2 What Made Britannia Great? How Much of the Rise of Britain to World Dominance by 1850 Does the Industrial Revolution Explain?

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By 1850, at the apogee of its power, Britain had 1.8 percent of world population. The area of the British Isles is less than 0.2 percent of the world land mass. Yet Britain then strode as a colossus on the world political, military, and economic stages. It had extensive colonial possessions, including Ireland, much of modern India, Pakistan, Bangladesh, and Sri Lanka, Canada, Australia, New Zealand, the Cape Colony in South Africa, Belize, Jamaica, Trinidad, and Guyana. Its navy was the largest in the world, by design larger than the next two largest navies combined. In 1842 it humiliated the proud Chinese empire, forcing it to cede Hong Kong and to allow the British to ship opium into China. By 1860 the British and French had captured Beijing and forced even more degrading terms on the empire.[1]

Even where it did not exert formal control, Britain considerably influenced the economic policy of many states, as in the Indian subcontinent. Britain was so confident of its manufacturing prowess that it pursued both within its formal empire and beyond a policy of free trade, even though many of its trading partners had far lower wages. Thus Britain supported Brazilian independence from Portugal in return for preferential trade privileges, and used the threat of force in both Egypt and Persia in 1841 to persuade these states to grant it free trade.[2]

The ascendance of this minor country on the northwest corner of Europe, which in 1700 had a population about one-third that of France, and about 4 percent that of both China and India, to the position of power it occupied by 1850 is often seen as being largely the result of the Industrial Revolution, which occurred in Britain after 1760. Thus Kennedy (1983, 150–151) wrote,

> [The Industrial Revolution] was to provide the foundation for the country's continuing and increasing growth, making it in to a new sort of state—the only real

world power at the time. Industrialization not only furthered the British supremacy in commerce and finance and shipping, it also underpinned its own naval supremacy with a previously unheard-of economic potential.

He states even more bluntly, ''Britain enjoyed effortless naval supremacy in the years following 1815'' in part because its competitors ''possessed an industrial strength that was infantile by comparison'' (157). The eventual decline of Britain's political and military position is similarly traced to the decline of its economic position. ''Whether historians date the beginnings of imperial decline from about 1870 or after 1914, they associate it almost exclusively with the steady erosion of Britain's industrial supremacy'' (Cain and Hopkins 1986, 502).

However, Britain in the years 1760–1860 experienced two completely different, and independent, revolutionary changes. The first, of course, was the famous Industrial Revolution based on technological advance in industry. But the second was a population explosion that has been dubbed by some the Demographic Revolution. This growth in population occurred all across the English economy with equal force, from the centers of the new revolutionized industry to the remotest rural backwater.[3] It began just before the discoveries in cotton textiles that date the beginnings of the Industrial Revolution in the late 1760s. But there is no direct link between population growth and the unusual technological growth of England in this era.

Here I argue that for most of the ways in which the Industrial Revolution mattered for the British position in the world—relative living standards compared to Britain's competitors, relative economic output, relative military capacity—the technological gains of the Industrial Revolution were irrelevant. Suppose efficiency (TFP) in both industry and agriculture in the 1860s had stayed exactly as it had been in the 1730s. This would have significantly reduced living standards in England by the 1860s compared to their actual level. But it would have little affected Britain's *relative* position in the world economy, its income relative to its competitors such as France or the Netherlands. The size of the industrial sector would have been nearly as large, and the degree of urbanization nearly as great. Britain would have still shifted in the late eighteenth century from near autarky toward great reliance on raw material imports paid for by manufactured exports. That shift would in turn have given the political impetus for formal and informal imperialism, and the desire to maintain a strong navy to protect vital shipping routes.

If, however, England's population had stayed at its 1730s level, then even with significant technological advance, most of the features of the

Industrial Revolution era would not be replicated. With a population size in 1815 of closer to 6 than to 12 million, the defeat of Napoleon would have been more difficult, even with the classic productivity growth of the Industrial Revolution. A Britain with smaller population in 1860 would have been much more agricultural, more rural, less urbanized. Crucially it would have engaged in much less international trade. Thus one of the great driving forces for nineteenth-century imperialism, the need to assure markets for Britain's great manufacturing exports, and to assure raw material supplies for the British economy, would have been absent. The supply of officials, police, and soldiers to govern Britain's colonial possessions would similarly have been reduced, as would the supply of convict labor to people Australia.[4] Even with the same rate of TFP advance in each industry, the overall rate of productivity growth for the economy would have slowed significantly had a population boom not accompanied the Industrial Revolution.

This chapter is not the first to consider such counterfactuals. Mokyr (1999, 114–115) considered what income per person would have been in England in 1830 absent technological advance. His conclusion, however, was that technological change was likely more important to income levels than is suggested by the model developed here. More recently Crafts and Harley (2004) carried out a related counterfactual exercise, for the shorter period 1770–1841, which focused just on what most importantly caused the shift of the labor force in Britain out of agriculture in the Industrial Revolution: population growth, unbalanced technological progress in industry, or labor-releasing institutional change in agriculture. Their conclusion, contrary to the one here, is that population growth played a very minor role in reducing the share employed in agriculture by 1841. Instead, they conclude, in line with O'Brien (1996), that it was the (alleged) switch in Industrial Revolution England from peasant to capitalist agriculture, which substantially increased labor productivity in agriculture, that accounted for most of the structural shift. I show that this conclusion stems from their assumption that absent population growth, nonfarm prices would have risen significantly relative to farm prices. I also explain why the assumption made here, that the relative prices observed in the 1860s would be the same at a smaller British population, is the right one.

