THE MEANING OF THE INDUSTRIAL REVOLUTION

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"There be daily many things found out and daily more may be which our fore fathers never knew to be possible."

Sir Robert Filmer (1653).

When was the decisive break from the pre-industrial world of slow technological advance and stagnant living standards to the modern world of constant technological progress and steadily improving living standards? Most historians have assigned the dawn of the modern world to England in 1770. There has followed a long debate about the cause of the Industrial Revolution. Here I argue that there was no significant break in 1770 from the earlier world. That break only occurred later in the nineteenth century. Instead the Industrial Revolution was most likely the last of a series of localized growth spurts stretching back to the Middle Ages, as in the Netherlands from 1500 to 1650, and northern Italy in the fourteenth century. Accidents of demand, demography, trade, and geography made this spurt seem different than what had come before – but it was really more of the same.

Introduction

To a first approximation the path of world income per capita between 8,000 BC and 2,000 AD is best represented by figure 1 (where income in 1800 is set as 1).

Figure 1: Income per Capita, 10,000 BC – 2,000 AD

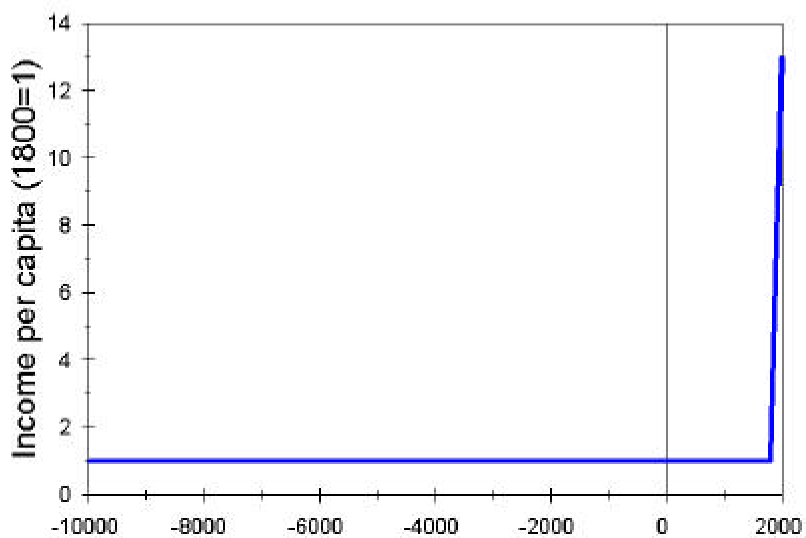
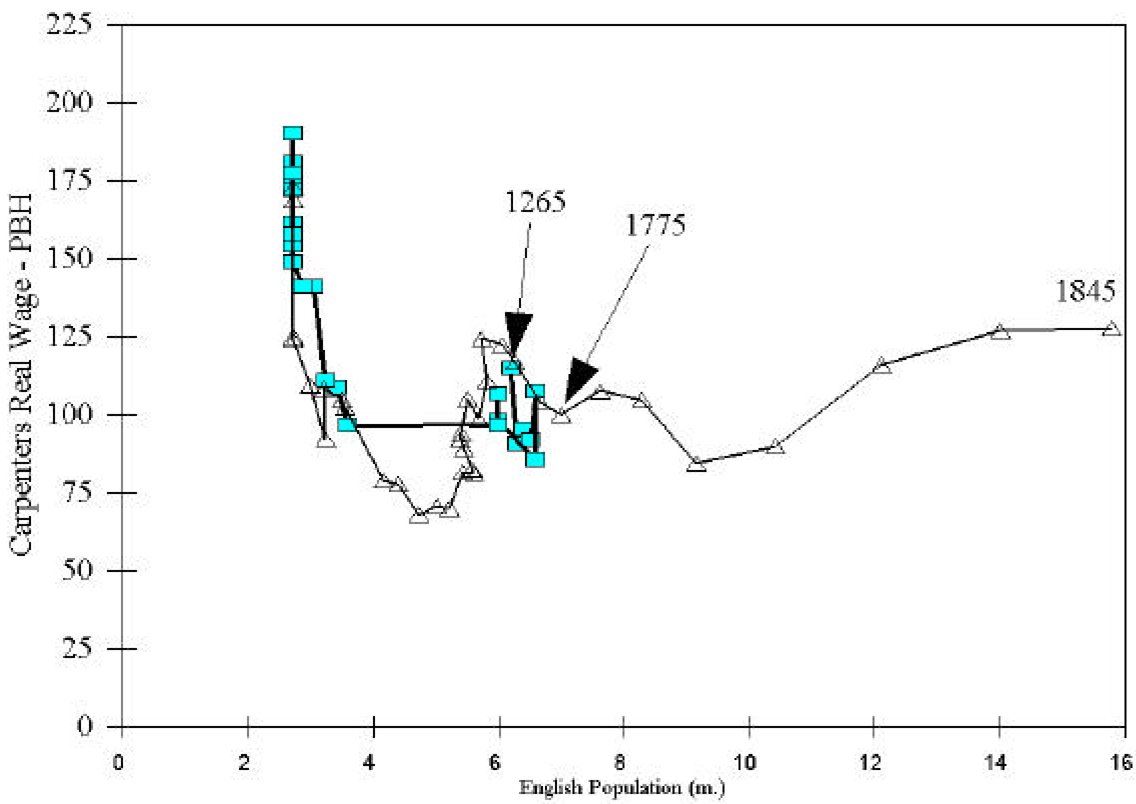


Figure 2, which shows English population in millions by decade from 1260-9 to 1840-9, and the real wages of craftsmen as measured by Phelps-Brown and Hopkins clearly suggests that something dramatic happened in the English economy between 1770 and 1860 after 500 years of stasis. Before 1770 population and wages had seemingly been inversely linked along the same curve for at least 500 years. If population rose, real wages fell. The productivity of the economy was seemingly fixed, with demography determining the marginal product of labor, and hence wages.

Figure 2: Real Craftsmen's Day Wages from PBH Versus Population by Decade, 1260-1849



Notes: The triangles show observations for the decades after 1500, the squares observations for the decades before 1500.

Sources: Real wages. Phelps-Brown and Hopkins (1962). Population, 1540-1850. Wrigley, Davies, Oeppen, and Schofield (1997), pp. 614-5. Population, 1250-1530. Hatcher (1977), Poos (1991), Hallam (1988).

For this reason the Industrial Revolution of 1770 has come to be thought of as the great turning point in human history. In 1770 was launched the modern era of unending economic growth, of liberation from the constraints of the land base under the old organic technology.[1] There has followed from this an intense debate on the features of the British economy in 1770 that precipitated the break from the past. Generations of economic historians have thrown themselves at the problem, like waves of infantry in World War I going over the top. Politics, science, religion, slavery, and markets have all been promoted as the cause of the great event. Generations of economic historians have failed to identify any plausible feature of the economy that could create such a break. But still fresh recruits come forward, seemingly undeterred by the scattered remnants of their fallen colleagues. In the years 1997-9 the article from the Journal of Economic History most often downloaded from JSTOR was Douglass North and Barry Weingast, "Constitutions and Commitments" which seeks to explain why the Glorious Revolution of 1688-9 lead to the Industrial Revolution of 1760. Ken Pomeranz in his recent work, The Great Divergence promotes access to the land of the Americas as the key factor in European industrialization after 1760.

In this paper I make the following argument. There was nothing special about the events of 1770 and later in England. 1770 was just the latest of a series of episodic spurts of growth that had been occurring in Europe since the Middle Ages. That growth was indeed confined to a small region of the English economy. England itself had quite significant economic growth in the bad old days of the sixteenth century. That is why no one can find the significant cause of the events of 1770. Nothing unusual happened. The seeming dramatic industrialization of the British economy in these years was the result just of the unusual demographic experience of

[1] 1770 is the most popular date for the start of the Industrial Revolution of two great innovations in cotton spinning

England compared to the rest of Western Europe. This population growth combined with rapid productivity growth in small parts of the English economy spurred rapid structural change and urbanization. Similar events had occurred on a smaller scale in Europe in the years before.

The argument of this paper is the following:

1. Growth of output per person, and of productivity, was much less in the Industrial Revolution than even the pessimistic estimates of Crafts and Harley have suggested. Output per person increased by only 33% from 1760 to 1860, or at a rate of 0.29% per year, compared to Crafts estimates of a 73% gain (0.54% per year). Estimated total factor productivity increased by only about 43% in a hundred years, or 0.36% per year, compared to Crafts estimate of a gain of 109% (.58% per year).[2] Figure 3 shows estimated real GDP per person from 1500 to 1869 for England. Compared to modern growth rates of output per person this is an order of magnitude slower.

2. Output per person must have increased significantly in the years 1600 to 1760. Thus the growth rate of output from 1600-9 to 1700-9 was 0.19% per year, not that much less than in the Industrial Revolution era. Indeed if we fit a long run trend line with growth of output at 0.23% per year from 1600 to 1869 then there is very little deviation all the way through.

3. The sources of growth in 1760-1860 were confined to a very small sector of the economy. Almost all the growth that can be attributed to technological innovations came from one sector, the textile industry. Of the growth rate of 0.36% for productivity in the economy as a whole, 0.24% came from the textile sector, even though this was only one tenth of the economy by the end of this period. The great mass of the economy, including agriculture, construction,

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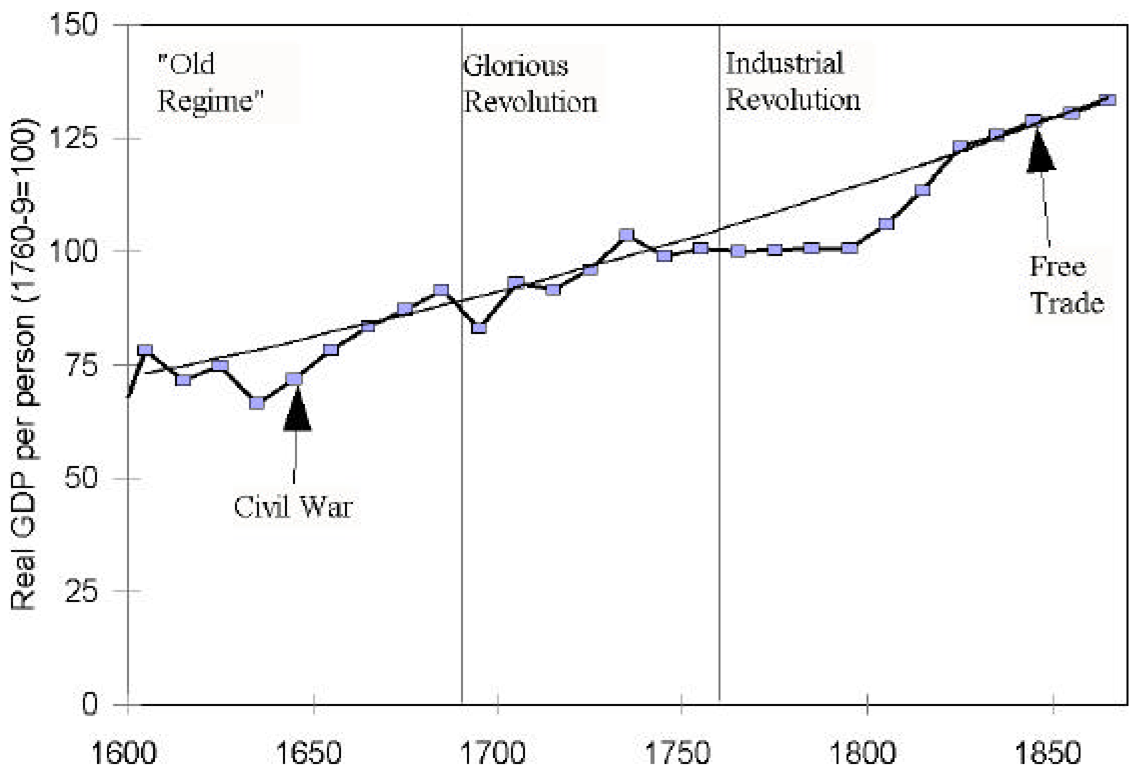
made in 1768 and 1769. These were the spinning jenny, and the water frame.

