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Chapter 5: Too Much Revolution - Recent Views of the Industrial Revolution

Introduction

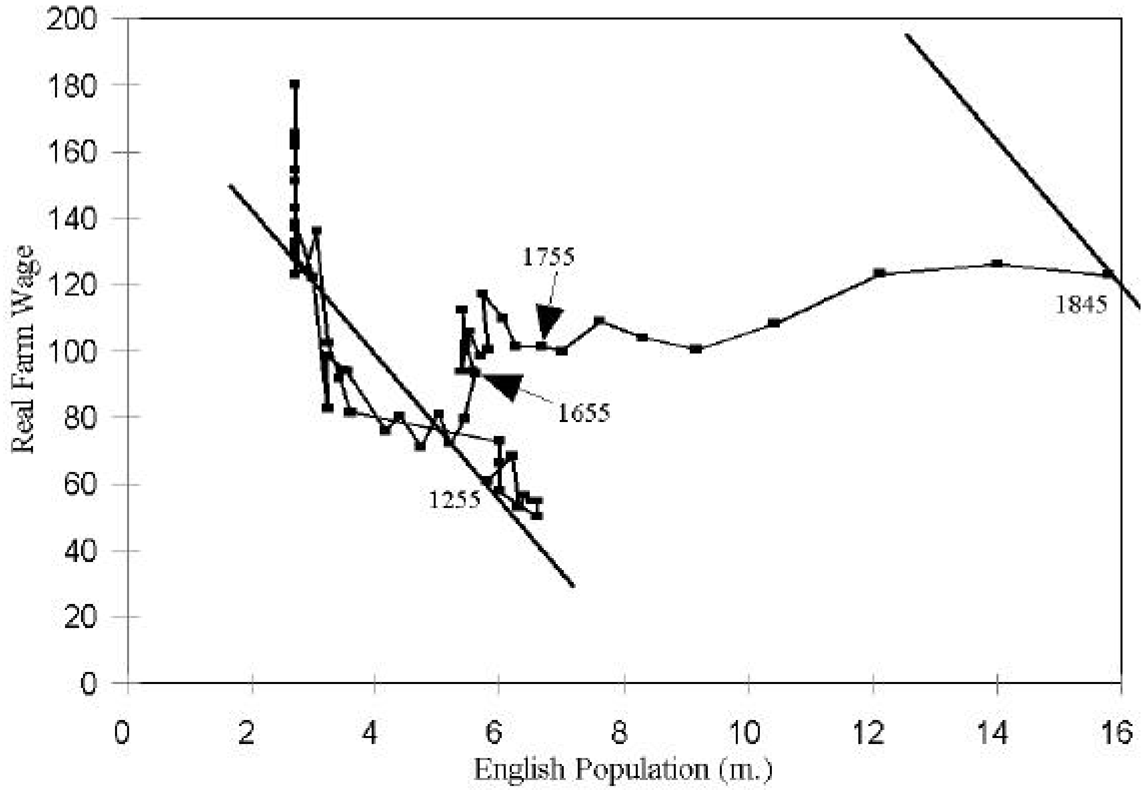
Figure 1, which shows English population in millions by decade from 1250 to 1850, and the real wages of farm laborers clearly suggests that something dramatic happened in the English economy between 1750 and 1850. Before 1650 population and wages had seemingly been inversely linked along the same curve for at least 400 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. From 1650 to 1750 there are signs of movement away from this medieval equilibrium. By 1740 real wages were nearly doubles their level in the early fourteenth century even though population in 1740 was just as high as in 1300. But from 1750 to 1850 the break from the medieval equilibrium becomes much more dramatic. Real wages did not rise much in the Industrial Revolution, but the ability to sustain wages in the face of massive population growth was unprecedented.

In the past thirty years there has been a steady stream of work on the Industrial Revolution by economic historians trained in more formal quantitative methods. This work has sought to measure the growth of output and of productivity, and analyze by sector what explains this. Despite the dramatic changes we see in Figure 1, this work has resulted in a continual reduction in the estimates of how dramatic a change the Industrial Revolution really was. Below I give the latest round of estimates by such experts as Nick Crafts and Knick Harley and show what they imply about productivity growth in Britain from 1760 to 1860. Though their estimates tend to be pessimistic they still argue for a 6.5 fold increase in output between 1700 and 1860, and a near doubling of output per worker.

But below I show that the current round of revisions are not pessimistic enough yet. Specifically they assume a lot of economic growth in the Industrial Revolution era came from agricultural productivity advance. Yet the estimates of agricultural productivity growth in the Industrial Revolution period can be easily shown to be wildly over optimistic. Agriculture experienced very slow productivity growth in this period, slower than the rest of the economy.

Correcting the estimates of the growth of output from agriculture leads to much slower growth rates of output per person in England from 1700 to 1860. At first it might seem mysterious that removing the agricultural revolution threatens the Industrial Revolution. Agriculture is, after all, reckoned as only 18% of GNP by 1861. But it turns out that given the way output growth is calculated in the Industrial Revolution period, removing the agricultural revolution from the scene cuts the growth of income per capita from 1760 to 1860 from the already pessimistic 65% estimated by Crafts and Harley to a mere 31%. For a slower growing agriculture gets much more weight in national income in 1760 or 1700. Correspondingly the fast growing industrial sector gets

Figure 1: Population and Real Wages, 1250-1850



much less weight. The Industrial Revolution looks more and more like an isolated phenomena of the textile industries, as opposed to an economy wide transformation.