English Economic History, 1730s–1860s

Table 2.1 shows the basic facts of the English economy from the 1730s to the 1860s, as constructed from new data on prices, wages, land rents, and

Table 2.1
The Basics of Growth, England, 1730s, 1860s

Variable	1730–1739	1860–1869
Population (millions)	5.8	21.1
Farm[a] efficiency	100	121
Nonfarm[a] efficiency	100	160
p_{NF}/p_F	1.00	0.716
Farm share of employment	0.55	0.24
Land rent/GDP (%)	20.6	6.9
GDP	100	548
GDP per person	100	149
Efficiency (TFP)	100	145
Farm share output	0.50	0.20
Farm output	100	176
Farm output per person	100	48
Nonfarm output	100	980
Nonfarm output per person	100	269
Farm imports/GDP	0.0	0.22
Farm consumption per person	100	102
Nonfarm consumption per person	100	297
Farm share of consumption	0.50	0.42
Real income/N	100	141
Urban share (%)	15	62

Sources: Nominal output is estimated as a combination of the estimates of Clark (1998; 1999; 2001; 2002a; 2002b; 2002c; 2005) and Clark and Jacks (2006) on farmland, property, wage, and capital incomes. Real outputs are estimated from the prices from Clark (2004) and Clark and Jacks (2006) for farm and coal, and unpublished series for other prices. Efficiencies are estimated as the ratio of costs to prices in each sector and nationally. Population is from Wrigley et al. (1997).
Note:
a. Farm includes the coal industry. Nonfarm is the economy minus farm and coal.

returns to capital.[5] Total nominal income is calculated for the economy as a whole and for the farm sector. This income was deflated by various different price indices, calculated as detailed in appendix B, to calculate the growth of GDP, farm output, nonfarm output, and income.[6]

England moved from an agrarian autarkic economy in the 1730s to a largely industrialized open economy in the 1860s. From the 1730s to 1860s population increased to more than 3.5 times its level in the 1730s, mainly from the increased birth rate. Yet agricultural output increased by only 54 percent. Thus farm output per person in England in the 1860s

Table 2.2
Farm Consumption per Person in England, 1700s, 1860s

	1700–1709	1860–1869
Population (millions)	5.51	21.15
English farm net output (£ millions)	63.1	107.2
Net food imports (£ millions)	2.2	75.2
Net raw material imports (£ millions)	−1.3	62.7
Domestic coal consumption (£ millions) (at pithead price)	1.7	17.5
Total food, energy, and raw material consumption (£ millions)	65.7	262.6
Consumption per person (£)	11.9	12.4
Imports as a share of consumption (%)	1	53

Sources: Farm output, Clark (2002c); coal, Flinn and Stoker (1984, 26), Church (1986, 19, 53, 85–97). Pithead prices, Clark and Jacks (2006). Trade 1860–1869, Parliamentary Papers (1870), Mitchell (1988, 221–222); trade 1700–1709, Schumpeter (1960, tables 7, 9, 10, 12, 13, 15, 17).
Note: Cotton, wool, flax, and silk retained for home consumption are estimated by subtracting the raw material content of textile exports, estimated using figures given in Deane and Cole (1967). The import figures are for the United Kingdom, but it is assumed that on net these all went to England (Ireland was supplying food imports to England, which I assume equaled its share of food and raw material imports).

was only 42 percent of its level in the 1730s.[7] This domestic farm output was supplemented by two main sources of the goods traditionally produced by the farm sector. First were imports of food and raw materials. Second was English coal output. Thus by the 1860s England depended heavily on food and raw material imports, and on locally mined coal, to supply the food, raw materials, and energy its population required. Table 2.2 shows the food, energy, and raw materials account for the 1700s, where the situation would be very similar to the 1730s, and the 1860s. In the 1700s the economy had few net raw material imports (sugar and spices were being imported, but wool in woolen goods exported). These had swollen to 22 percent of income by the 1860s.

Since coal was a close substitute for wood energy produced in the farm sector in what follows, and in table 2.1, I amalgamate domestic coal production with farming output (coal production in this period was very similar to farming, involving a lot of digging and human hauling of materials, except done underground). Valuing coal output at pithead prices increases farm output per person in the 1860s to 48 percent of the level of the 1730s, as compared to 42 percent. This is the number reported in table 2.1.

England paid for imported food and raw materials mainly through exporting manufactures. As Temin (1997) noted, these included not just the classic textiles and iron and steel of the new Industrial Revolution

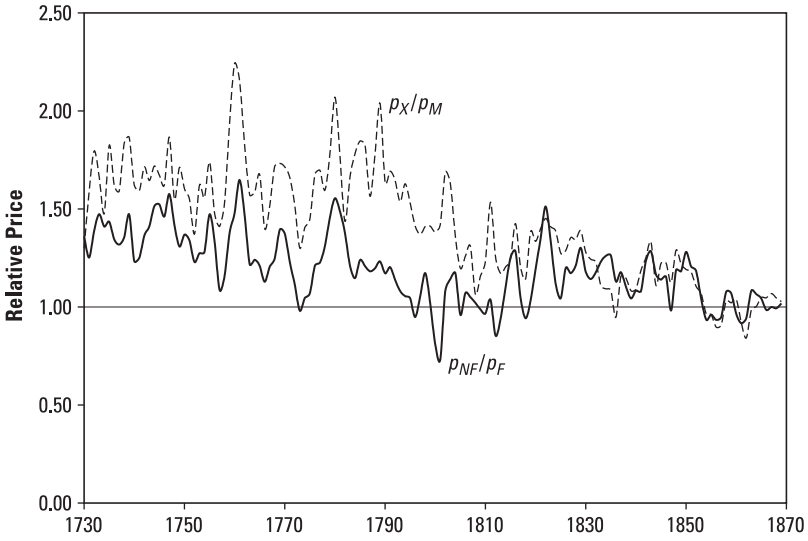

Figure 2.1
Terms of trade between farm and nonfarm output, England, 1730s–1860s. Farm prices from Clark (2004), Clark and Jacks (2006). Nonfarm prices, import prices, and export prices are unpublished calculations of the author from the sources listed in Clark (2005b).

industries, but a host of products from industries that are not believed to have experienced significant technological advances. Together other manufactures were about 22 percent of all exports. With this rise in exports nonfarm output rose nearly tenfold between the 1730s and 1860s. England truly became the workshop of the world.

Relative prices changed in England over these years, as relative productivities in different sectors of the economy changed. The price of nonfarm output relative to farm output fell to 72 percent of its earlier level. Figure 2.1 shows the price of English-produced nonfarm items relative to the price of farm output, and the price of English exports relative to imports. Export prices declined even more relative to import prices.