[2] The TFP growth rate is estimated as minus the growth rate of an index of output prices plus a share weighted average of the growth rate of indexes of payments to factors. The share weights were adjusted each decade.

Figure 3: Real GDP per Person, England, 1600-1869



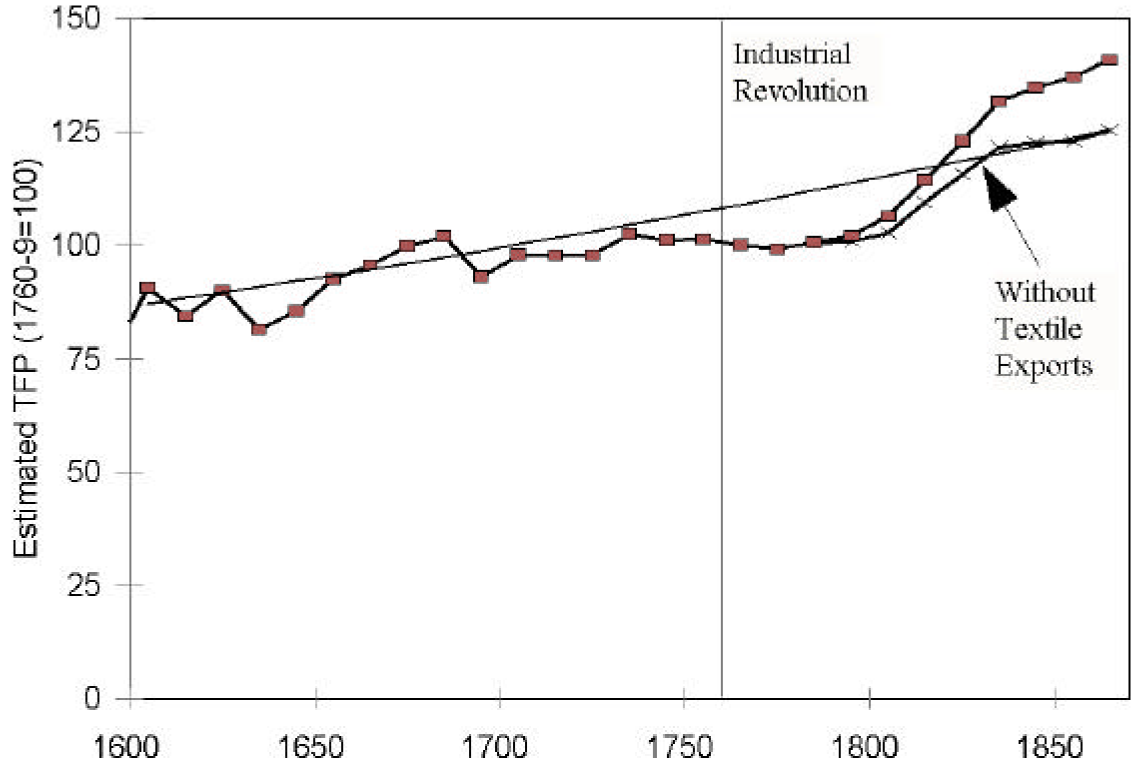
services, and most manufacturing saw very little productivity increase. The gains in income per capita were thus the result of a lucky technological advance in one area.

4. The effects of productivity growth in textiles on the TFP of the whole economy crucially depended on the ability of Britain to export these products on a large scale. Had these industries produced only for the home market then the productivity growth rate from 1765 to 1865 would have dropped by a third. Figure 4 shows calculated TFP for the years 1600 to 1869. Again if we fit a trend of productivity through the endpoints we see little sign of any great upturn in the years 1760-1869.

5. The southern half of England saw almost no productivity growth in the Industrial Revolution period. The industrial sectors which saw productivity growth – principally textiles and iron production - were heavily concentrated in the north of the country, as table 1 shows. And we shall see below that in the case of agriculture where we can compare productivity growth by region, there was productivity growth in the north but not in the south.

6. Prior to 1760 there were productivity advances in individual sectors that were just as dramatic as for textiles in the Industrial Revolution era. They just happened to affect smaller areas of the economy. Thus the introduction of the printed book in 1445 in southern Germany represented an advance in book reproduction technology as great as that in cotton textiles in the Industrial Revolution. It just so happened that books were a much smaller fraction of consumer demand than clothing. Even in the sixteenth century when the printing industry in Europe was producing 1.75 million book copies per year, that would still have required the labor of only 3,200 workers to supply 60 million people with printed books, a fraction of a percent of the labor force.

Figure 4: Total Factor Productivity, England, 1600-1869



Note: Productivity growth is calculated as g_A = ? .g_r + ? .g_w + ?.g_s – g_p where g_ represents a growth rate, and ? , ? , ?? are the share in national income of payments to capital, labor and land. Since some of reported land rentals represent payments instead to capital investments in farm buildings, fences, roads, drainage and soil fertility, I assumed throughout that 40% of land rent was payments to capital.

Table 1: Regional Distribution of Occupations, 1851

Region	North	Midlands	South
All Occupations	**1,920,046**	**1,186,118**	**3,114,059**
Agriculture	**347,956**	**366,700**	**830,987**
Cotton Textiles	242,190	12,192	4,857
Worsted	61,640	1,341	1,383
Wool Textiles	85,114	2,057	29,669
Linen Textiles	14,144	493	2,317
Silk Textiles	34,751	21,794	26,848
All Textiles	**437,839**	**37,876**	**65,074**
Service and Govt.	**186,730**	**121,924**	**553,477**

Notes: Workers in adult male equivalents based on relative wages of men, women, boys and girls.

7. Other places in Europe in the years 1200 to 1760 saw similar episodes of productivity growth that were as significant as those in England from 1760 to 1860. Thus between 1550 and 1650 the Netherlands saw significant productivity advance.

8. The appearance that the Industrial Revolution in England represented a decisive break from the past is largely a product of the unusual demographic experience of England in the Industrial Revolution years. This demographic growth would have spurred industrialization absent any productivity advance. This demographic growth, by driving up land rentals and creating urbanization, spurred a number of changes in the economy, such as the enclosure of common lands, improvements in transportation, and the expansion of coal mining.

Current Understanding of the Industrial Revolution

Recent thinking about the Industrial Revolution has been dominated by the idea that the driving force in events in Britain after 1760 was an unprecedented set of technological advances, spread across a wide range of sectors in the economy. Cotton textiles, iron and steel production, mechanical power sources, shipping, railways and agriculture all saw significant advances and together these more than doubled the overall productivity of the economy. Table 2 shows the recent estimates of output and inputs in Britain or England from 1700 to 1860 from Crafts (1985), and Crafts and Harley (1992) and the implications these have for output per worker, output per unit of capital, and total factor productivity. Though their estimates tend to somewhat more pessimistic than a previous generation of economic historians they still argue for a 5.7 fold increase in output between 1700 and 1860, and a near doubling of output per worker.

Table 2: Conventional Estimate of Outputs and Inputs, 1700-1860

Period	1700	1760	1801	1831	1861
Population	100	119	160	240	367
GNP	100	143	210	361	764
Capital	(100)	143	210	351	640
Land	100	100	100	100	100
Output per person	**100**	**120**	**131**	**150**	**208**
Output per unit of capital[1]	**(100)**	**100**	**100**	**103**	**119**
Total Factor Productivity[2]	**100**	**116**	**128**	**150**	**209**

Notes: [1]Capital per unit of output in 1700 is assumed the same as in 1760.

[2]Calculated assuming wages were 50% of output, capital 35% and land 15%.

Sources: Crafts (1985); Crafts and Harley (1992), Industry, GNP 1700-1831; Wrigley and Schofield (1997), population.

Second their estimates suggest that the rate of productivity growth was gathering momentum over time. Table 3 shows the calculated productivity growth by period.

Third investigation of the productivity growth rates of the “revolutionized” sectors, and their likely contribution to national productivity growth, suggest that all the productivity growth can be accounted for by the sectors listed above. Aggregate productivity growth rates will be the sum of productivity growth rates in each sector, weighted by the share of output in that sector in GDP. Thus

$$g_A \; ? \; \underset{i}{?} \; ?_i \, g_{Ai}$$

where g_A is the overall productivity growth rate, $?_i$ is the share of each industry in GDP, and g_{Ai} is the productivity growth rate of each industry. If we calculate sectoral productivity growth rates on a value added basis, then the weights $?_i$ will be value added in each sector relative to GDP. If we calculate productivity growth rates treating intermediate inputs as factors of production in each industry, then the weights will be the ratio of gross output of each industry to GDP, and these weights will add to more than 1.

Using the estimates made by McCloskey of sectoral productivity growth rates from 1780 to 1860 using input and output prices we see in table 4 that six revolutionized sectors, plus agriculture, explain all the productivity advance in the economy. The great bulk of the economy, including manufacturing, apparently saw no productivity advance from 1780 to 1860. In terms of importance the revolution in textiles matters most, explaining about 42% of all the productivity growth in the economy from 1780 to 1860. But even without anything happening in

Table 3: Productivity Growth in the Industrial Revolution, Crafts

Period	Output per Person Q/L (%)	Capital per Person K/L (%)	Land per Person T/L	Total Factor Productivity
1700-1760	0.30	0.31	-0.29	0.24
1760-1801	0.21	0.22	-0.72	0.24
1801-1831	0.45	0.36	-1.35	0.53
1831-1861	1.09	0.59	-1.42	1.10
1760-1861	**0.54**	**0.37**	**-1.12**	**0.58**

Note: Productivity growth is calculated assuming that the share of capital in national income is 35%, and the share of land is 15%, so that the share of labor is 50%.