The total output of the British economy is still estimated to have increased by more than five fold between 1700 and 1860. But the growth is now overwhelmingly for demographic reasons – there simply were many more people in the economy by 1860. The transformation of Britain from an agrarian to an industrial economy between 1700 and 1860 owed much to the fact that agriculture untransformed could not employ any more of an expanding work force – the extra labor had to move into industry. The failure of agriculture to expand output much meant that there had to be huge imports of food and raw materials, and to pay for these corresponding exports of industrial products. Indeed had no technical revolution happened in textiles the British economy in 1860 while poorer would not have looked dramatically different. It would still have been urban, industrial and export based. Britain was transformed by the accident of earlier and more extensive sex, not by technology, in the years before 1860.

The implied weak growth of income per capita in the years 1700 to 1860 does, however, promote the cause of English exceptionalism in 1700. In 1860 English agriculture is much more efficient than agriculture in most European economies. The new output and productivity estimates below suggest that even in 1700 there was no labor surplus in English agriculture, and very little productivity gap between agriculture and industry. English exceptionalism dates to much earlier than the Industrial Revolution era. The triumph of scrawny little Britain against a big and meaty France for dominance in Europe in the eighteenth century may have been aided by a much greater output per capita in England than in France even in 1692.

Modern Pessimism on the Industrial Revolution

Table 1 shows the latest estimates of the growth of output and of output per worker in Britain in the industrial revolution period, from Nick Crafts and Knick Harley, with the indexes set to 100 in 1700. As can be seen from 1700 to 1861 industrial output is estimated to have increased nearly fifteen fold. Overall GNP only expanded by about half this amount, but still rose nearly eight fold. GNP rose by much less than industrial output because other sectors of the economy such as agriculture were not estimated to be expanding so quickly. Allowing for the great increase in population this still implies a rough doubling of GNP per person.

It is interesting that on the Crafts-Harley story there is a very big difference in output per capita between agriculture and industry in 1700, which largely disappears by 1860. Thus looking at the share of GNP generated by agriculture in the table compared to the share of employment we see that in 1700 output per worker in agriculture was less than half that of output per worker in the rest of the economy. This despite the fact that in 1700 most employment outside agriculture was in traditional trades and activities, and that wages were reputedly only one third of the value of output in agriculture (which would be smaller than their share in the value of output in the rest of the economy). Hence the Crafts-Harley view implies a large misallocation of labor in the pre-industrial economy in England.

Table 1: Estimated Output Levels, 1700-1860

Period	1700	1760	1861
GNP	100	151	750
Industrial Output	100	147	1,423
Agricultural Output	100	143	385
GNP/N	100	120	198
Agriculture's share in GNP (%)	37	37	18
Agriculture's share in Employment (%)	56	48	19
Relative output/worker (Agric/non-agric)	.46	.64	.93

Notes:
Sources: Crafts (1985); Crafts and Harley (1992), Industry, GNP post 1760; Wrigley and Schofield (1997), population.

Table 2: Growth in the Industrial Revolution

Period	Output Q	Capital K	Labor L	Land T
1760-1801	1.0%	1.0%	0.8%	0.0%
1801-1831	1.9	1.7	1.4	0.0
1831-1861	2.5	2.0	1.4	0.0

Table 3: Productivity Growth in the Industrial Revolution

Period	Output per Capita Q/L	Capital per Capita K/L	Land per Capita T/L	Productivity A
1760-1801	0.2%	0.2%	-0.8%	0.25%
1801-1831	0.5	0.3	-1.4	0.60
1831-1861	0.9	0.6	-1.4	0.90
1760-1861	0.5	0.35	-1.2	0.55

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%). Remember that $g_A = g_Q - \alpha . g_K - \beta . g_L - \gamma . g_T$. Do the calculation yourself to check you understand the method!

Table 4: Growth in the Industrial Revolution Compared

Country	Q/L	K/L	T/L	A (efficiency)
Britain, 1760-1861	0.50	0.35	-1.20	0.55
Britain, 1950-1980	2.05	3.07	-0.33	1.30
Germany, 1950-1980	4.35	5.24	-0.66	3.07
Japan, 1950-1980	6.67	6.90	-1.10	5.00

Note: [a]Capital growth rate not known, set equal to output growth. The shares of capital, labor, and resources in income are assumed to be 0.25, 0.70, and 0.05 in 1950-80.

Though these changes may seem dramatic they imply very slow growth compared to the achievements of modern economies. Table 2 shows the estimated growth rates of output, labor and capital for the years from 1760 to 1861. Table 3 shows what this implies about productivity growth.

Table 4 shows the performance of the British economy in this period compared to the post World War II interlude for Britain and Germany and for Japan. As can be seen British growth in the Industrial Revolution period is extremely anemic by modern standards. Everything happened extremely slowly. The rate of growth of output per person was very slow, the rate of increase of the capital stock per person was very slow, productivity growth was slow. Thus while output per person grew by 70% in Britain in the 100 years between 1760 and 1861, output per person in Japan grew 640% in the thirty years from 1950 to 1980. The only thing that was reasonably fast by modern standards was the standards was the growth of population. Further the period of the great innovations, 1769-1800 experienced the slowest productivity growth and rates of growth of income per person. Growth did have a modern character, however. It was based largely on efficiency growth with capital playing a much smaller part.

While growth was slow the cumulative effect was significant. Despite the fact that British population more than doubled in the Industrial Revolution period, output per person rose by 70%. Indeed when we look at the total output growth over this period we find that the size of the British economy increased by 400% in the Industrial Revolution, an unprecedented achievement historically.