Importantly for what follows the decline in the relative price of nonfarm to farm goods closely echoed the observed changes in relative productivities across the two sectors. Thus in a competitive market for each product, i, the price will be

$$p_i = \frac{r_i^{a_i} w_i^{b_i} s_i^{c_i}}{A_i}$$

where r is the return on capital, w the wage, s land rents, A the TFP of the

sector, and a, b, and c the shares of each input in costs. The relative price of nonfarm versus farm products will thus be

$$\frac{p_{NF}}{p_F} = \frac{A_F}{A_{NF}} \frac{r_{NF}^{a_{NF}} w_{NF}^{b_{NF}} s_{NF}^{c_{NF}}}{r_F^{a_F} w_F^{b_F} s_F^{c_F}}$$

Over the Industrial Revolution era agricultural efficiency increased by only 21 percent, and coal mining efficiency growth was also modest (Clark 2002c; Clark and Jacks 2006). Efficiency growth was concentrated in the nonfarm, nonmining sector, where it is estimated at 60 percent. Thus the relative prices of nonfarm goods fell only slightly more than their relative productivity within England. The reason that relative price movements in the Industrial Revolution were largely predictable from relative TFP levels is that capital rents, wages, and land rents moved in similar ways over the years 1730–1870. Thus the different shares of these factors in the farm and nonfarm sectors made little difference to relative prices.

These relative price movements also imply that the productivity gains of the Industrial Revolution mainly went to consumers rather than to entrepreneurs in the revolutionized sectors. Importantly these consumers lived abroad as well as at home.

We can portray this transformation of England between the 1730s and 1860s, summarized in table 2.1, using production possibilities frontiers (PPFs). Figure 2.2 shows outputs and consumption in each period, and the associated relative price lines.

British History, 1730s–1860s, A Simple Model

What would Britain have looked like in the 1860s without the Industrial Revolution? To consider this counterfactual I employ the simple model detailed in appendix A. There are just two goods, farm (including coal) and nonfarm, and only two inputs, land and labor.[8] Farm, but not nonfarm, output requires land. Britain in the 1730s is assumed self-sufficient with no net imports of farm products. I am not, however, assuming that the economy in the 1730s was closed to international trade. The assumption is just that the relative more equal land endowments of England and the other European states as of the 1730s, as portrayed in table 2.3, limited the possibilities of trade.

The six parameters of the model—α, β, A_F, A_{NF}, θ, and H—are chosen so that the crucial features of the 1730s economy are reproduced: the

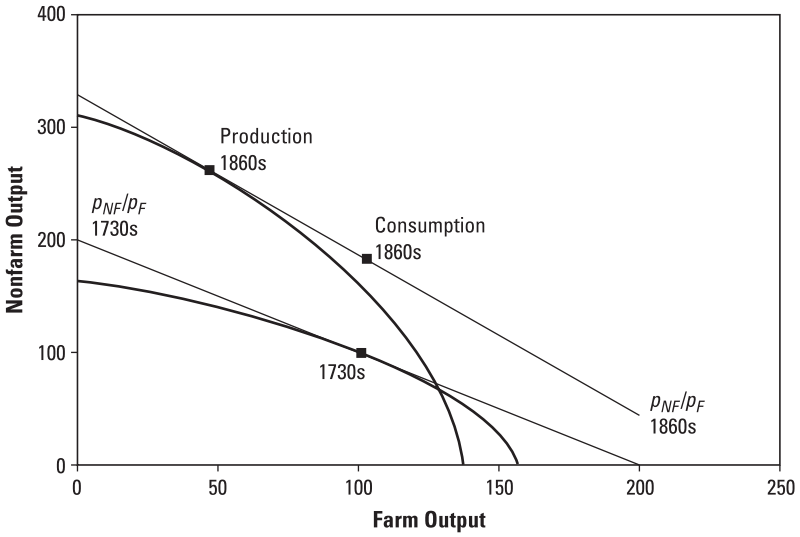

Figure 2.2
The change in the English economy, 1730s–1860s.

share of land rents in total output, the share of employment in each sector, the share of output from each sector, the absence of significant farm imports, and the income elasticity of farm output demand.

Fitting the model to these data for the 1730s requires setting all six parameters, leaving no degrees of freedom to adjust the results for the 1860s. Thus the model cannot precisely fit the actual situation in the 1860s. Once population, A_{F}, A_{NF}, and the labor share in agriculture were set for the 1860s, all the other variables were constrained. Thus, as will be seen by comparing the last column of table 2.1 with the second column of table 2.4, the model only approximates the key parameters in the 1860s. In particular, the price of nonfarm output relative to farm is 0.674 as opposed to the correct value of 0.716. However the fit with these parameters derived from the 1730s, as well as these efficiency changes, is still very good for the 1860s.[9]

The shift from the 1730s to the 1860s as estimated from this simple model looks just like figure 2.2. Thus this very simple model, parameterized for the 1730s economy, fits the gross outlines of the Industrial Revolution reasonably well. In the following sections I employ this model to ask what history would have looked like absent either the Demographic Revolution or the Industrial Revolution.

Table 2.3
Farmland and Population in England relative to Europe and the United States, 1730s, 1800s

	1730s	1800s	1860s
England			
Population (millions)	5.5	9.2	21
Farm area (million acres)	26	26	26
Acres/*N*	4.7	2.8	1.2
Western Europe[a]			
Population (millions)	83[b]	103	152
Farm area (million acres)[c]	317	317	317
Acres/*N*	3.8	3.1	2.1
Russia			
Population (millions)	42[b]	53	74
Farm area (million acres)[c]	702	702	702
Acres/*N*	16.7	13.2	9.5
U.S.			
Population (millions)	≈ 1	6.2	35
Farm area (million acres)	—	—	407
Acres/*N*	—	—	11.6

Sources: Food and Agriculture Organization of the United Nations (FAO) statistics database; Mitchell (1998).
Notes:
a. Western Europe includes Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland.
b. Estimated to be equal to the 1760s populations.
c. Based on modern areas from the FAO.

England in the 1860s without Productivity Growth

Suppose we abolished all the productivity growth of the Industrial Revolution era. What would England look like in the 1860s? To answer this we need to crucially answer what would be the relative price of industrial as opposed to farm goods in that case in the 1860s.