Table 4: McCloskey on the Sources of Productivity Growth in the Industrial Revolution, 1780-1860

Sector	Productivity Growth Rate, 1780-1860 (%)	Average Share of Output Value/GDP	Contribution to Productivity Growth Rate (%)
Revolutionized Industry		**0.29**	**0.52**
1. Cotton	2.6	0.070	0.182
2. Worsted	1.8	0.035	0.063
3. Woolens	0.9	0.035	0.032
4. Iron and Steel	0.9	0.020	0.018
5. Canals and Railways	1.3	0.070	0.091
6. Coastal and Foreign Shipping	2.3	0.060	0.138
Agriculture	**0.45**	**0.27**	**0.12**
Rest of the Economy	**0.02**	**0.85**	**0.02**
All		**1.36**	**0.66**

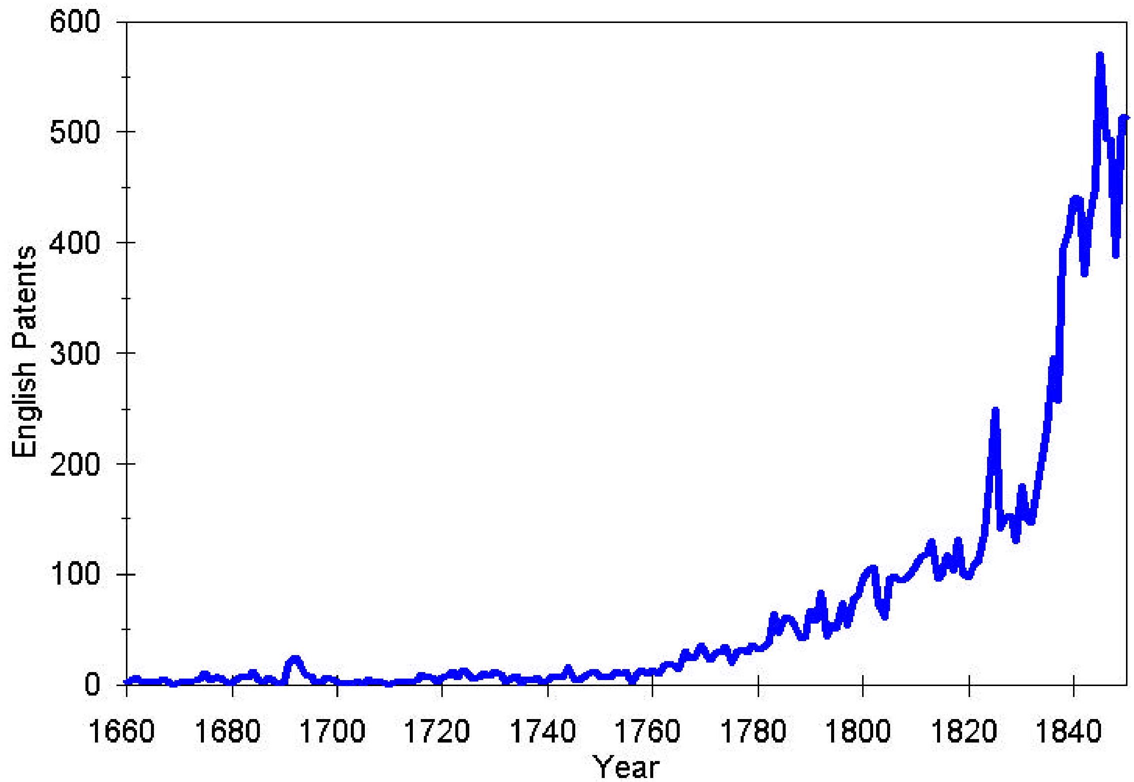
Source: Sectoral productivity growth rates McCloskey (1981). Overall productivity growth rate calculated from table 3.

textiles from 1780 to 1860 it would still have been a period of unusual productivity advance, with a productivity growth rate of 0.39% per year, above the rate in the years 1700-1760, and certainly above the 0% rate of 1265-1700. Improvements in transport and in agriculture would have significantly expanded output without any textile revolution. Thus the Industrial Revolution is still a fairly broad based occurrence. It is unlikely to be explained by chance since there was little or no connection between the advances occurring in textiles, in metallurgy, in steam power, in shipping, and in agriculture.

Broad based technological advance as an explanation of the Industrial Revolution is seemingly also supported by the patent statistics of the era. Figure 5 shows patents taken out per year in England from 1600 on.

Note that on this picture of what happened in the Industrial Revolution output per person grew by 73% from 1760 to 1860. But Feinstein's recent estimates suggest real wages per person grew by only about 44% between 1770 and 1860. Thus the share of income claimed by capital and land owners seemingly increased during the Industrial Revolution.

Figure 5: Patents per Year, 1660-1851



A revised view of the Industrial Revolution

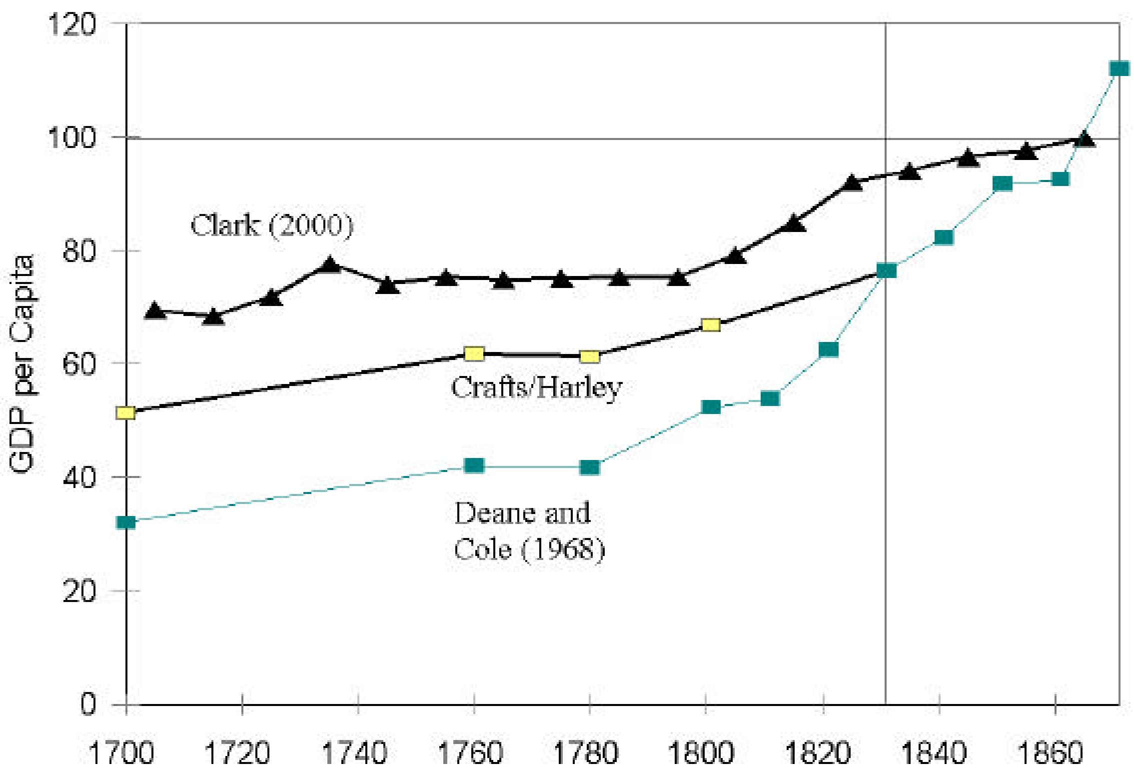
The first claim I want to make here is that the conventional estimates of output growth per person in Britain from 1700 to 1861 are still too high. Figure 6 gives a revised set of estimates of real output per person. This output series is estimated as the sum of factor payments plus indirect taxes in England from 1700-9 to 1860-9, divided by a GDP deflator. Notice that the implied series on output per head is radically at variance with the current wisdom on growth in the Industrial Revolution in the years 1820-1869. Astonishingly on these figures income per person was only 8% higher in the 1860s as in the 1820s, just when the Industrial Revolution was supposed to be getting in gear. Indeed since the systematic quantitative study of the Industrial Revolution began in the 1950s the trend in estimates of output growth has been generally downwards.

Before I discuss the details of this estimate I had better explain how was this possible given the undoubted productivity improvements occurring in some sectors of the economy, particularly textiles? Figure 7, for example, shows the estimated productivity of the cotton textile industry in turning cotton into plain cotton cloth from 1770 to 1869, where 1770-1779 is set at 100.

How could we have such phenomenal productivity growth in an important sector like textiles with so little increase in output per person at the national level? The answer lies in the arithmetic of productivity growth. The aggregate productivity growth rate is just the sum of the productivity growth rates of individual sectors weighted by their share in national outputs. Table 5 shows the contribution of cotton textiles, and of the sister woollen industry to national productivity growth in the years 1770-1869.[3] As can be seen while productivity in cotton textile

[3] I have assumed half of the worsted industry was cottons, and half woolens, and divided the output accordingly.

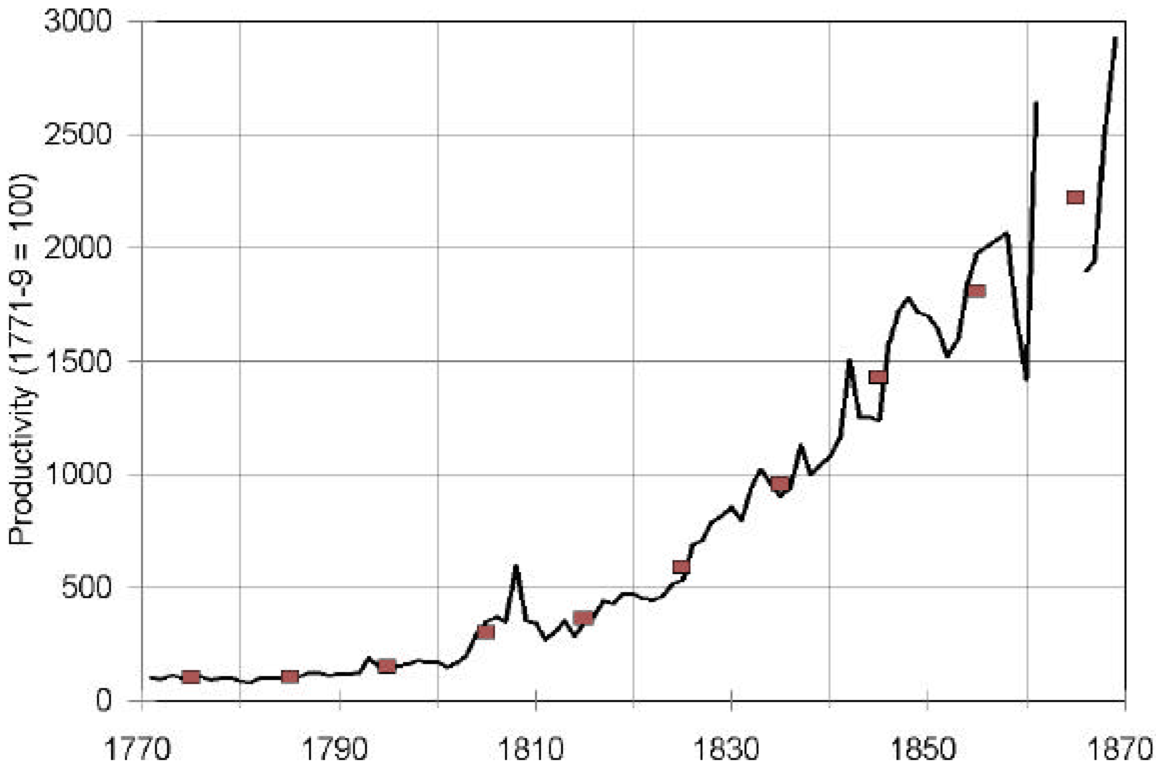
Figure 6: Real Output per Person, 1700 to 1869



Note: The Deane and Cole and Crafts/Harley numbers pertain to Great Britain.

Source: Deane and Cole, British, pp. 78, 166, 170. Crafts and Harley, "Output Growth," p. 715, Crafts, British, p. 45.

Figure 7: Productivity in Cotton Spinning and Weaving 1770-1869 (1770-9 = 100)



Note: The squares show the decadal average productivities. The years 1862-5 were omitted because of the disruption of the cotton famine.