Capital Accumulation

In modern economic growth typically about one third of the growth of output per person is directly explained by capital accumulation (though at a deaper level this capital accumulation may be driven by technological advance as we saw in Chapter 3). Yet in the Industrial Revolution period of the output growth rate of 0.50% per year, only 0.09% comes from more capital per person. Indeed capital per person increases much more slowly than output per person which is unusual for modern economies.

Why was there so little growth of capital per person in this period? Overall the capital stock per person rose by only 34% from 1760 to 1860. With all the investment in cotton mills and mines, with the building of over 5,000 miles of railway, 18,000 miles of turnpike roads, and over 2,000 miles of canals, why was the capital stock not significantly increased? The answer in part comes if we look at the composition of the British capital stock in 1860, as is shown in table 5.

Buildings alone are over half of the capital stock. The new investments of the Industrial Revolution era, railways, mines, industrial machinery, are still in 1860 only 20% or so of the capital stock. The railroads, while they had large fixed capital costs, may have saved capital invested in inventory in that they made the distribution of goods in the economy faster and more reliable. If we look at the investments in textile mills alone in 1860 we find that the total value of the buildings and the machinery for cotton mills was only £46 million, less than 2% of the national capital stock. Most of the capital was housing and infrastructure that would be determined largely by the size of the population and the real income per person.

Table 5: The British Capital Stock in 1860

Type of Capital	Amount in 1860 (£ million)
Agriculture: buildings, land improvements, etc.	£400
Dwellings	£600
Buildings, Public Works	£650
Railways	£270
Mines, gasworks, waterworks	£110
Industrial Machinery	£170
Other Machinery (ships, etc.)	£ 80
Inventories	£210
Total	£2,760

But this still leaves a puzzle as to why as people got richer they did not by proportionately more housing. We shall discuss below to what extent government policy, and in particular the use of government debt on a large scale to finance the many wars of the years 1692-1815 might explain the very slow accumulation of capital over this period.

But overall right from the start of the Industrial Revolution the message is the same one as for modern economies – efficiency growth is the key. If we want to understand what triggered the Industrial Revolution, and why it occurred when and where it did we need to understand why efficiency grew in the economy.

The Contribution of Each Sector to Productivity Growth

It is possible to analyze how much each sector of the economy contributed to the overall productivity growth. For it turns out that overall productivity growth can be decomposed into the productivity growth of each sector of the economy using the following formula.

$$g_A = \sum_i q_i g_{Ai}$$

Where g_A is the overall productivity growth rate, θ_i is the share of each industry in GNP, and g_{Ai} is the productivity growth rate of each industry.

The rate of productivity growth in an industry or an economy can be calculated either from the rate of growth of output minus the weighted rate of growth of the inputs. Or it can be calculated as the weighted sum of the rates of growth of input prices minus the rate of growth of the output prices. Suppose, for example, the cost of capital, wages, and land rents in an industry all are growing at 5%, but the price of output is growing at 2%. What is the rate of productivity growth? It is 3% per year.

For the Industrial Revolution period it is possible to apply the price and costs technique to looking at productivity growth in individual industries, and then figure out how much each industry contributed to the overall productivity growth rate. This gives the numbers shown in Table 6. As can be seen the gains in spinning and weaving were the most important contributors to productivity growth, generating about 40% of all the gains. Their overall contribution is small relative to the very fast productivity growth rates calculated for cotton spinning above because the average weight of cotton textiles in the economy started as very small. The industry essentially did not exist in 1760, and even by 1861 was only about 11% of employment. The events in the textile industry really are central to the Industrial Revolution.

Table 6: The Sources of Productivity Growth in the Industrial Revolution, 1760-1860

Sector	Productivity Growth Rate	Share of Labor Force in 1861	Contribution to Productivity Growth
Revolutionized Industry			
1. Spinning, Weaving	2.5	11.0	0.22%
2. Iron and Steel, Steam Engines, Railways	2.7	1.5	0.04%
Traditional Transport (canal, roads, ships)	2.4	4.5	0.11%
Agriculture	0.64	19.0	0.16%
Rest of the Economy	0.0	64	0.02%
All		100	0.55%

The contribution of the development of steam engines, the railway, and the iron and steel industry is surprisingly small. In the case of railways this is because the canal was a good substitute for goods carrying, and the road system was available to carry passengers. If inputs and outputs in agriculture are calculated as described in chapter 3 agriculture turns out to have a very significant role in overall productivity increase. The calculated rate of productivity growth in agriculture is quite small compared to cotton spinning, only 0.64% per year, but since over this period agriculture on average constituted at least 25% of the economy, it has a big weight in determining overall productivity growth. Transport by roads, canal, and ships similarly contributed a large chunk of overall productivity growth. Interestingly the majority of the economy, the remaining 64% of employment, is estimated to have experienced no productivity growth at all from 1760 to 1861. Also the technological advances given great prominence in the traditional account explain less than half of the observed productivity growth. Most of the growth came from the reorganization of the transport system, which mainly depended on organizational rather than technical changes, and from agriculture.

Agriculture

While up until now productivity growth in agriculture has been estimated from estimated outputs and inputs, it is possible to construct good measures of average land rents, wages, returns on farm capital, and agricultural prices for English agriculture in the years 1600 to 1912. Using the records of large numbers of plots of land held by local charities from all over England we can get a good idea of the market rental value of land all the way from 1600 to 1912. These same records also give good estimates of the return on capital for the same years. Agricultural wages are more difficult to estimate, but there exist sufficient surviving estate labor accounts to again form a fairly reliable estimate of average wage levels for adult male workers.