I assume that this would stay as in the 1730s. The justification for this is that the English price relativity in the 1730s seems to have been close to the European price ratio. Indeed, food prices were low enough in England that in some years in the early eighteenth century there were grain exports. And English demand and supply of food and raw materials was a small share of European and North American demand. Table 2.3, for example, gives data illustrating the smallness of England relative to just Europe and North America in terms of farm area and population in these

Table 2.4
England in the 1860s under Two Alternative Counterfactuals

Variable	Baseline	No Industrial Revolution	No Population Growth
Population (millions)	21.1	21.1	**5.8**
Farm efficiency	121	**100**	121
Nonfarm efficiency	160	**100**	160
p_{NF}/p_F	0.674	**1.00**	**0.674**
Farm share of employment	0.24	0.30	0.48
Land rent/GDP (%)	8.7	10.7	17.7
GDP	528	329	152
GDP per person	145	90	152
Efficiency (TFP)	145	100	139
Farm share output	0.21	0.26	0.43
Farm output	171	167	110
Farm output per person	47	46	110
Nonfarm output	982	477	214
Nonfarm output per person	270	131	214
Farm imports/GDP	0.26	0.35	0.02
Farm consumption per person	107	94	114
Nonfarm consumption per person	181	83	207
Farm share of consumption	0.47	0.53	0.45
Real income/N	135	94	144

years. It also shows the enormous addition of farmland and woodland in the United States to the effective European land stock in the late eighteenth and early nineteenth centuries. The farm area of England by the 1860s was less than one-tenth that of the rest of Western Europe, and only about 2 percent of the combined area of all areas shipping food to England.

Thus without an Industrial Revolution there is no reason to expect farm prices to have become higher relative to nonfarm prices in England by the 1860s compared to the 1730s. Instead the addition of the farm areas of North America would, if anything, have increased nonfarm prices in England relative to farm, leading to even greater industrialization than predicted here.

With the assumption of an unchanged price ratio, figure 2.3 shows the predicted outcome for the economy with no Industrial Revolution. What

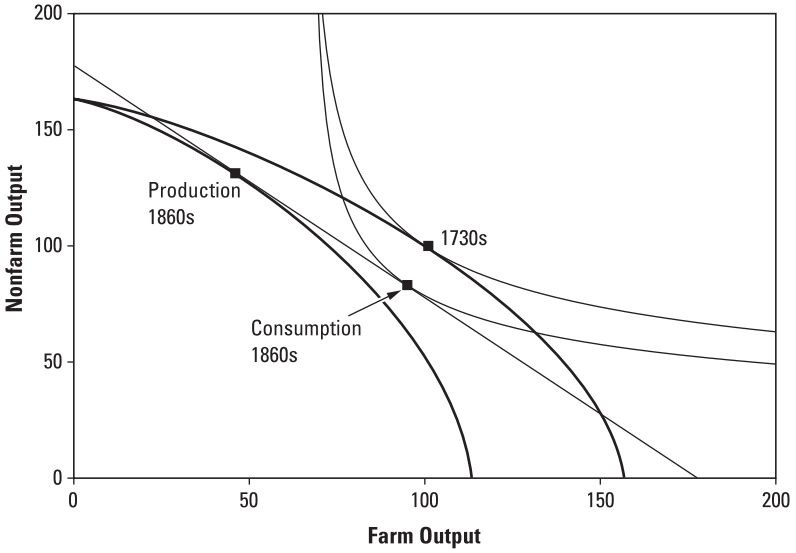

Figure 2.3
England in the 1860s without the Industrial Revolution.

is remarkable is that apart from the lower level of industrial output per person, England looks just the same in the 1860s without an Industrial Revolution than it did with it. Table 2.4 shows the detailed predicted values of various features of the economy. The share employed in farming (including coal) is predicted to have fallen sharply from 55 percent to 30 percent, compared to the actual fall to 24 percent. Land rents fall from 21 percent of income to 11 percent, creating exactly the decline in the economic position of the traditional landed ruling classes as was actually witnessed.

Imports supply as large or larger a share of farm consumption by the 1860s, at 57 percent. Industrial production rises sharply to pay for these food, raw material, and energy imports, so that total industrial output is nearly five times its level of the 1730s, despite the absence of productivity advances. This shift to industrial production would have produced the rise in towns and cities in England that was witnessed in the Industrial Revolution era. The need to pay for food and raw materials with exports of manufactured product would have supplied the same impetus as before, given the protectionist tendencies of independent states such as the United States to use military power to ensure access to markets through a process of formal and informal imperialism.

Incomes per person would, of course, have been significantly lower in this case than they were in practice in the 1860s, and indeed about 6 percent lower than they were in the 1730s. But in terms of Britain's position relative to its competitors—France in particular—the absence of the Industrial Revolution would make modest differences. For the competitive nature of product and labor markets, and the very poor protection of property rights in new techniques in the Industrial Revolution era, meant that there was little extra gain to those areas and people who devised more effective production techniques in the cases where the outputs were tradable. The main gainers from the improved techniques of the Industrial Revolution were the consumers of the products, and it did not matter whether these consumers were in England, in Ireland, or in the Netherlands or France.

This can be illustrated in several ways. First consider what happened to real wages in the Industrial Revolution period in the north versus the south of England. Figure 2.4 shows that these two regions had very different productivity growth rates in these years. The north, with its heavy em-

Figure 2.4
Efficiency growth rates in north and south England, 1770–1869. The north is Cumberland, Northumberland, Westmorland, Lancashire, Durham, Yorkshire, and Cheshire. The aggregate productivity growth of England was split into the contribution from north and south by attributing all productivity growth in cotton and wool textiles to the north and correspondingly reallocating farm productivity growth. Same sources as for table 2.1.

phasis on the revolutionized sectors of cotton, linen and wool textiles, saw rapid productivity growth. The south, which was much more heavily involved in agriculture, in government, and in services, witnessed very little productivity growth at all. In many ways the south of England had the same relationship to the Industrial Revolution as France or the Netherlands. It was a bystander. Corresponding to this difference in productivity growth was a difference in population growth as labor migrated south to north, and from Ireland to the north. Thus from 1801 to 1841 the north had a 103 percent gain in population, but the south only a 71 percent gain.