Table 5: The Contributions of Cotton and Wool Textiles to National Productivity Growth

Period	Cotton Productivity Growth Rate (%)	Cotton Share of GDP	Contribution to National Productivity Growth Rate (%)	Woollen Productivity Growth Rate (%)	Woollen Share of GDP	Contribution to National Productivity Growth Rate (%)	Total Contribution (%)
1765-1775	0.00	0.013	0.00	0.50	0.042	0.02	**0.02**
1775-1785	0.46	0.026	0.01	1.02	0.042	0.04	**0.05**
1785-1795	3.54	0.043	0.15	1.92	0.042	0.08	**0.23**
1795-1805	6.98	0.050	0.35	4.20	0.040	0.17	**0.52**
1805-1815	1.88	0.054	0.10	1.07	0.039	0.04	**0.14**
1815-1825	4.85	0.063	0.31	-1.59	0.037	-0.06	**0.25**
1825-1835	4.88	0.069	0.34	1.14	0.036	0.04	**0.38**
1835-1845	4.00	0.071	0.28	-1.21	0.036	-0.04	**0.24**
1845-1855	2.37	0.069	0.16	4.59	0.034	0.16	**0.32**
1855-1865	2.05	0.055	0.11	2.95	0.030	0.09	**0.20**
Overall	3.10	0.051	0.181	1.46	0.031	0.054	**0.235**

<u>Sources</u>: Cotton cloth prices, Harley (199-). Raw cotton prices, Mitchell (19--).

production grew at a very respectable rate of 3.1% per year, this on its own contributed only an average of 0.18% to national productivity growth rates, because on average the cotton industry was only 5% of English GDP. This still implies that between 1765 and 1865 the cotton industry alone contributed a gain of 20% in the economy's productivity level. Woollen textiles saw a much slower productivity growth rate of only 1.46% per year, and this combined with the smaller share of woolens in GDP resulted in woolens contributing only 0.054% per year to the national productivity growth rate.

Even though the share of cottons and woolens was never large, this share was only attained because of very substantial exports of cotton and woolen goods. Thus by the 1860s at least two thirds of English cotton goods output was exported, and about one third of woolens. These exports were traded in world markets for foods and raw materials demanded by England's rapidly growing population. Had these industries been confined to serving the domestic market, assuming that income per capita was unaffected then the contribution of these industries to national productivity growth would have been as shown in table 6.

How can I derive such radically different estimates of output per person? The estimates of Crafts, Harley and others of the growth of output in the Industrial Revolution period turn out to be surprisingly weakly based. The original estimates of the growth of output from 1801 to 1861 stem from Deane and Cole. Their method was to estimate nominal income from factor payments at 10 year intervals from 1801 on, and then deflate this by a price index. They derived information on all incomes other than wages primarily from the statistics of the income and property tax levied in 1803-1815 and 1842-1861. There is a long gap in the tax information from 1816-1841 because in these years there was no income or property tax. Further the legislation

Table 6: The Contributions of Cotton and Wool Textiles to National Productivity Growth without Exports

Period	Cotton: consumption share of GDP	Contribution to National Productivity Growth Rate (%)	Woollens Consumption share of GDP	Contribution to National Productivity Growth Rate (%)	Total Contribution (%)
1765-1775	0.011	0.00	0.027	0.013	**0.01**
1775-1785	0.015	0.01	0.027	0.027	**0.03**
1785-1795	0.026	0.09	0.027	0.051	**0.14**
1795-1805	0.024	0.17	0.025	0.107	**0.28**
1805-1815	0.019	0.04	0.025	0.027	**0.06**
1815-1825	0.025	0.12	0.027	-0.042	**0.08**
1825-1835	0.032	0.15	0.027	0.031	**0.18**
1835-1845	0.032	0.13	0.027	-0.033	**0.10**
1845-1855	0.028	0.07	0.025	0.115	**0.18**
1855-1865	0.026	0.05	0.020	0.059	**0.11**
Overall	0.024	0.082	0.021	0.036	**0.118**

ending the first tax at the end of the Napoleonic Wars called for destruction of all the tax records to prevent the information in them being used to aid the reimposition of an income tax. The income tax was reimposed in essentially the same form as for the years 1803-1815 in 1842. This later tax seems to have been fully assessed. The assessed value of land, for example, was high compared to other information on rents in the years after 1842. Deane and Cole thus naturally assumed full assessment of most income categories under the earlier period of income taxation. Using the benchmarks this gave them for 1801 and 1811 they interpolated incomes in the years 1821 and 1831 from ancillary information. Table 7 shows their nominal income estimates for 1801-1871 (reduced from Britain to England based on relative population).

When Crafts revised Deane and Coles estimates in 1985, what primarily troubled him was not their estimates of nominal incomes, but the price deflator they used to go from nominal to real incomes. This was the Rousseaux index of 1938 which relied mainly on wholesale prices and the unit values of imports of agricultural commodities and industrial raw materials. This index shows extraordinarily high values for the war years 1801 and 1811. Table 7 shows Deane and Cole’s nominal income estimate, reduced to the basis of the English population, and the deflator they derive from Rousseaux to translate these nominal incomes into real incomes. Since the price deflator seemed much more stable after 1831, Crafts concentrated on deriving revised estimates for the years before 1831, assuming the Deane and Cole nominal income estimate for 1831 was correct. As Table 7 shows, where the price deflator I use is given also, Crafts was right to suspect that the Rousseaux index would exaggerate prices in 1801 and 1811, and hence increase the measured rate of growth. Crafts calculated revised growth rates for 1700 to 1831 using very different methods. But he still estimates agricultural income in 1801, when agriculture was one third of employment, from the tax reports used by Deane and Cole.

Table 7: Nominal Income and Prices, 1801-1871

Period	Deane and Cole Nominal National Income (£ m.)	Rousseaux Price Index (1860-1869 = 100)	Period	Clark Nominal National Income (£ m.) (by decade)	Clark Price Level (by decade)
1801	196	142	1800-9	242	112
1811	254	152	1810-9	321	122
1821	243	92	1820-9	335	101
1831	284	92	1830-9	363	93
1841	379	97	1840-9	427	89
1851	441	90	1850-9	495	91
1861	560	100	1860-9	625	100
1871	762	99		-	-

Note: My income nominal income estimates have been adjusted to be equal to those of Deane and Cole for 1865 where I assume a constant growth rate of nominal income between1861 and 1871.

Unfortunately there is good evidence that the first experiment with an income tax in 1803-1815 did not produce full assessment of most property incomes, and that indeed the underassessment was substantial. For I have been able to construct a rental series on farmland in England from 1500 to 1912, and on housing from 1640 to 1912 which suggests strongly that the earlier tax assessments undervalued rental values. The charity rent series suggest an under assessment in the tax returns of 1806-9 of 32 percent for houses and 36 percent for land. For 1810-14 the underassessment is 41 percent for houses and 38 percent for land.[4] The discussions on the Income Tax of 1801-1814 are silent on the question of how the authors know incomes were assessed in full.[5] Though the tax was based on assessing the annual values of property, the years 1790-1815 saw rapid growth in house and land rental values. Many properties were let on leases of 21 years or longer, so the even if the assessments were made according to the rules the assessed value for taxes would be well below market rental values.

Here I derive new estimates of national income from the payments to factors, and indirect taxes.

(a) **Wages and salaries**. To derive estimates of total wage earnings over this long period I use just three series that we can measure relatively well. To measure rural wages I use wages for male agricultural laborers. To measure urban wages I use wages for building laborers, and wages of building craftsmen. The ratio of the wage of building craftsmen to building workers gives some information on the skill premium in the labor market. The ratio of building wages to agricultural wages tells us about the wage gap between rural and urban employments. Table 8 shows the resulting wage estimates. For comparison the more comprehensive wage measures of Feinstein that includes female workers, and many more occupations, for the years 1770-1869 are

[4] For land rents see Clark, "Farmland."

also shown. As can be seen generally the two aggregate wage measures move together for these years. My wage series rises 121% between 1770-9 and 1860-9 in nominal terms, compared to 118% for Feinstein's series. It suggests that projecting back with this simple measure will work relatively well.

The wage structure was pretty stable over these years. As already noted by Phelps-Brown and Hopkins the ratio of craft wages to laborers wages in building changed little. Further the ratio of laborers wages in building, mainly in urban areas, to those of laborers in agriculture again changed little. Despite the urbanization of the population that accompanied the Industrial Revolution, and the consequent migration from countryside to the city, the wage gap between country and city widened little. Figure 8 shows the ratio of urban to rural, and of skilled to unskilled wages in the years 1700-1869. This stability suggests that we can use these three wage series to index overall wage movements of the skilled and unskilled.

This wage series does imply a respectable rise in real wages. Figure 9 shows that though there were no gains before the 1820s, thereafter real wages rose by about 60%.

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[5] See, for example, Hope-Jones, Income Tax, Deane and Cole, British Economic Growth, pp. .

Table 8: Wages in Industrial Revolution England

Decade	Farm Laborer Wage (d. per day)	Urban Laborer Wage (d. per day)	Urban Craftsman Wage (d. per day)	Share Farm	Overall Wage (d. per day)	Overall Wage (Feinstein) (d. per day)
1700-09	10.0	14.2	19.0	0.500	**12.1**	
1710-19	10.1	14.3	19.1	0.483	**12.3**	
1720-29	10.2	14.5	19.6	0.467	**12.6**	
1730-39	11.0	14.6	19.4	0.450	**13.0**	
1740-49	10.9	14.9	19.7	0.433	**13.2**	
1750-59	11.0	14.8	19.9	0.417	**13.3**	
1760-69	11.4	15.5	20.5	0.400	**13.9**	
1770-79	12.2	16.8	22.0	0.383	**15.0**	13.5
1780-89	13.3	17.2	23.3	0.367	**15.9**	14.5
1790-99	15.1	20.2	26.8	0.350	**18.4**	18.2
1800-09	19.2	27.5	35.6	0.333	**24.6**	24.5
1810-19	22.6	32.7	42.9	0.316	**29.4**	26.6
1820-29	19.8	29.4	41.0	0.300	**27.1**	22.6
1830-39	19.6	28.9	39.7	0.283	**26.7**	22.5
1840-49	20.5	30.8	39.2	0.266	**27.6**	23.9
1850-59	21.6	31.3	40.6	0.250	**28.7**	26.1
1860-69	23.6	36.0	46.7	0.210	**33.2**	29.5

Notes: The level of the wages in any year does not matter since the purpose here only is to create an index of wage movements.