With these measures we can construct three key series: the rent of land in terms of farm output prices, the day wages of farm workers in terms of farm output prices, and the percentage return on farm capital. Figure 2 shows each of these three series where they have been adjusted so that 1860-9 is set to 100 in each case. The return on farm capital is calculated as the return paid by farmland plus 5% for depreciation. As can be seen the return on capital falls through much of this period, real farmland rents rise by about 70% between 1700 and 1860, but farm day wages increase by only about 10%. The productivity growth rate will be

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\begin{aligned}
g_A &= \alpha.g_r + \beta.g_w + \gamma.g_s - g_p \\
&= \alpha.g_r + \beta.g_w + \gamma.g_s - (\alpha+\beta+\gamma)g_p \\
&= \alpha.(g_r - g_p) + \beta.(g_w - g_p) + \gamma.(g_s - g_p) \\
&= \alpha.g_{r/p} + \beta.g_{w/p} + \gamma.g_{s/p}
\end{aligned}
$$

where α, β, and γ are the shares of capital, land and labor in the value of output, and g_r, g_w, g_s, and g_p are the growth rates of the return on capital, wages, land rents, and output prices. Table 7 shows the values of wages etc in English agriculture for the years 1700-9, 1760-9, and 1860-9 which we need to calculate productivity growth.

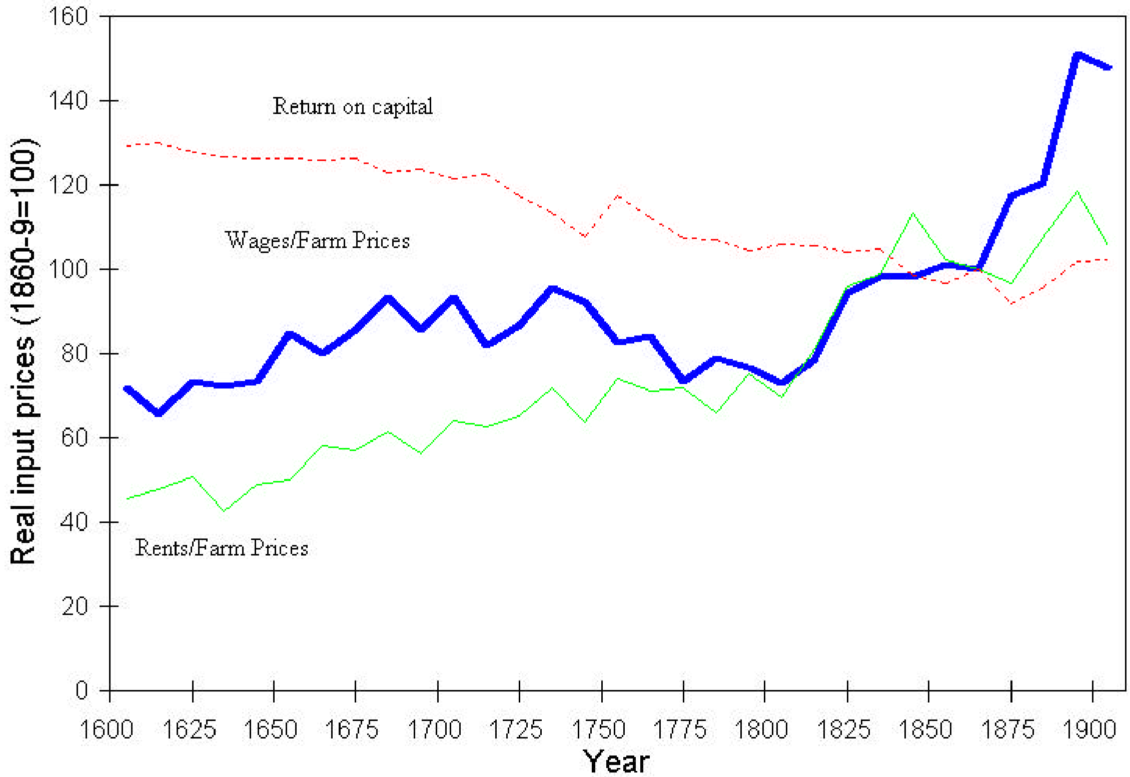
Table 7: Agricultural Productivity Growth

Period	Rents on Capital	Wages	Land Rents	Prices	Productivity
Levels					
1700-9	100	100	100	100	100
1760-9	107	111	132	114	105
1860-9	189	228	307	195	127
Growth Rates (%)					
1700-1760	0.11	0.17	0.46	0.22	0.06
1760-1860	0.57	0.72	0.84	0.54	0.20

Notes: The share of capital in factor payments was assumed to be 0.20, that of wages 0.40 and land rents 0.40 also. Do the calculation to get productivity growth to ensure you understand the method.