But despite the huge difference in productivity growth rates, and the evidence of labor migration, wages in the north rose little relative to those in the south. Figure 2.5 shows the relative wage in the north versus the south for building workers and farm workers from the 1760s to 1860s. Wages in the north increased relative to those in the south by only 11 percent in the mainly urban building industry and 25 percent in agriculture. The great majority of the Industrial Revolution productivity gains in the north went to consumers all across England, and indeed across the world, in the form of lower prices. There was a relatively elastic supply of labor and capital from traditional industries, from agriculture, and from non-revolutionized regions into the flagship industries of the Industrial Revolution. Consequently the efficiency advances went to consumers.

Evidence of this can be found in the movement of real wages in Ireland compared to England in these years. Ireland had few of the high

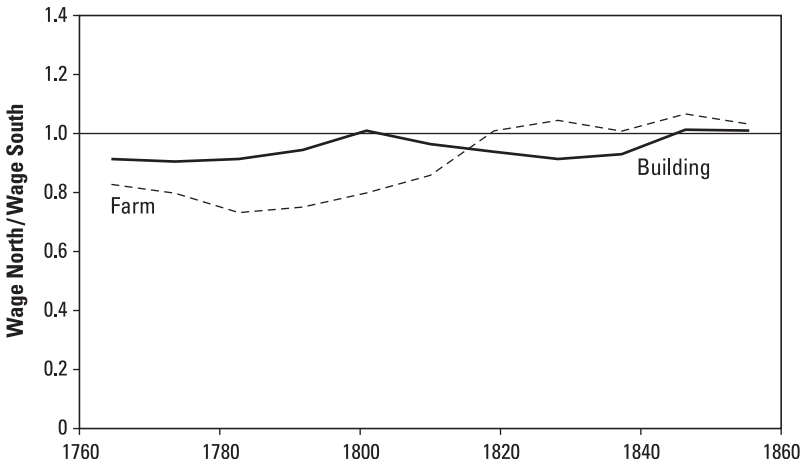

Figure 2.5
Wages in the north vs. the south in the Industrial Revolution. From Clark (2001; 2005a).

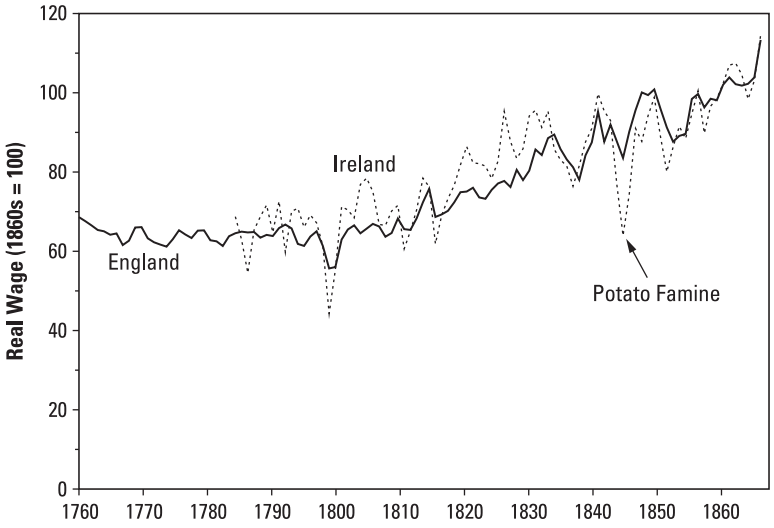

Figure 2.6
Real wages in England and Ireland, 1760s–1860s. From Clark (2005a, 1324–1325), Geary and Stark (2004).

productivity growth industries of the Industrial Revolution, except for linens. By the nineteenth century its main exports were agricultural products sent to England in exchange for industrial goods: clothing, housewares, machinery. Its labor market, as measured by the much lower wage in Ireland than in England, was less integrated with that of the high productivity growth region of northern England than was the rest of England. Yet, as figure 2.6 shows, real wages, as measured for building workers in Ireland, grew just as fast as those in England, even in the years before the famine of 1845 when Ireland's population was growing fast.

Finally, we can do a very rough comparison on income per person from 1600 on for England and the Netherlands. Figure 2.7 shows that comparison, using both my estimates of English real income per person and the GDP estimates of Crafts and Harley (1992) for 1700–1831 and Deane and Cole (1967) for 1831–1871. Any gains in English income compared to the Netherlands would show up in the decades after the 1780s, since there was no significant TFP advance in England as a result of the Industrial Revolution until the 1790s. Yet between the decade of the 1780s and the 1860s, in an interval when income per person in England rose 53 percent as a result of the Industrial Revolution, income per person in the Netherlands relative to England fell by only 12 percent. Income per cap-

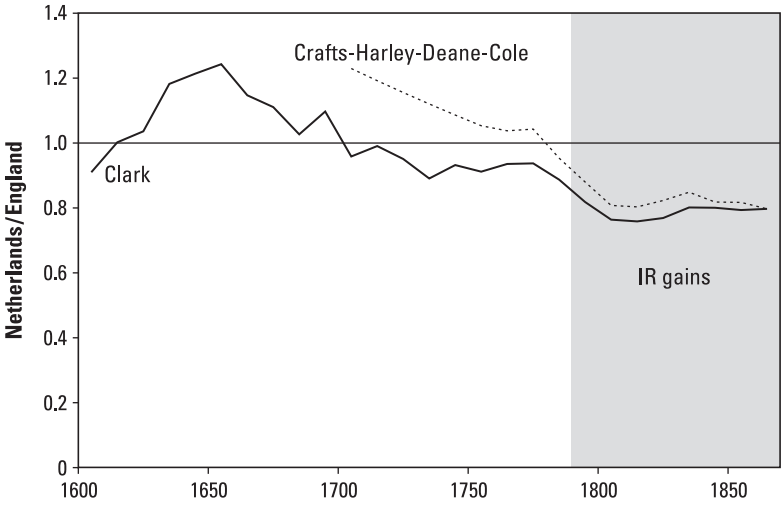

Figure 2.7
Income per person, the Netherlands versus England, 1600–1869. Income per person in England: same sources as for table 2.1; Crafts-Harley-Deane-Cole from Crafts and Harley (1992); Deane and Cole (1967). Smits, Horlings, and van Zanden (1999) estimated Dutch GDP from 1807 to 1913. De Vries (2000) tentatively carries these estimates back to 1600. Dutch GDP per capita in 1913 is assumed to be 79 percent that of England, based on Prados de la Escosura (2000).

ita in the Netherlands rose 39 percent as a result of the Industrial Revolution, almost as much as in England. Britain gained little compared to either Ireland or the Netherlands as a result of the technological advances of the Industrial Revolution, and I suspect the same may be true of other countries such as France. So the loss in England's comparative position in Europe—in terms of total output relative to its competitors—from the absence of an Industrial Revolution would be small. The gains of the Industrial Revolution were being exported to England's competitors, either in the form of more favorable terms of trade for English industrial goods or in the form of the use of the knowledge itself for production in these countries.