Figure 8: Relative Wages in the Industrial Revolution

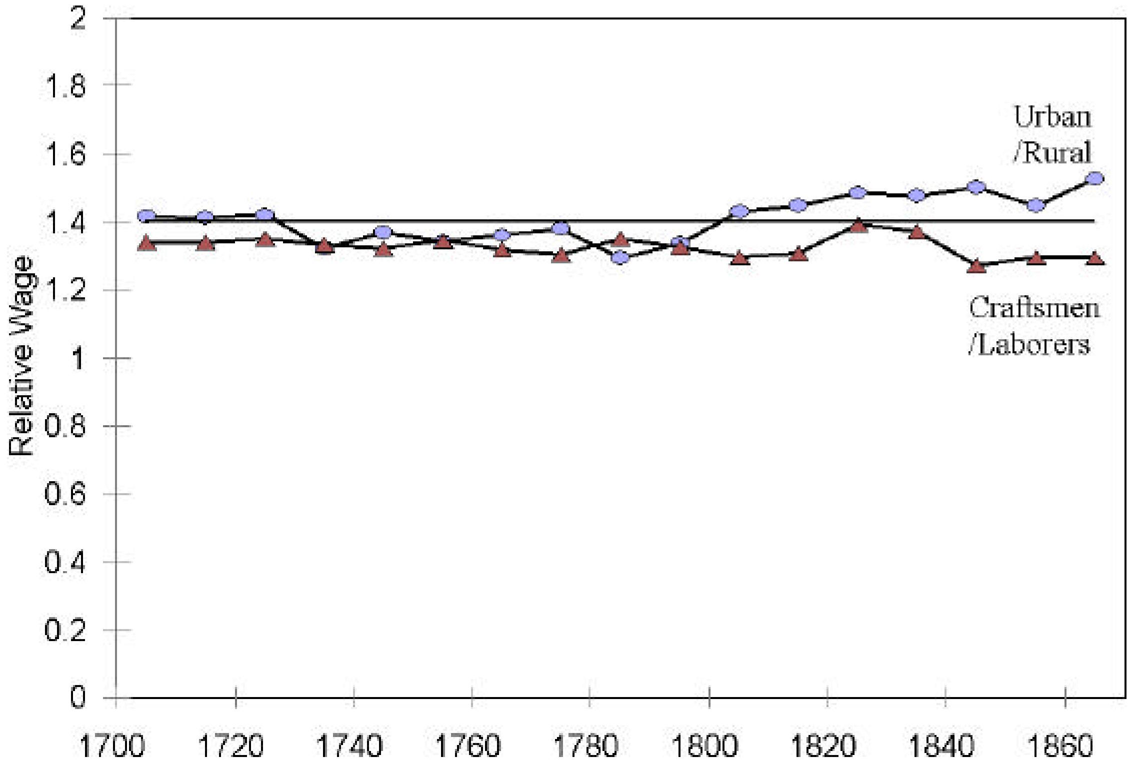
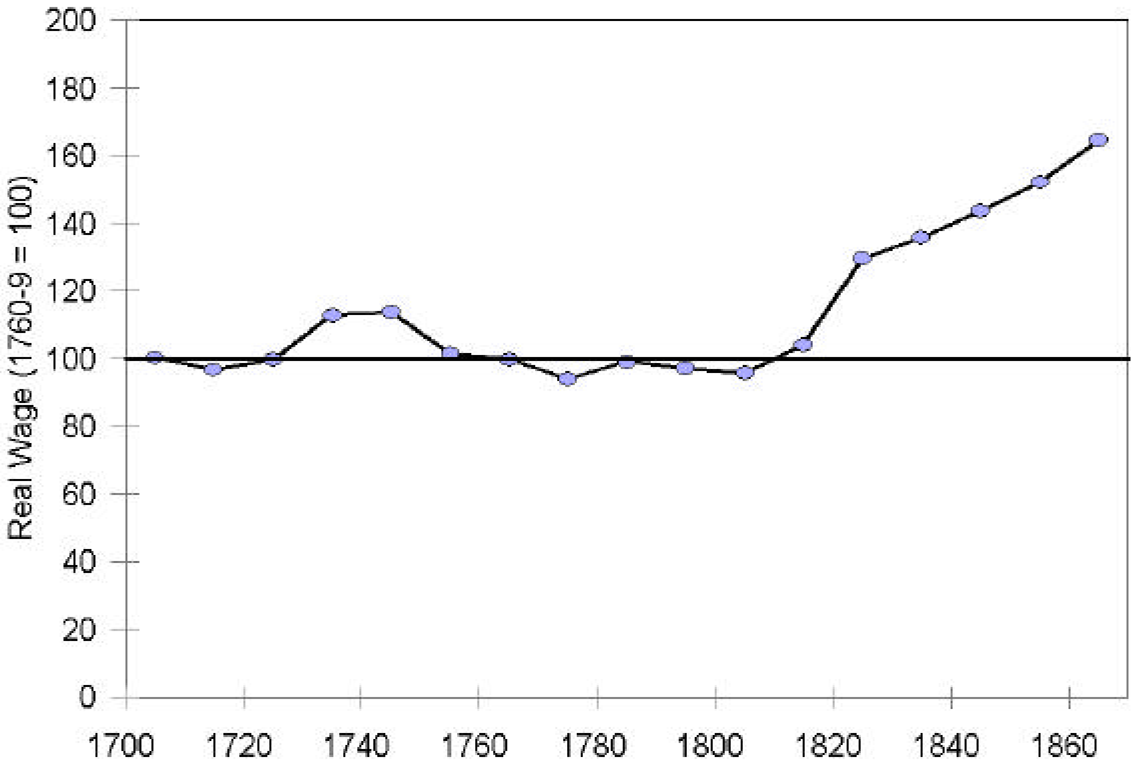


Figure 9: Real Wages in the Industrial Revolution (1760-9 = 100)



(b) Property Income

I estimate of property income as the sum of the rental value of housing, public houses and shops, the rental value of farmland, and other forms of property income such as mineral rents, payments on turnpike mortgages, and canal and rail payments to capital owners. Table 8 shows estimates of population, and of implied farmland and building rental values from 1640 to 1869. The estimates for the years after 1841 are from the property tax returns and for "houses" include commercial property. The earlier data is inferred from the movement of rents on housing as derived above and on charity owned farmland. They are adjusted to be at the same level as the Property Tax data after 1840. The total rental value of "housing" is inferred as the rental value per dwelling, multiplied by the estimated stock of non-farm houses.[6] Circa 1700 land rental values are almost four times house rental value. By 1860 land rental values are only about 75 percent of house rental values.[7] As land declined as a source of property income, other real assets became much more important, and show up in the accounts of charities. These included mineral rents, turnpike mortgages, canal bonds and shares, and railway bonds and shares. For the years after 1842 we get tax data on the extent of these rents. For the years before I can approximate the rental earnings from the transport and mining sectors using various sources

[6] In the early nineteenth century the population censuses suggest a relatively stable average number of occupants per house. From 1801 to 1851 the number varies in a narrow range from 5.17 to 5.44. For the years before 1801 I assumed 5.44 people per house as in 1801. Since farm houses were included in the rental value of land throughout I assumed, based on the number of farmers in the 1851 census, that there were 160,000 farm houses.

[7] The total implied rental of land and houses circa 1700 of £20.1 m. is double the assessment of land and house rents under the land tax in 1698. But the land tax can be shown to have under-assessed charity farmland rents by 40-50. For houses the degree of underassessment is unknown.

Table 9: Property Income 1640-1849 as Implied by Charity Holdings, England and Wales

Period	Population (millions)	Land and Farmhouse rental values (£. m)	Houses, Shops etc. rental values (£. m)	Mines, Canals, Railways etc. (£. m)	Rental Income per Capita (£.)	Real Rental Income per Capita (1860-9 = 100)
1640-79	5.5	15.3	4.4	-	-	-
1680-1719	5.5	15.6	4.5	0.2	3.7	110
1720-59	6.0	17.6	5.0	0.3	3.9	117
1760-99	7.4	23.6	8.6	1.0	4.4	106
1800-09	9.2	39.0	17.5	2.3	6.3	97
1810-19	10.4	49.8	24.6	3.2	7.4	104
1820-29	12.1	43.5	30.2	3.2	6.3	104
1830-39	14.0	41.3	35.2	4.0	5.7	102
1840-49	16.7	42.3	37.0	7.1	5.2	95
1850-59	18.8	41.9	43.4	11.4	5.1	92
1860-69	21.1	46.3	60.2	19.3	5.9	100

Notes: All rental incomes from 1842 on are from the Property Tax returns. Land and house rents are from the Charity Commission reports. "Houses" here include public houses, shops, and other commercial property. The rents of commercial properties are assumed to be the same relative to houses for the years before 1842. Rental incomes from coal mining, canals and turnpikes was approximated for the years before 1842 from the sources listed.

Real property income was calculated using a price index which weights food 45 percent, drink 15 percent, clothing ten percent, fuel and light five percent, housing rents 15 percent and personal service ten percent.

Sources: Stamp, British Incomes, pp. 49-51, 220-1. Population from Wrigley et al, English Population adjusted to England and Wales. Clark, "Farmland Rental Values." Mining rents estimated from Flinn, History, pp. 26, 292-3, 303-4, 324-5, and Church, History, pp. 3, 53-4, 58-9, 530-1. Canal rents are estimated from Ginarlis and Pollard, "Roads" assuming the same rate of return throughout as for the 1840s. Turnpike bond payments are from Albert, Turnpike, pp. 68, 194 and Pawson, Transport, pp. 155-6, 214, 224-6. Prices post 1770 are from Feinstein, "Pessimism" except for the rental cost of housing. Prices before 1770 from Clark, "Farm Wages."

which are poorer the further back I go. But it does not matter much to the estimate of rental income per capita, since these sources of rental income only become important in the nineteenth century. The fifth column of table 9 shows these estimated other rental incomes. Even when we add in these other sources which increase rapidly in the mid nineteenth century with the arrival of the railroads and the growth of coal mining, the overall trend in the Industrial Revolution period is still a slight decline in real rental income per capita, where the deflator used is one with weights for the economy as a whole.

The numbers in table 9 omit other sources of rental income that it is very difficult to derive information on: farmer's capital, and manufacturing and commercial capital for example. But based on Feinstein's estimates of net domestic assets in 1860 the rentals reported in table 9 represent the returns on 82 percent of private domestic assets in 1850, and 78 percent in 1760.[8] Thus the inclusion of the rents on these other assets is unlikely to change the overall conclusion that rental incomes per capita were declining in the Industrial Revolution period because of the decline in real farmland rents per capita.

There has been a long debate about the living standards of wage earners in the Industrial Revolution period. Feinstein has recently argued that the assessment of Peter Lindert and Jeffrey Williamson of substantial real wage gains is too optimistic. He finds more modest gains of about 30 percent in real terms from the 1770s to the 1840s.[9] I similarly find with completely different sources that real farm wages increased by only 33 percent from the 1770s to the 1840s.[10] The casual assumption for the Industrial Revolution period has been that real wage growth would set

[8] Feinstein, "Appendix", pp. 437, 439, 464-5.
[9] Lindert and Williamson, "English Workers'", Feinstein "Pessimism."
[10] Clark, "Farm Wages."

the lower bound for the growth of real GDP per person, since rents and profits were likely to be increasing more rapidly.[11] In fact, however, the information from charity holdings on house and farmland rental values suggests that real property income per capita probably fell in the Industrial Revolution, and that consequently the overall gains in income per capita was likely less than the gains in real wages.

(c) Nominal GDP

In table 10 I set out by decades a very rough calculation of gross domestic income per capita for England and Wales between 1700 and 1869 calculated by the income approach. The second and third columns show rental payments and taxes paid by property occupiers, since such taxes were excluded in the assessed value under the Property Tax. The total amount of poor rate payments for the years before 1812 where official figures are not available was estimated from the records of 24 parishes in Bedford, Cambridge, Dorset, Essex and Warwick. The fourth column shows estimated wages and salaries. The estimate is fixed in the decade 1860-9 using Leone Levi's estimate for 1866 of wage and salary earnings. His wage estimates are close to those of Feinstein's for the same year

The fifth column of table 10 shows customs and excise revenue, and income from the post office. These are indirect taxes that have to be added to wages and rents to estimate national domestic product because of the omission of such things as the return on the working capital of farmers, manufacturers and traders, and entrepreneurial returns. But it does cover a very large share of GDP. Column seven shows GDP calculated by Deane and Cole, assuming GDP per

[11] See, for example, Feinstein, "Wage-Earners," p. 201.