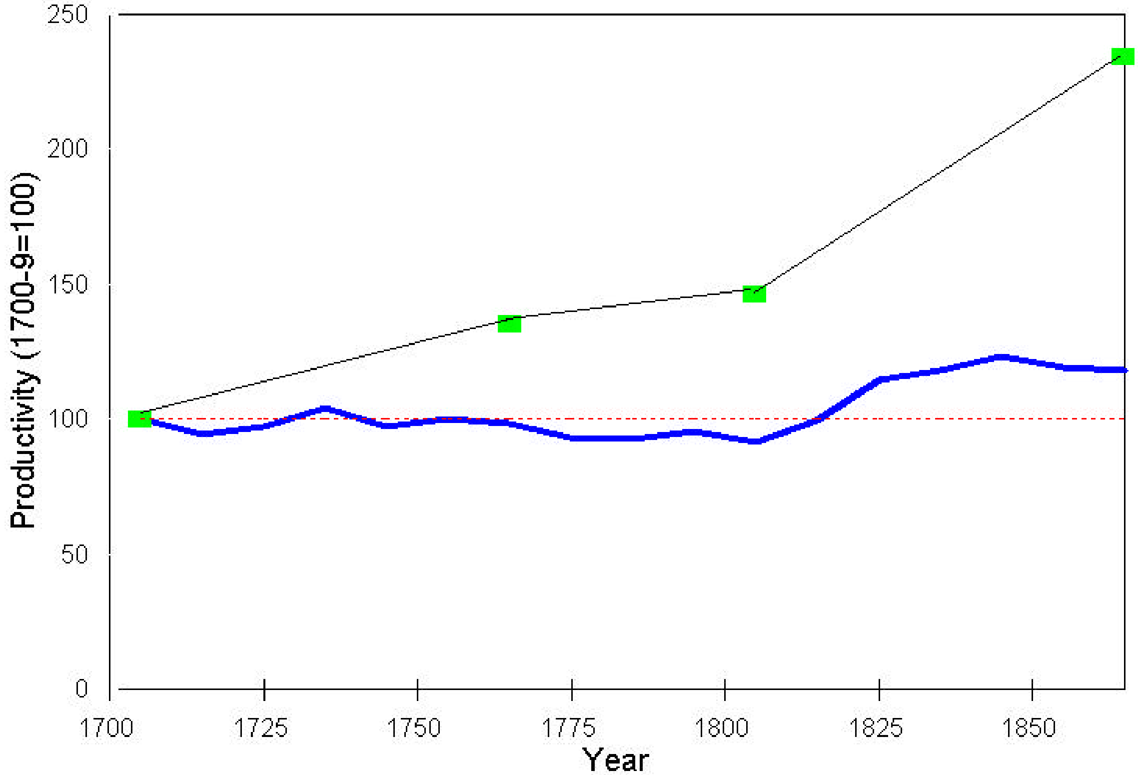
Figure 3 shows productivity calculated this way for English agriculture from 1700 to 1860-9, compared to the productivity levels implied by Craft's estimates. The shares of land and wages are taken as 40% each, and capital as 20%. As can be seen between 1700 and 1860 productivity grew by a total of less than 25%, compared to the 150% growth predicted by Crafts. Further what little measured productivity growth occurred is concentrated in the first three decades of the nineteenth century. From 1700 to 1800 there is no measured productivity growth at all.

FIGURE 2: REAL RENTS, WAGES AND RETURN ON CAPITAL



<u>Sources</u>: Return on capital, Clark (1998a). Rents, Charity Commission reports. Wages, Clark (1998b). Prices, see text.

FIGURE 3: PRODUCTIVITY GROWTH IN ENGLISH AGRICULTURE



Notes: Crafts' productivity estimates for agriculture are given by the filled boxes. The solid line shows productivity levels estimated from the series in figure 2.

What might have gone wrong with this calculation? One issue we need to consider is that the single series with most influence on the calculation is the price series. The series used here is a weighted average of eight subseries: wheat, barley, oats, beef, mutton, butter, cheese, and wool. To measure agricultural productivity the prices used should ideally be farmgate prices. In practice the meat and dairy prices mainly show the prices paid by institutions, some of which were in London. These prices thus measure also the efficiency of the transport and distribution system. In this respect we are likely to overestimate gains in productivity in agriculture alone since gains from the improvement of roads and the introduction of railways will be incorporated.

The value of output in any industry has to equal the sum of the total of the payments to the factors of production. This implies

$$Q = \frac{rK + wL + sT}{p}$$

Thus I can also use the information portrayed in figure 2 on wages, rents, and prices to estimate the total amount of output produced by the agricultural sector if I have some idea of the numbers of workers in 1700 to 1860, the area of land, and the amount of capital. Real agricultural output which is what matters most directly for economic growth in the Industrial Revolution period.

Table 8 shows the estimated numbers of farm workers from 1700 to 1861, as well as their implied wages (wL). Also shown are total estimated land rents (sT), and payments to capital owners. These sum to total farm output in nominal terms. Dividing by prices we find that if farm output in 1700 was set at 100, then output in 1860-9 was only 142, far less than the level of 385 shown in Table 1. Agricultural output grew very little in the course of the Industrial Revolution. Thus there was no Agricultural Revolution.

TABLE 8: NOMINAL AGRICULTURAL EARNINGS, ENGLAND, 1700-1861

Years	Male farm workers (m.) L	Total Wages (£. m.) wL	Rents (£. m.) sT	Payments to capital owners (£. m.) rK	Total farm output (£. m.) pQ
1690-1709	0.897	15.3	13.6	9.4	38.3
1800-9	0.919	29.6	36.4	17.8	83.8
1860-9	1.043	38.4	43.6	20.5	102.5

Sources: See text.

CAN WE LIVE WITHOUT AN AGRICULTURE REVOLUTION?

If output in English agriculture increased by only 50% or less from 1700 to 1850, then there was a decline in agricultural production in England per head of population, and this clearly is problematic. In the prices of 1851, production per person of agricultural products in Britain in 1851 was £6.7. If output rose only by 50% then English agricultural production per person in 1700, measured in 1851 prices, was £14.1 per person. How could output of agricultural products per person decline so greatly from 1700 to 1851, especially in a time of economic growth?