Thus Britain in the nineteenth century, absent the technologies of the Industrial Revolution, would not have been significantly poorer compared to its European competitors.

But could it have achieved the same domination outside Europe with a GDP that was one-third lower in the 1860s, without steam power, and without cheap iron and steel for European weapons? Here it is important to emphasize that naval power remained based on sailing ships until

surprisingly late in the Industrial Revolution. The first steam-powered ocean-going warship, the French *Le Napoléon*, did not enter service until 1852. This was still a wooden ship. The modern iron-hulled armored battleship came only with the British *Warrior*, which entered service in 1861. So until 1850 naval ships would have looked very similar with no Industrial Revolution.

Similarly the triumph of the British Navy in the Napoleonic War era was achieved not mainly by technological advantages that the Industrial Revolution conferred on British ships, but by the greater sailing abilities of the British, and their ability to deliver a much higher rate of fire from their guns (Kennedy 1983, 123–128; Baugh 2004). In part these abilities came from the large numbers of British merchant seamen the Royal Navy could draw on from their normal employment in coastal and foreign shipping. But the switch to an industrial economy created by population growth even absent the Industrial Revolution would have created similar increases in the volume of British merchant shipping after 1760.

English History, 1760–1860, without the Demographic Revolution

Alternatively, what would have happened if the Industrial Revolution had occurred in an England that maintained after 1740 the population stability that had characterized it for the hundred years before 1740? To consider this counterfactual, I fix population in the 1860s in the model detailed in appendix A to its value in the 1730s. I assume productivity advance by sector was the same as in the actual Industrial Revolution, as were relative farm and nonfarm prices.

The prices are kept at those of the actual 1860s prices on the basis of the preceding discussion that relative price movements in the Industrial Revolution era seem to have depended mainly on relative productivity movements. A smaller population in England by the 1860s would have reduced farm product demands for the European and North American suppliers of England. But given the population sizes of Britain versus its trading partners, shown in table 2.3, the effect would have been minimal.

The results are shown in figure 2.8 and detailed in the last column of table 2.4. Now farm production within England is close to farm consumption, so that there is little net export of industrial goods or net import of farm produce. The share of the labor force in the farm sector at 48 percent is close to the share in the 1730s. England in these respects looks much as it did in the 1730s.[10]

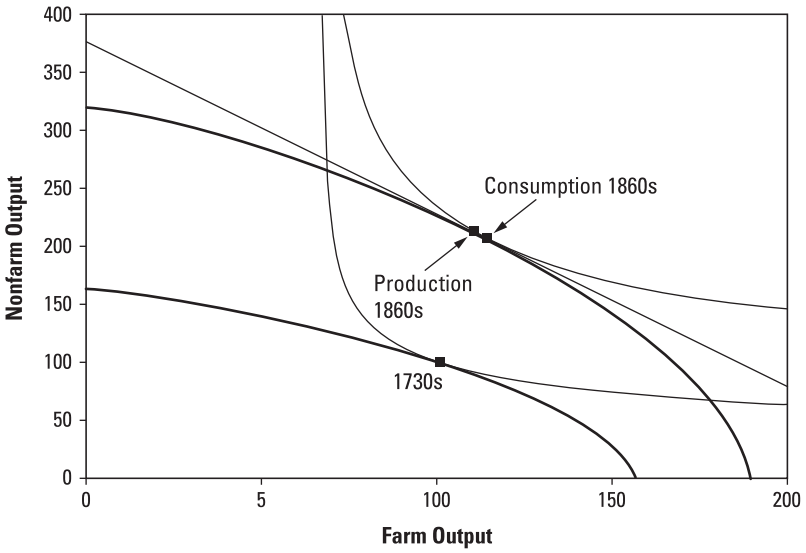

Figure 2.8
England in the 1860s without population growth.

Real income would increase somewhat more than it did with this model when population growth accompanied the Industrial Revolution (44 percent versus 35 percent) because of the greater amount of land per person. But GDP increases by only 52 percent overall, compared to 229 percent under the alternative counterfactual of not productivity gains but substantial population growth. Similarly, total industrial production increases more from population growth than from the productivity advances of the Industrial Revolution per se.

The economywide growth of TFP would have been lower without population growth, even though the growth rates in each sector were the same. This is because the national TFP growth rate is

$$g_{\text{TFP}} = \sum_i \eta_i g_{\text{TFP}_i}$$

where i indexes subsectors of the economy, and η_i their share in value added in the economy. In the model economy TFP grows 21 percent in farming and 60 percent in industry. But the increase in the relative size of the farming sector without population growth reduces overall TFP growth from 45 percent to 39 percent. Thus though there was no direct

connection between population growth and the TFP advance of the Industrial Revolution, indirectly population growth contributed more to TFP advance in Britain in the Industrial Revolution than did most of the innovators celebrated in the conventional histories of the period. Population growth alone increased national productivity advance by more than 15 percent.

In this connection we also see that another factor leading to greater measured rates of TFP advance in England in the Industrial Revolution era that appears in this model is the low share of the population in England already, by the 1730s, engaged in farm production. At 55 percent this was low by the conventional standards for preindustrial economies, where we typically find 70 percent to 80 percent of the population engaged in farming. English incomes in the 1730s were high for a preindustrial economy because England in the years 1600–1740 followed a strong version of the European Marriage Pattern, which significantly limited fertility (see Wrigley et al. 1997). In the Malthusian world before 1800, England was unusually wealthy, and consequently the farm share in consumption was low.