Table 10: National Income, England and Wales, 1700-1869

Period	All Property Rents (£. m)	Taxes on Property Occupiers (£. m)	Wages and Salaries (£. m)	Indirect Taxes (£. m)	"GDP" (£. m)	GDP (Deane and Cole) (£. m)	Real "GDP" Per person (1860-9 = 100)
1700-9	20.0	0.5	41	2.5	64		**69.7**
1710-9	21.4	0.7	42	3.1	67		**68.6**
1720-9	23.0	0.8	45	3.7	72		**71.9**
1730-9	22.4	0.7	46	3.8	73		**77.7**
1740-9	21.2	1.0	49	3.7	75		**74.2**
1750-9	25.6	1.0	50	4.5	82		**75.4**
1760-9	26.3	1.4	56	6.1	89		**75.0**
1770-9	33.5	1.8	63	6.7	105		**75.3**
1780-9	32.3	2.4	74	8.5	117		**75.4**
1790-9	39.5	3.6	101	11.9	156		**75.4**
1800-9	58.1	5.3	150	24.4	237	217	**79.4**
1810-9	77.5	7.9	184	32.2	302	250	**85.0**
1820-9	76.4	7.5	182	32.7	299	259	**92.3**
1830-9	79.7	7.0	210	29.3	326	319	**94.1**
1840-9	86.4	7.0	266	29.3	389	403	**96.6**
1850-9	96.8	7.5	327	32.3	463	485	**97.9**
1860-9	125.8	9.5	414	35.4	585	633	**100.0**

Note: British Income from Deane and Cole was multiplied by the share of the population in England and Wales in each decade.

Sources: Deane and Cole, British, p. 166. Tax receipts are from Mitchell, Abstract, pp. 386-8, 392-3, 410. The other sources are as for Table 7.

capita was the same in Scotland as in England and Wales. For the benchmark decade of the 1860s the GDP I calculate covers 93 percent of the full GDP reported by Deane and Cole.

To convert nominal GDP into real output we need a GDP deflator. This is the most troubling part of our calculation. For the GDP deflator should cover only domestically produced goods, or only the domestic component of production. But while we have prices series for most goods consumed in quantity by working class consumers, we are missing price series for more high income commodities such as house wares, furniture, books, firearms, and clocks. The GDP deflator I construct has a series for domestic agricultural prices, beer, fuel, light, clothing, housing, services, construction. It also has deflators for value added in cotton cloth production, wool cloth production, and iron and steel, since these goods were exported in large quantities, and we have to include them in estimating total output.

Table 11 shows the GDP deflator in comparison to the price index used to calculate real wages. Surprisingly the price index for production as a whole rises more between 1770 and 1860 than the index for working class consumption goods. That is another reason why real incomes are estimated to have risen more than did output per worker in the Industrial Revolution period. The major reason for this is that the price series for domestic farm output increases more than the series of food prices used to estimate real wages. The major imported goods in food consumption - sugar, tea, coffee, and grains – saw less price increase over this period than the meat, milk and butter which more heavily characterized domestic farm output, in part because of a decline in the burden of tariffs in the 1840s and later.

With this estimate of real output we can redo table 4 on contributions to productivity growth of the various sectors.

Table 11: Prices in Industrial Revolution England

Decade	Consumption Price Index	GDP Price Index	English Farm Output (Production index)	English Food Consumption (Consumption index)
1700-09	76.0	82.5	76.0	
1710-19	80.0	86.7	81.7	
1720-29	79.2	85.5	80.7	
1730-39	72.3	80.7	73.7	
1740-49	72.7	82.4	76.8	
1750-59	82.0	85.5	83.2	
1760-69	87.1	90.2	86.7	
1770-79	100.1	100.0	100.0	100.0
1780-89	100.7	101.5	99.5	99.5
1790-99	119.0	118.1	123.3	116.2
1800-09	161.1	157.5	175.9	149.7
1810-19	177.5	171.6	188.8	160.2
1820-29	131.3	142.3	141.0	125.6
1830-39	123.6	130.7	132.5	120.9
1840-49	120.8	125.1	131.4	121.4
1850-59	118.3	127.5	136.5	118.3
1860-69	126.7	140.2	147.9	120.7

Notes:

Table 12: The Sources of Productivity Growth in the Industrial Revolution, 1760-1860

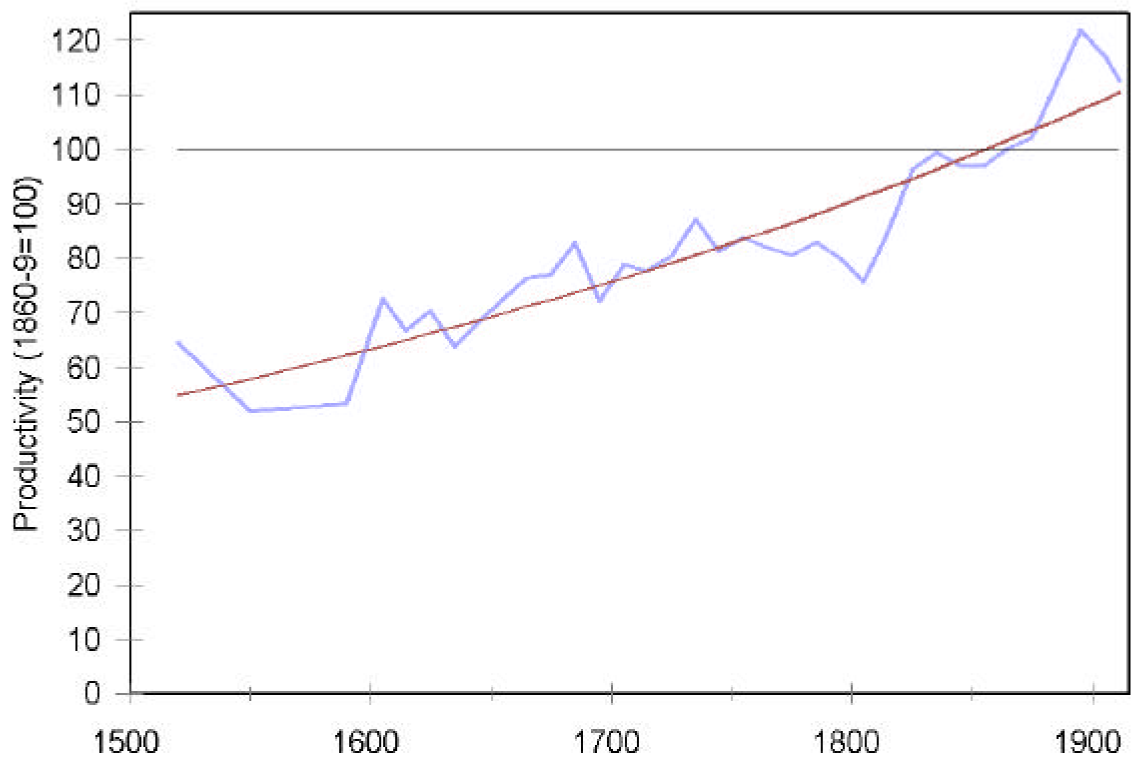
Sector	Productivity Growth Rate, 1760-1860 (%)	Average Share of Value Added /GDP	Contribution to Productivity Growth Rate (%)
Revolutionized Industry		**0.10**	**0.251**
1. Cotton	3.1	0.045	0.181
2. Woolens	1.5	0.031	0.054
3. Iron and Steel	1.0	0.015	0.015
4. Railways (1830-1860)	0.9	0.008	0.001
Traditional Transport	(2.44)	0.045	(0.11)
Agriculture	**0.20**	**0.33**	**0.062**
Rest of the Economy	**0.00**	**0.54**	**-0.06**
All	**0.36**	**1.00**	**0.36**

Source:

The implications are that the Industrial Revolution very slow and narrow. Half of all the productivity gains came from one sector only, cotton textiles. There were further modest gains from agriculture, though these were little greater than for the previous 260 years. Figure 10 shows the rate of productivity growth in agriculture from 1500 to 1912.

Further the national productivity gains from cotton textiles owed a lot to the ability of the industry to export the majority of output by the 1850s. In 1760 British imports and exports were both a small share of GDP. Had Britain not been able to make the switch towards importing much of its food and raw material consumption, and paying for this by exports of manufactured goods in the course of the early nineteenth century, then the gains from technological advance in textiles would have been much less.

Figure 10: Estimate Total Factor Productivity in English Agriculture, 1500-1912



Productivity Growth through Technological Advance before 1760

The effects of technological advance depend crucially on the size of the sector affected and the price elasticity of demand. The nature of technological advance is generally that some new idea leads to a long period of productivity advance in an industry as the consequences of the new technique are played out. If demand is price inelastic then reductions in prices created by the early phase of a technological advance will limit or even reduce the share of expenditure on the good, so reducing the general productivity gains from further advances. Advances in cotton textiles in the Industrial Revolution had big impacts because textiles were a substantial share of expenditure by the 1760s and demand was price elastic. The share of income spent on clothing if anything increased with the price declines of the Industrial Revolution. Even fairly broad categories of goods vary dramatically in their price elasticities. Thus for the modern USA we get:

Metals	1.52
Furniture	1.26
Motor Vehicles	1.14
Oil	0.91
Clothing	0.64
Housing	0.55
Food	0.12

Only a technological revolution in sectors above the line would have substantial long run impacts of the productivity growth rate of the economy. Suppose that prior to the Industrial Revolution innovations were occurring randomly across various sectors of the economy - innovations such as guns, spectacles, books, clocks, painting, and building techniques – but that just by chance all these innovations occurred in areas of small expenditure and/or low price elasticity.

Consider the years 1200-1600 for example. Real wages had not advanced in England between these years, and the population was similar, implying little or no technological advance. But if we were to take pictures of England in 1200 and 1600 and show them to someone who knew nothing of the periods they would quickly notice that 1600 was much more technologically advanced than 1200 in a number of respects. To see this just consider figures 11 and 12. The second figure is a formal portrait rather than a book illustration, but the advance in the ability to realistically portray people is very clear.

Similarly consider the introduction of the printed book by Gutenberg in 1445, again in the period where we can find no evidence of aggregate productivity growth, at least in England. Around 1450 it took 45 scribes 22 months each to prepare for Cosimo de Medici copies of a collection of 200 works, which implies 124 days per volume, assuming a 300 day year. Assuming 250 pages per volume, this would imply a scribe could copy only two pages per day.[12] From the sixteenth to the eighteenth century a printing press required a team of six operatives (two compositors, two pressmen, one apprentice and a proof corrector), but the press would produce between 2,500 and 4,000 sheets per day circa 1600. Thus printing workers could

[12] George Haven Putnam, ----, p. 248.