There is every evidence for this period that when incomes rose people ate more food in terms of value. The way we measure this is through the **income elasticity of demand**, which shows by what percentage consumption of a good increases when income increases by 1%. For groups of poor workers in Britain between 1787 and 1863 the estimates were as shown in Table 8. A 1% gain in incomes would lead to roughly a 0.6% gain in food expenditures. Real incomes as shown in figure 1 above rose about 20% between 1770 and 1850. Thus we should have seen increases in food consumption of about 12% per head, not dramatic declines.

Table 8: Income Elasticities of Demand for Food in the Industrial Revolution Period

Income elasticity	1787-96	1837-41	1863
All food expenditures	0.63	0.60	0.63
Calories	0.45	0.43	0.41
Grains	0.34	0.30	0.32
Group	195 poor rural families	76 poor families	481 poor families

Is there any way of reconciling the evidence from food demand which implies rapid output and productivity growth in agriculture with the evidence from the payments in the agricultural system?

The answer, at least in part, lies in the fact that those who argue for an agricultural revolution based on population growth focus on agriculture as a producer of food. But in the pre-industrial economy agriculture provided not only food for human consumption, it also provided the raw materials for clothing and bedding (wool, flax, dyestuffs, hides), housing and furnishings (wood), and energy in the form of wood and fodder for horses, as well as energy for human labor. By the mid nineteenth century there were large imports into Britain not only of foodstuffs, but even more significantly of fibers, hides, dyes, and wood that previously must have come from the agricultural sector.

Further the coal industry in Britain increased its output more than twenty fold from 1700 to 1850.[1] This supplied coal for fuel to households who would have previously relied on wood, turf, or furze for fuel. Thus coal used for domestic consumption is estimated for Britain in 1700 at as low as 0.2 tons per capita. By 1855, coal consumption per capita for domestic purposes had climbed to 0.73 tons per capita. But coal also substituted for fodder as motive power in the transportation system. Coal also replaced wood as the energy source in such energy intensive activities as iron and steel, brick and pottery making. Thus coal consumption per capita in England circa 1700 was only 0.4-0.5 tons, whereas by 1854-6 consumption per capita was 2.6 tons. Either energy consumption for heating, construction, and transportation in 1700 was at one fifth the level of the 1850s, or the agricultural sector in 1700 was supplying significant energy supplies in the form of underwood, furze, and turf, and grains and fodder for horses. To take one example, it is estimated that iron production in England in the early eighteenth century was about 17,000 tons annually. But it is conventionally noted that a ton of iron required the felling 10 acres of woodland. In this case these annual 17,000 tons of iron alone would have required 2.6 million acres of woodland devoted to iron production, or about 11% of the agricultural area.[2]

As an example of how imports replaced supplies from agriculture for raw materials consider wood for construction and furniture. Imports of wood to England were negligible in 1700, but by the 1850s imports to Britain were £9.7 million annually. If the charity land was typical then the domestic supply of wood for construction was only somewhere between £0.2 - £1.3 m. in the 1850s, so that imported timber was 89%-98% of consumption.[3]

A sign that coal was substituting for other fuel sources, which must have been wood from the domestic agricultural sector, comes from the experience of the London coal market. Coal consumption per capita in London exhibited the following pattern in terms of tons per capita: 1700, 0.8; 1750, 1.0; 1800, 1.3; 1830, 1.3. Thus either coal consumption per capita rose by 60% between 1700 and 1800 in London, at a time when there is little sign of income increases, or Londoner's were still using significant quantities of billets and faggots from the agricultural sector even in 1700.[4]

Table 9 shows estimated farm output per capita for 1700 for England and 1850 for Britain in the prices of 1850, as well as supplies of food, raw materials and energy from imports and from the coal industry. Counting all of these sources of supply of food, raw materials and energy, despite the absence of an

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[1] Even though there was this great increase in output the coal industry is not normally regarded as having experienced much productivity advance. The extra output came from adding more workers, and more capital rather than from any great increase in output per worker or per unit of capital.

[2] Assuming the trees were cut each 15 years. Wrigley (1988), p. 80, quotes the 10 acres per ton figure.

[3] On the charity land timber sales were 1.1% of tenant rent payments in the 1820s, but by the 1890s this had fallen to 0.2%. Clark (1998b).

[4] Tons consumed is from Flinn (1984, p. 274). The population of London is from Wrigley (1985) for 1700, 1750 and 1801, and thereafter from the census.

agricultural revolution there is only a modest decline in the consumption of food, raw materials and energy per capita. As a result of greater trade opportunities British agriculture in the period of the Industrial Revolution specialized in food production and reduced production of dyes, fuel, wood, and fibers. The slight fall in food consumption per capita between 1700 and 1850 is still problematic, given the expectation we have of growth of income per capita in the Industrial Revolution period. But the difficulties this cause us are slight compared with the problems any attempt to maintain a doubling or tripling of agricultural output creates.

TABLE 9: PRODUCTION AND IMPORTS OF FOOD, RAW MATERIALS AND ENERGY, 1700-1850

Period	Area	Population (m.)	Domestic Farm Output (£ m.)	Food and Raw Materials - Net Imports (£ m.)	Coal Output (£ m.)	Per Capita supplies of food, raw materials and energy (£)
1700	England	5.24	73.8	2.5	1.0	14.8
1850	Britain	20.82	138.7	53.8	92.0	13.7

Notes: Cotton, wool and silk retained for home consumption are estimated by subtracting the raw material content of textile exports. All prices are those of 1850.