Even with the sectoral productivity growth rates of the Industrial Revolution, without the demographic changes England in the 1860s would have had much less trade with the rest of the world, and hence much less incentive to maintain and defend bases on these trade routes and to secure access for its manufactures to markets across the world. Thus Britain's outward orientation in the nineteenth century, its engagement with the rest of the world, can be attributed much more to unusual population growth than to unusual development of technology.

Conclusion

Britain by 1850 was the envy of nations. It had high living standards, extensive colonies, extensive informal political influence, and the biggest navy in the world. There is a tendency to think that the explanation of the relative economic and political success of Britain by 1850 must lie with the technological advances of the Industrial Revolution.

Here I have argued to the contrary that very little of the position of Britain in 1850 is directly explained by such things as innovations in textiles. High British incomes relative to its competitors were probably mainly achieved before the Industrial Revolution. Insofar as economic forces influenced the political and military successes of Britain, the one that mattered more in the competition with the other European states

was population growth, not technological advance. Further, the transformation of Britain from the 1730s to the 1860s from a heavily agrarian economy dominated politically by the landed classes to the urban, industrialized economy of the 1860s again depended almost entirely on population advances. Finally, the outward orientation of the economy, with huge volumes of imports and exports, and a substantial merchant navy, with the political and military consequences that entailed, again was created by population growth, not technological advance.

Thus it seems that Britain's rise to world dominance was a product more of the bedroom labors of British workers than of their factory toil.

Appendix A: The Model

Production

There are two sectors in the model economy, farm and nonfarm. The production functions for these, per capita, are

$$q_{\mathrm{NF}} = A_{\mathrm{NF}} n_{\mathrm{NF}}^{a}$$

$$q_{\mathrm{F}} = \frac{A_{\mathrm{F}} n_{\mathrm{F}}^{b}}{N^{1-b}}$$

where n_{NF} is the share of labor in the nonfarm sector, n_{F} the share in the primary sector (including coal). N is total population. Industry has no land constraint, but agriculture does. Since I assume that there is a perfectly elastic supply of capital at a constant real rate of return, r, capital in the industrial sector will be employed in fixed proportion to labor. That is why capital is not shown explicitly.

This implies that the production possibilities frontier (PPF) for England, measured in terms of outputs per person is

$$q_{\mathrm{NF}} = A_{\mathrm{NF}} \left[1 - \left(\frac{q_{\mathrm{F}}}{A_{\mathrm{F}}} \right)^{1/b} N^{(1/b)-1} \right]^{a}$$

The marginal rate of transformation (MRT) from farm into nonfarm output, the slope of the PPF at any level of q_{F}, is

$$\frac{dq_{\mathrm{NF}}}{dq_{\mathrm{F}}} = -\frac{p_{\mathrm{F}}}{p_{\mathrm{NF}}} = -\frac{a}{b} A_{\mathrm{NF}} A_{\mathrm{F}}^{-(1/b)} (N q_{\mathrm{F}})^{(1/b)-1} \left[1 - \left(\frac{q_{\mathrm{F}}}{A_{\mathrm{F}}} \right)^{1/b} N^{(1-b)/b} \right]^{a}$$

The curvature of the MRT is determined by a and b. The larger these are, the less curvature. In the simulations b is taken as 0.750 on the basis of studies of English agriculture (Clark 2002c). To fit the empirical data in

the 1730s with this simple model we also need to have $a = 0.614$. This is because the share of agriculture in the value of output, s_F, is

$$s_F = \frac{an_F}{an_F + bn_{NF}}$$

Since in the 1730s, $n_F = 0.55$, and $s_F = 0.50$, that in turn implies that $a = 0.614$.

The price of nonfarm relative to farm goods is

$$\frac{p_{NF}}{p_F} = \left(\frac{1 - s_F}{s_F}\right)\frac{q_F}{q_{NF}}$$

Consumption

The utility function of the representative consumer is

$$U(q_F, q_{NF}) = (q_F - H)^{\theta} q_{NF}^{1-\theta}$$

Taking agricultural output as the numeraire, the budget constraint is

$$y = q_F + p_{NF}q_{NF}$$

Maximizing utility subject to this constraint gives

$$q_F = \theta y + (1 - \theta)H, \qquad y \geq H$$

$$q_{NF} = \frac{(1 - \theta)}{p_{NF}}(y - H)$$

Thus the consumer is assumed to consume a minimum subsistence food amount H, then a constant share, θ, of income above H as food. At income $y = H$, only food is consumed. As income rises, the food share falls. θ was taken as 0.25 in the simulations.

With this specification the income elasticity of demand for farm and nonfarm outputs are

$$\eta_F = \frac{dq_F}{dy} \cdot \frac{y}{q_F} = \frac{\theta y}{\theta y + (1 - \theta)H} < 1$$

$$\eta_{NF} = \frac{dq_{NF}}{dy} \cdot \frac{y}{q_{NF}} = \frac{y}{y - H} > 1$$

At very high levels of income both income elasticities approach 1. At close to the subsistence level of food consumption, H, the income elasticity for food approaches θ, and that for industrial products approaches

infinity. θ and H were chosen to make the income elasticity of demand for food in the simulation be about 0.5, in line with empirical estimates (Clark, Huberman, and Lindert 1995).

The price elasticities of demand are

$$\varepsilon_{\mathrm{F}} = \frac{dq_{\mathrm{F}}}{dp_{\mathrm{F}}} \cdot \frac{p_{\mathrm{F}}}{q_{\mathrm{F}}} = -\frac{\theta}{s_{\mathrm{F}}} > -1$$

$$\varepsilon_{\mathrm{NF}} = \frac{dq_{\mathrm{NF}}}{dp_{\mathrm{NF}}} \cdot \frac{p_{\mathrm{NF}}}{q_{\mathrm{NF}}} = -\frac{(1-\theta)(y-H)}{s_{\mathrm{NF}}} > -1$$

Again, as y gets very large, both price elasticities approach -1. At close to the subsistence level of food consumption H, the price elasticity for food is lower and approaches -0.25.