Figure 11: A Young Man Knighted, from Historia Major (Chronica Majora), 1233

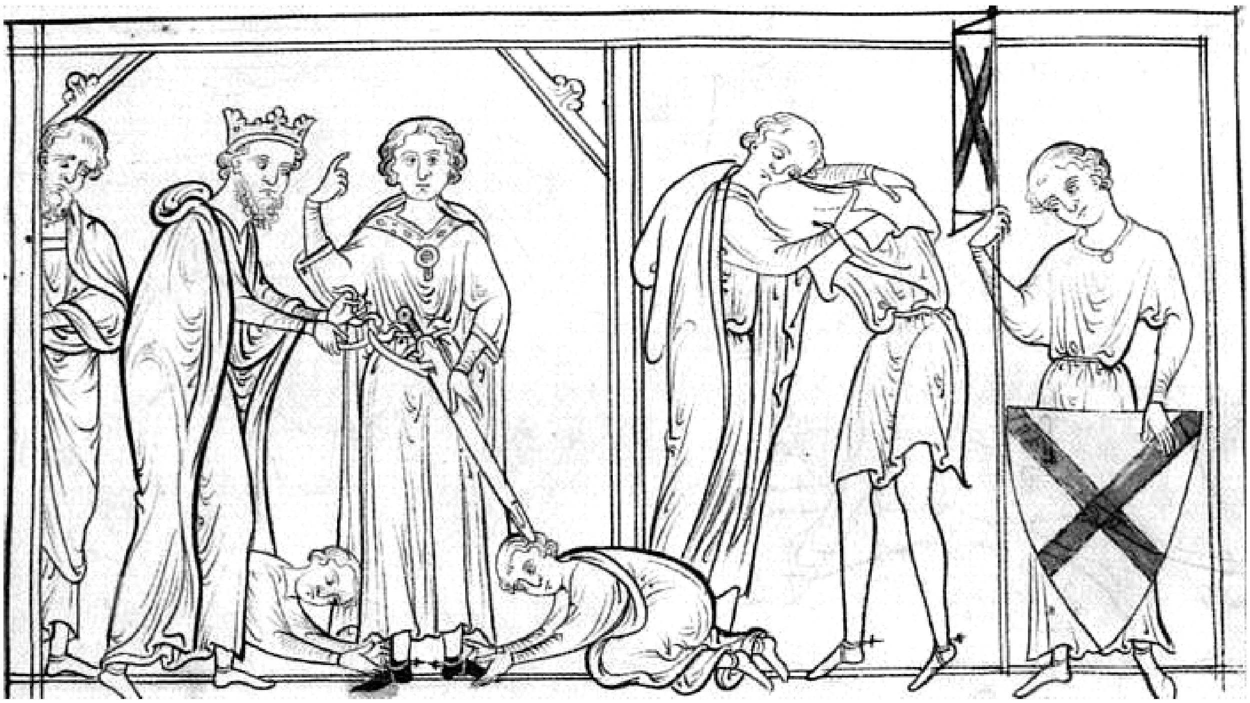


Figure 12: Portrait of Sir Thomas Kytson, 1573

produce between 800 and 1400 pages each per day.[13] Thus for any book which could sell a standard early print run of 1,000 copies the new printing technology represented a potential decline in costs (neglecting paper and capital costs) to 0.15-0.25%. The existence of these other costs means the reduction would be much less than this, but the productivity advances from printing would still within the first few years of its introduction have been as great for book reproduction as the gains in cotton textiles in the Industrial Revolution. A sign of the magnitude of these gains is the estimate that by 1500 there had been printed 12-20 million book copies on Gutenberg presses. This is estimated to equal the total of all manuscript book copies produced in the previous 900 years. Since printing only got started on a large scale around 1470 this implies an output that was 30 times the previous one as a result of these advances. That in turn implies that with any reasonable price elasticity there had to have been very large price reductions through the printing of books.

If the 900 years from 570 to 1470 saw the copying of only 12-20 million manuscripts, then average production would be only about 18,000 manuscript volumes per year. Allowing for some growth in the later period let us assume that by 1450 30,000 copies of manuscripts were being made per year. Assuming the figures for Cosimo de Medici's scribes are typical this would require 12,000 full time copyists. Since the population of Europe would then be no more than 60 million in total, and assuming copyists earned twice the average wage, then manuscript books would represent no more than .04% of expenditure in Europe in 1450. After 1470 500,000 books were being printed per year. But a 300 page book would require only 0.5 man-days of printing labor. Thus these books would occupy only 800 printers. Thus the introduction of printing seemingly reduced the share of expenditure on books below even the .04% of 1450

[13] Assuming each sheet corresponded to two pages.

devoted to manuscripts. No matter how dramatic the technological achievement of printing, the innovation could leave no imprint on the aggregate productivity statistics. By the sixteenth century the production of books had increased 10 fold over the numbers for 1470-1500. But that would still imply a printing cost for all books that was less than 0.03% of GDP for Europe.[14] Dramatic technological change had occurred a number of times before the Industrial Revolution, but change with limited economic consequences.

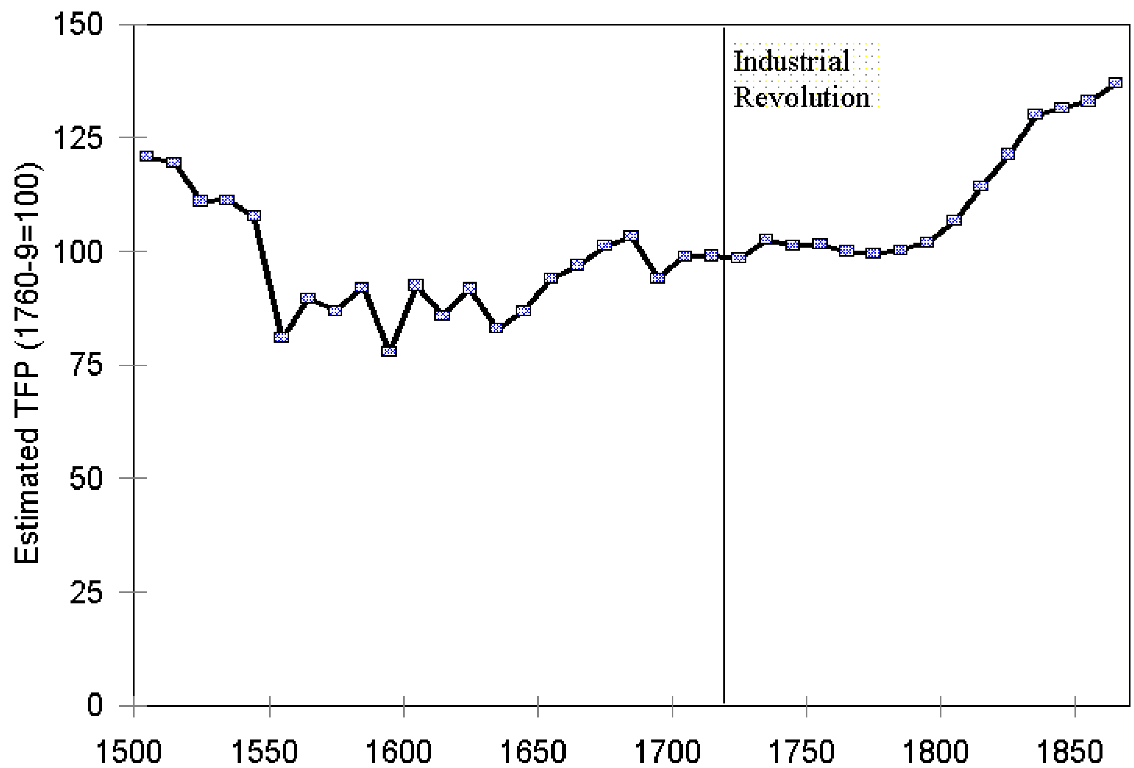
Not Out of the Woods Yet – How do we explain events before 1600?

I calculated aggregate productivity growth above from wages, rents and returns on capital and prices for the years 1760-1869 assuming a Cobb-Douglas production function at the national level, and reweighting by decades since the shares do change. The result was modest gains in estimated productivity. Yet if we carry this calculation back in time to 1500 using data on wages, rents, returns on capital and prices, even reweighting decade by decade the shares of land and labor, we find that productivity is estimated to have declined in the years 1500-1600. Figure 13 shows this result. Estimated productivity declines by about a quarter between 1500 and 1560. Since there is no reason to believe there was any such productivity decline in these years, this suggests that the Cobb Douglas assumption, even with decadal reweightings, is not correctly representing the production structure in the economy.

An alternative is to take English experience in the years 1200 to 1600, when there was no apparent productivity grains, and use that to estimate the underlying production structure of the economy. Let us assume a CES production function with land, labor and capital. Thus

[14] Febvre and Martin (1976), p. 262.

Figure 13: Calculated Productivity, 1500-1869



$$Q ? E(aK^{?} ? bL^{?} ? cT^{?})^{1/?}$$

where Q is output, E the level of efficiency, K is capital, L labor and T land. The greater is E the greater the output per unit of input.

$$? ? \frac{1}{1 ? ?}$$

is the elasticity of substitution.

Let us index efficiency, capital, labor and land quantities in 1600-39 as each being 1, and wages, rents, and the return on capital as again being 1. In that case a, b, and c will be just the shares of capital, labor and land in output circa 1600: these I estimate for England as 0.13, 0.56, and 0.31. With this specification the effect of population on wages and land rents in the years 1200-1600, assuming a fixed level of efficiency E, and a constant real rate of return on capital, depends only on a, b, c and ?. Thus for any other decade,

$$K_1 ? \left(\frac{bL_1^{?} ? c}{1 ? a} \right)^{1/?}$$

$$s_1 ? K_1^{1??}$$

$$w_1 ? \left(\frac{K_1}{L_1} \right)^{1??}$$

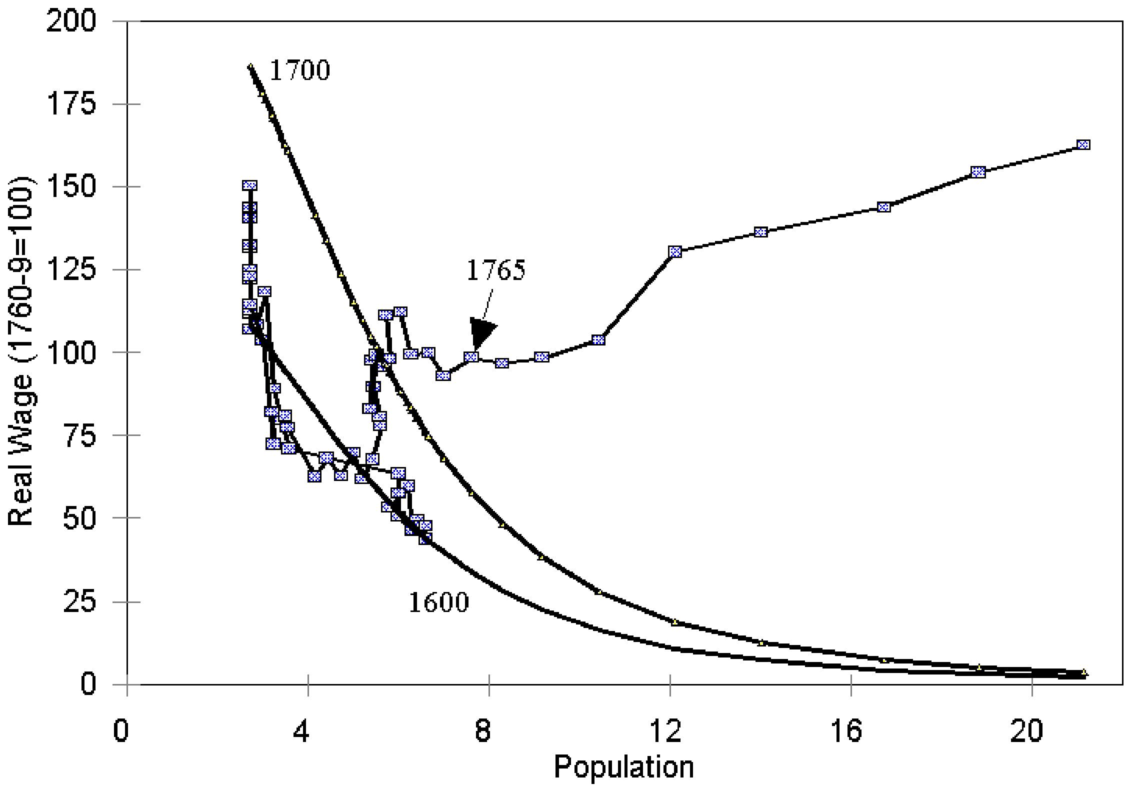
where the subscript "1" indicates the level of each variable in each of the other decades. We can then choose the value of ? that produces the best fit of the observed real wage data from 1200 to

1600 with the predicted wage. Figure 14 shows the population and real wage data by decade, as well as the wage predicted by the best fitting production function from the years 1200-1600, labeled "1600." This curve predicts that as population grew in the years after 1600 wages should have fallen. The best fitting production function has an elasticity of substitution between factors of only 0.3. But if this is the underlying production function then the increase in wages between 1600 and 1700 at a time of increasing population implies significant productivity gains. The wage/population curve through 1700 has an implied productivity level 62% greater than that for 1600.

