the British distribution of 1965: shorter, that is, than 97% of children of the same age in the late twentieth century. Meanwhile, upper-class children enrolled at the Royal Military Academy (Sandhurst) in the 1830s were five inches (12.7 cm) taller. Nor was the time trend in mean heights encouraging. On some estimates, mean heights of adult soldiers fell irregularly for almost a century, to a low of 163 cm among those born around 1840 (Cinnirella 2008; Komlos and Küchenhoff