Appendix B: Price Indices for England, 1730–1869

Define the following price indices:

p_{FO} = price of final outputs of the English economy (retail prices)

p_{GDP} = price of gross domestic output

p_{M} = price of imports (wholesale prices)

p_{X} = price of exports

p_{DC} = price of domestic consumption (including investment)

p_{F} = price of domestic farm output (including coal)

p_{NF} = price of domestic nonfarm output

The price indices are calculated as geometric indices:

$$p_{\mathrm{M}} = \prod_i p_i^{a_i}, \qquad p_{\mathrm{FO}} = \prod_i p_i^{b_i}$$

where a_i and b_i are the shares, respectively, in import and export costs of each good, and $\sum_i a_i = \sum_i b_i = 1$.

For each price the annual rate of change is defined as

$$\pi = \frac{\dot{p}}{p}$$

Define θ as the ratio of the value of imports to GDP. Then

$$\pi_{\mathrm{FO}} = \left(\frac{1}{1+\theta}\right)\pi_{\mathrm{GDP}} + \left(\frac{\theta}{1+\theta}\right)\pi_{\mathrm{M}}$$

$$\Rightarrow \quad \left(\frac{\dot{p}}{p}\right)_{\mathrm{GDP}} = (1+\theta)\left(\frac{\dot{p}}{p}\right)_{\mathrm{FO}} - \theta\left(\frac{\dot{p}}{p}\right)_{\mathrm{M}}$$

$$\Rightarrow \quad \ln(p_{\mathrm{GDP}}) = (1+\theta)\ln(p_{\mathrm{FO}}) - \theta\ln(p_{\mathrm{M}})$$

With this specification the GDP price index will be of the form

$$p_{\mathrm{GDP}} = \prod_i p_i^{c_i}$$

where $\sum_i c_i = 1$, but the individual weights can be positive or negative. Negative weights will correspond to imported commodities.

Both the final output and import prices are measured as including all taxes and fees. By similar reasoning we can also establish that, where ϕ is the ratio of the value of imports to domestic consumption,

$$\pi_{\mathrm{FO}} = \left(\frac{1}{1+\theta}\right)\pi_{\mathrm{GDP}} + \left(\frac{\theta}{1+\theta}\right)\pi_{\mathrm{M}} = \left(\frac{1}{1+\phi}\right)\pi_{\mathrm{DC}} + \left(\frac{\phi}{1+\phi}\right)\pi_{\mathrm{X}}$$

$$\Rightarrow \quad \pi_{\mathrm{GDP}} = \left(\frac{1+\theta}{1+\phi}\right)\pi_{\mathrm{DC}} + \left(\frac{\phi(1+\theta)}{1+\phi}\right)\pi_{\mathrm{X}} - \theta\pi_{\mathrm{M}}$$

$$\Rightarrow \quad \ln(p_{\mathrm{GDP}}) = \left(\frac{1+\theta}{1+\phi}\right)\ln(p_{\mathrm{DC}}) + \left(\frac{\phi(1+\theta)}{1+\phi}\right)\ln(p_{\mathrm{X}}) - \theta\ln(p_{\mathrm{M}})$$

If trade is in balance, so that the value of imports equals that of exports ($\theta = \phi$), then this simplifies to

$$\Rightarrow \quad \ln(p_{\mathrm{GDP}}) = \ln(p_{\mathrm{DC}}) + \theta\ln\left(\frac{p_{\mathrm{X}}}{p_{\mathrm{M}}}\right)$$

To calculate real GDP we thus just deflate total nominal incomes in the economy by the GDP deflator. To calculate real income we deflate by the Domestic Consumption deflator.

Farm versus Nonfarm

The rate of increase of the price of GDP can also be decomposed into the rate of increase of the price of domestic farm output and domestic nonfarm output, using the share of GDP that was domestic farm output. Thus,

$$\pi_{\mathrm{GDP}} = \mu\pi_{\mathrm{F}} + (1-\mu)\pi_{\mathrm{NF}}$$

I use this expression to calculate the movement of nonfarm prices from the movement of GDP prices, and that of farm output.

Notes

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1. It is claimed that by 1855 Chinese tariff policy was firmly under British control, the only restraint on the British being the fear of toppling the current regime by pushing it too far.

2. The British and French similarly in 1845 intervened in Uruguay in support of a liberal regime that favored freer trade. Cain and Hopkins (1980, 479–481).

3. Wrigley et al. (1997, 182–194) show for their sample group of 26 reconstituted parishes that fertility increases were as great in those classified as rural as in those that were engaged in trade or industry.

4. Convicts were transported to Australia between 1788 and 1852. By 1840, Britain had shipped 111,000 convicts.

5. This data construction is still in part a work in progress, but the series are near enough to their final form to serve as a good preliminary basis for the following discussion.

6. These data differ in a number of ways from the well-known series of Crafts and Harley (1992) on output growth in Industrial Revolution England. In particular, there is less growth of farm output than Harley (1993) assumes in these years on the basis of CGE modeling of the Industrial Revolution (neither Crafts and Harley 1992 nor Harley 1993 has direct observations on farm output).

7. This claim, based on Clark (2002a) and Clark (2004), is controversial. Allen (1994), for example, suggests much more output growth. But it is founded on very strong estimates of the factor incomes and prices in agriculture in these years.

8. This is because capital is assumed supplied elastically at a fixed rate of return, so that with the production functions used, capital per worker in each sector remains the same.

9. Land rents as a share of income may seem low in the 1730s compared to the measured share of land rents, but the rent here is the pure site value of the land, and that in England was much less than the rent paid per acre, which included rents for housing, roads, fences, and other land improvements.

10. In contrast, Crafts and Harley (2004) in a CGE exercise conclude that population growth explains only a modest part of the structural change in the British economy in the years 1770–1841. This conclusion follows mainly from the assumption that, absent British population growth, the British terms of trade would have shifted 44 percent toward industrial products. Without such a shift the absence of population growth in their model raises the farm share in employment in 1841 from the observed 22 percent to approximately 39 percent. This is similar to the results in table 2.4.

11. I have discussed why assuming that relative industrial prices would be substantially higher at the end of the Industrial Revolution without British population growth seems unwarranted.

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