THE INDUSTRIAL REVOLUTION WITHOUT THE AGRICULTURAL REVOLUTION

These new estimates of agricultural output growth in the Industrial Revolution have surprisingly big implications for the overall growth rate. Agricultural output is much greater than expected in 1700, and even in 1800. Thus growth rates in the Industrial Revolution will be slower because of less growth of agricultural output. Since agriculture is only 18% of GNP in 1861 this might appear to have a small overall impact. But slower growth of agricultural output means that agriculture has a larger weight in total output in the economy before 1861. This means that there is a further effect of slow growth in agriculture – in earlier years it reduces the impact on overall growth of the rapidly expanding manufacturing sector. Moreover, from 1700 to 1800 Crafts estimates the growth rate of the commercial sector, 16% of the economy, as being the rate of growth of overall output. Thus again before 1800 lower growth estimates for agriculture mean lower growth estimates for services.

Table 10 shows total output and output per capita in Britain or England as estimated by Crafts, Crafts and Harley and Deane and Cole between 1700 and 1861. Also shown are the revised growth estimates adjusting for slower agricultural growth as I have outlined. Now the growth of output from 1760 to 1861 falls from 397% to 294%, and the growth of output per person from 64% to 31%. As noted the reason the revisions to agricultural growth rates have such dramatic effects on overall growth is in part because they reduce the share of the fast growing industrial sector in GNP in earlier years. To illustrate this note that Crafts (1985) implies a value added in industry in 1770 at the beginning of the Industrial Revolution of £23 m. compared to a value added in agriculture which is only slightly higher at £27 m. I estimate agricultural output in 1770 at £45 m, which makes the agricultural sector still about double the size of the industrial sector.

Output per person in 1801 is only estimated to be 10% higher than in 1700. Thus the onset of growth in income per capita is pushed forward in time into the early nineteenth century. I also find that relative output per capita in non-agricultural and agricultural employment changes little between 1700 and 1860. Thus output per capita in non-agricultural employment is 32% higher than in agriculture in 1700, and 7% higher than in agriculture in 1861. There is thus little sign of a massive reallocation of labor out of relatively low productivity agricultural activities in the eighteenth century towards much higher productivity trade and industry. By 1700 there is no labor surplus to be extracted at low cost from agriculture and put to work in industry.

With these new output figures we can recalculate the growth rate of overall productivity in the Industrial Revolution period, and the contribution of each sector. This is done in table 11 below. As can be seen the productivity growth rate falls to only 0.36% per year. In part this is because agriculture itself is now estimated to contribute only .05% productivity growth per year to the economy.

We can also redo the calculated contribution of each sector to this overall productivity growth. This is done in table 12. Of this productivity growth the gains in textiles now explain the majority of the growth at 0.22%. The Industrial Revolution seems heavily concentrated on the gains in one sector, textiles. Indeed now one puzzle is that the productivity growth in individual sectors actually adds to more than the total productivity growth in the economy, implying that productivity was declining in the traditional industries.

TABLE 10: ESTIMATED OUTPUT LEVELS, 1700-1860, REVISED

Period	1700	1760	1861
Old			
GNP	100	151	750
Industrial Output	100	147	1,423
Agricultural Output	100	143	385
GNP/N	100	120	198
Agriculture's share in GNP (%)	37	37	18
Agriculture's share in Employment (%)	56	48	19
Relative output/worker (Agric/non-agric)	.46	.64	.93
Revised			
GNP	100	138	544
Industrial Output	100	147	1,423
Agricultural Output	100	100	142
GNP/N	100	110	144
Agriculture's share in GNP (%)	49	49	18
Agriculture's share in Employment (%)	56	48	19
Relative output/worker (Agric/non-agric)	.75	1.04	.93

Notes:
Sources: Crafts (1985); Crafts and Harley (1992), Industry, GNP post 1760; Wrigley and Schofield (1997), population.

Table 11: Productivity Growth in the Industrial Revolution Revised

Period	Output per Capita Q/L	Capital per Capita K/L	Land per Capita T/L	Productivity A
1760-1801	0.0%	0.2%	-0.8%	0.05%
1801-1831	0.5	0.3	-1.4	0.60
1831-1861	0.4	0.6	-1.4	0.40
1760-1861	0.3	0.35	-1.2	0.36

Table 12: The Sources of Productivity Growth in the Industrial Revolution, Revised

Sector	Productivity Growth Rate	Share of Labor Force in 1861	Contribution to Productivity Growth
Revolutionized Industry			
1. Spinning, Weaving	2.5	11.0	0.22%
2. Iron and Steel, Steam Engines, Railways	2.7	1.5	0.04%
Traditional Transport (canal, roads, ships)	2.4	4.5	0.11%
Agriculture	0.20	19.0	0.05%
Rest of the Economy	0.0	64.0	-0.08%
All		100	0.36%