Similarly the eighteenth century also saw significant productivity advance if the production function for the economy remained that for 1200-1600. Productivity advanced a further 91%. And the gains after 1800 were greater still. In terms of the traditional trade off between population and real wages from the years before 1600, the Industrial Revolution was a period of spectacular advance. The population growth of the eighteenth century would previously have led to a substantial decline in wages that would have ended the growth through higher mortality rates. This interpretation finds significant productivity growth again in the Industrial Revolution. But it locates the beginning of that growth even more firmly in the seventeenth century. It also implies that rapid productivity growth began in the Netherlands in the sixteenth century.

This interpretation treats England as a closed economy throughout, however. Suppose we instead assume that relatively free trade existed throughout the years 1200-1869. The internal grain market in England, for example, seems to have been integrated by the thirteenth

Figure 14: Population, Wages and Predicted Wages



century in England, and England is very close in terms of transport costs to France and the Netherlands even from the earliest years. In that case wages in England will be determined not by the land/labor ratio in England, but by the land/labor ratio in Europe as a whole. The English land/labor ratio will predict real wages only in so far as it moves in sympathy with the European land/labor ratio. But the Industrial Revolution years were notable for the much faster population growth of England compared to the rest of Europe, and in particular compared to the Netherlands and France. Figure 15, for example, shows the movement of population per acre in England and the Netherlands between 1500 and 1819. In the years 1500 to 1750 there is a remarkable concordance in the population movements. But after 1750 English population growth is much faster. Figure 16 shows relative to 1770 how English population moved relative to a wide group of other European countries. While for most of Europe population grew by only 79% between 1770-9 and 1860-9, the growth in England was of 187%. Thus the land constraint did not operating as tightly as would be expected in the Industrial Revolution period. Secondly advances in the productivity of agriculture in Eastern Europe, or the transport system that brought grain and timber from the East and South to Western Europe could all nullify the traditional relationship between land per person in England and real wages.

We can do an accounting of how much the land area of England was "expanded" by trade with other economies by 1855, by estimating imports of raw materials for domestic consumption compared to domestic farm output. Table 13 does this calculation. The combination of imports and the domestic coal industry effectively doubled the land area of Britain by 1850. This still implies that the effective ratio of land to labor did decline from 1600 to 1869, but by much less dramatic amounts than the crude population figures would suggest. But there is still a significant decline in the effective amount of land per worker. And shouldn't the expansion of the land

Figure 15: Population per Acre, 1500-1819

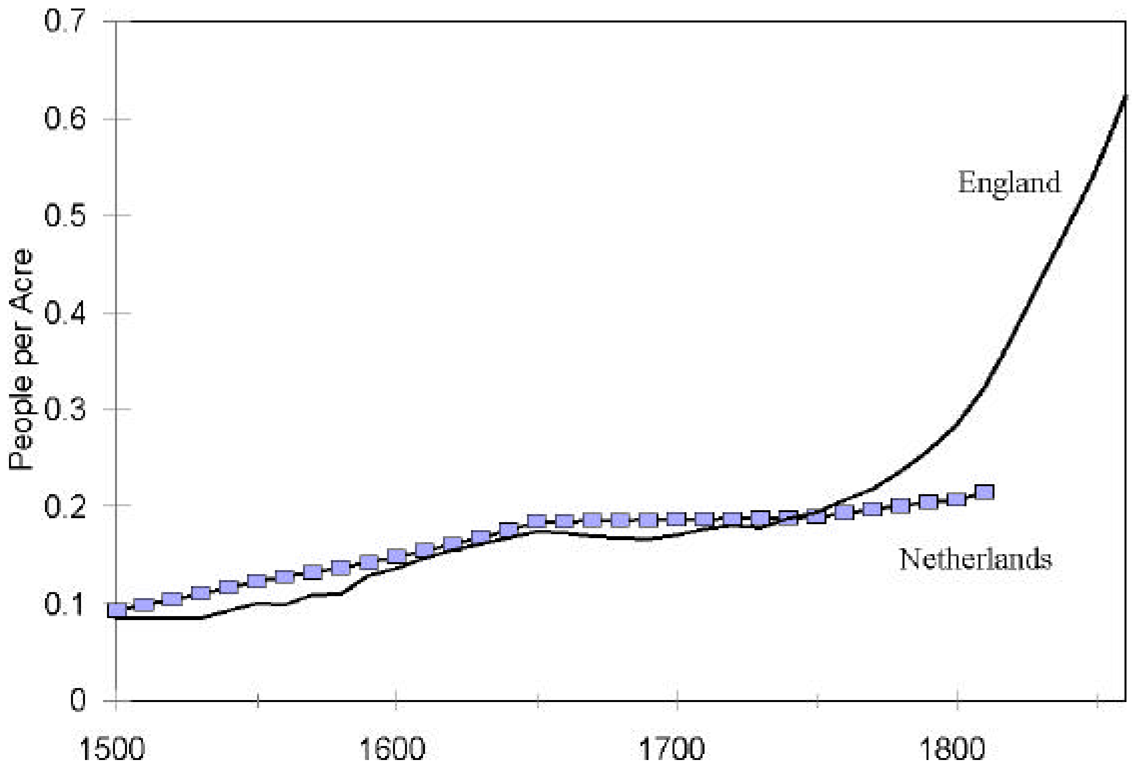
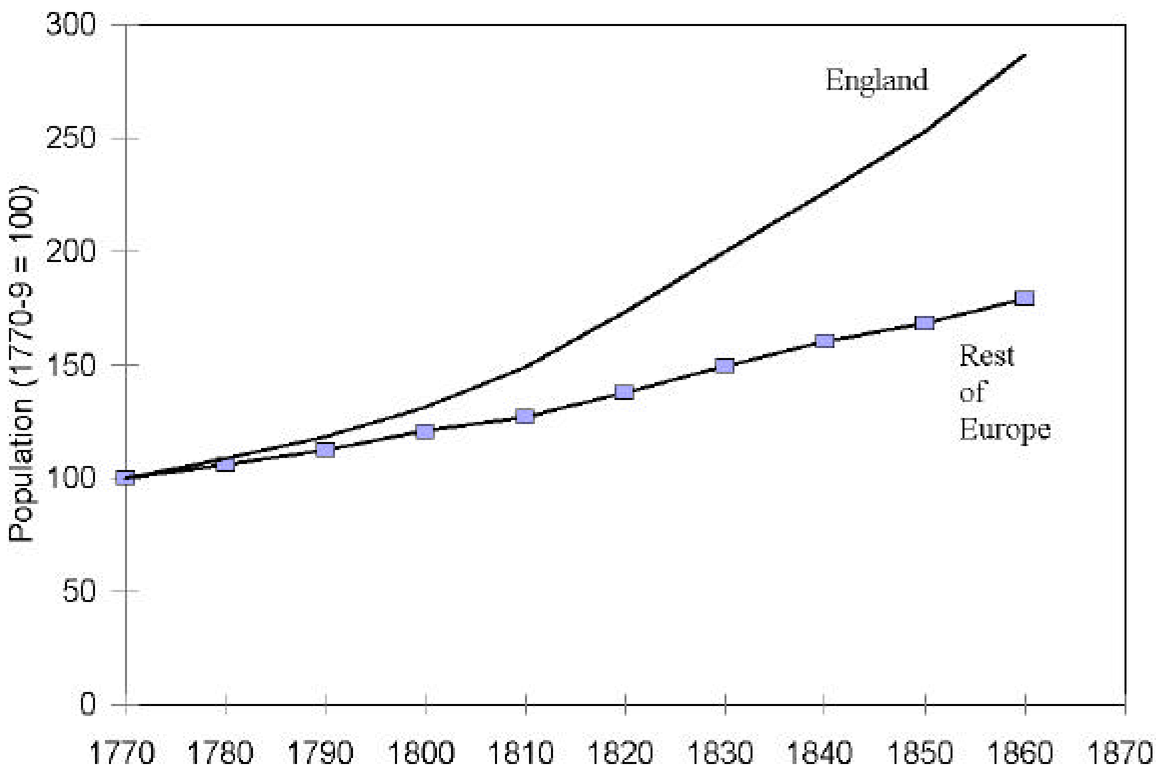


Figure 16: Population in England and Western Europe Relative to 1770-9



Note: The Rest of Europe after 1850 comprises Austria-Hungary, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, with a total population of 182 m. in the 1860s compared to 20 m. in England. The population of the equivalent area in the 1770s is estimated as 102 m. for Europe, and 7 m. for England.

Table 13: Production and Imports of Food, Raw Materials and Energy, 1700-1850

Period	Area	Domestic Farm Output (£ m.)	Net Imports Farm Produce (£ m.)	Domestic Coal Production (£ m.)	Effective Land Area (domestic 100)
1700	England	73.8	2.5	1.0	105
1850	Britain	138.7	53.8	92.0	205

Notes: Cotton, wool 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 (1968).

Sources: Coal production: Flynn (1984, p. 26) and Church (1986, pp. 19, 53, 85-97). Imports 1854-6: Davis (1979, Appendix tables 50, 57). Imports 1700-4: Schumpeter (1960, tables XV, XVII). Exports 1700-4: Schumpeter (1960, tables VII, IX, X, XII, XIII), Mitchell (1988), pp. 221-2).

constraint by domestic coal production get some credit as a productivity advance in the Industrial Revolution era?

Conclusion

This paper shows that the expansion of output per worker in the Industrial Revolution years was much less than previously though, and that there was significant growth of output per worker in the years 1600-1700, long before the supposed Industrial Revolution. That is the relatively easy part. But the interpretation of these new output figures is still uncertain, as thus is the meaning of the Industrial Revolution. Over the years 1500 to 1869 the share of farmland rents in national income varied substantially. By 1860-9 it was only 7%, but it was as high as 34% in 1600-9. If we approximate national productivity growth by using a Cobb-Douglas production function, but changing the factor shares in national income decade by decade, then the conclusion is that there was little productivity growth in the Industrial Revolution era beyond that explained by the technological revolution in textiles. Further the accident that textiles were exported on a large scale by 1800, explained by the need to import large quantities of food and raw materials given English population growth after 1760, accounts for a substantial fraction of the gains in productivity. The Industrial Revolution becomes very narrow. It can then be interpreted as just another isolated technological advance as European economies had been witnessing since at least the fifteenth century.

But the Cobb-Douglas approximation does not work well for the years before 1600. It implies, for example, that national productivity fell by a quarter in the sixteenth century. And it will not explain why wages rose so much as a result of the population losses of the Black Death in 1349. The data from before 1600 suggest that land and labor had much less than a unitary elasticity of substitution. But this production function specification extrapolated forward from 1600 implies dramatic productivity advance.

There are two possible ways of reconciling these findings. The first is that trade flows may have been so free from even the Middle Ages that the land input in England was always dictated by the European land/labor ratio. Low productivity growth after 1760 was compatible with the maintenance of high real wages despite very large population gains because the European land/labor ratio changed by much less. But it is still the case that the land/labor ratio nearly halved in Europe as a whole from 1770 to 1870. The second possibility is that there was a revolutionary change in the English economy in the years after 1760, but that it was in the exploitation of the possibilities of trade as opposed to technological advance. The exploitation of these possibilities would have allowed England to maintain output per worker in the years 1760 to 1869 even with no technological advance, by importing food and raw materials and exporting labor.

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