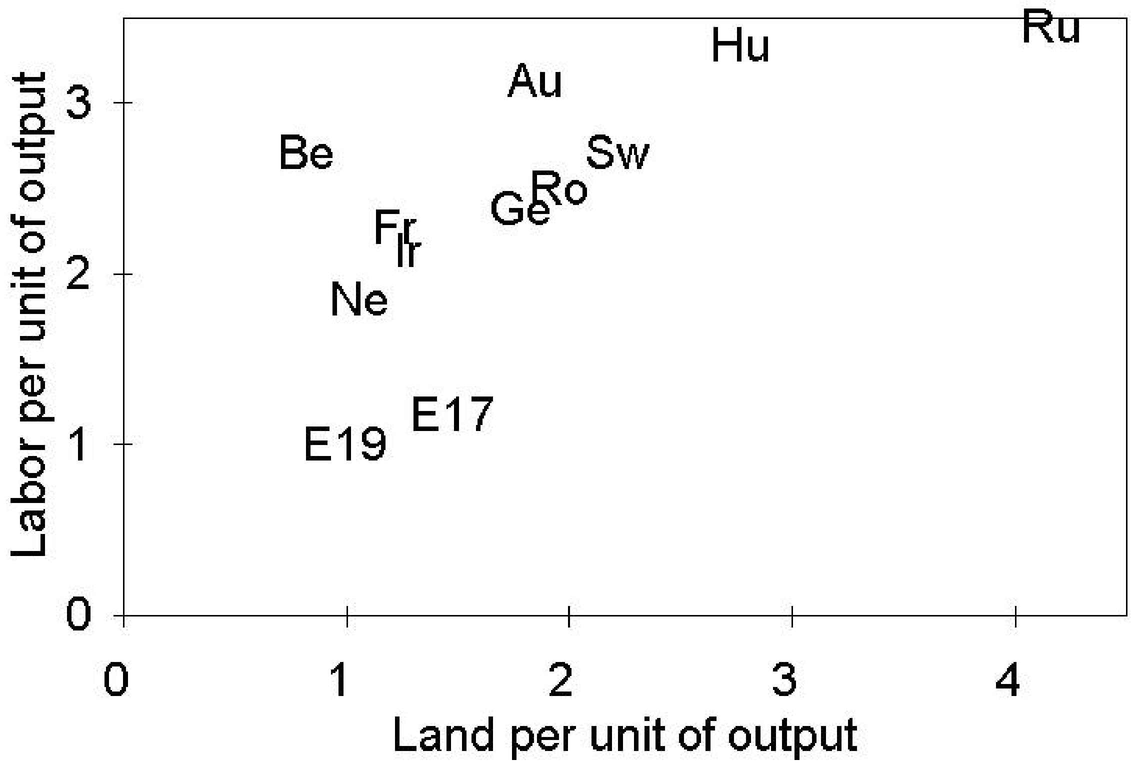
THE INDUSTRIAL REVOLUTION AS A DEMOGRAPHIC EVENT

These much reduced estimates of growth in the Industrial Revolution period also suggest a different assignment of importance to various factors in the Industrial Revolution. Modern scholarship has promoted technological change as being key to the Industrial Revolution. But imagine the following picture. Suppose that there had been no productivity advance in manufacturing from 1700 to 1860. Suppose also, however, that at fixed terms of trade Britain could import food and export manufactures. Then the marginal productivity of labor in industry would be constant. As population began to grow in the eighteenth century against a background of little improvement in agriculture there would be a movement of labor out of agriculture into manufacturing, increased imports of food and increased exports of manufactures. Population growth alone would drive industrialization. Had there been no technical change in textiles then we can still imagine a Britain of 1860 with nearly four times the population of 1700, with only a small fraction of the labor force in agriculture, and with an industrial sector that exported textiles and other manufactures, but manufactures produced still in hand powered industry. It would be a Britain in which living standards in 1860 were no higher, and probably somewhat lower, than in 1700.

But assuming that commerce, government and housing were always about 30% of GNP such a Britain would still have seen a growth in "manufactures" (including as do Crafts et al. mining and building) from the combined effect of a growth in population and a fixed land area for agriculture of **twelve fold**. Employment in industry would have gone from 14% of the population to 48%. Crafts and Harley estimate that industrial output, with the advantage of rapid technical advances in textiles, actually grew by 15 fold. So the role of the technical advances in textiles on Britain in the industrial revolution period turns out to be surprisingly minor. It allowed real incomes in Britain to rise, but since the advances in textiles turned the terms of trade against Britain, that increase would be by much less than even the modest gains in output per capita. It increased the rate of expansion of the industrial sector. But would Britain have looked dramatically different in 1861 without a textile revolution? No.

These new productivity and output estimates also have implications for our view of England prior to the Industrial Revolution. English agriculture was very productive relative to the rest of Europe by 1850. This is shown in figure 4, which shows the land and labor required per unit of output in various European countries in 1850-1870. As can be seen the great English advantage is in its very high labor productivity. If there was little productivity growth between 1700 and 1850 then it implies that English agriculture in 1700 was also highly productive, even relative to the standards of most European countries in the late nineteenth century. Since land productivity seemingly grew more than labor productivity between 1700 and 1850, England's advantage even in 1700 is estimated to be in unusually high output per worker in agriculture – in 1700 it was already nearly double that of any other European country as late as 1850. England on these measures looks different from Europe long before the Industrial Revolution.

FIGURE 4: LAND AND LABOR PRODUCTIVITY IN EUROPEAN AGRICULTURE, 1850-1870



<u>Note:</u> "E19" is English agriculture in 1850. "E17" is English agriculture in 1700. "Ne" is the Netherlands, "Be" Belgium, "Fr" France, "Ir" Ireland, "Ge" Germany, "Ro" Romania, "Sw" Sweden, "Au" Austria, "Hu" Hungary, "Ru" Russia.

The narrower view of productivity advance in the Industrial Revolution given here also lends support to the views of those who see the Industrial Revolution as essentially an accident. For it seems that English agriculture achieved high levels of productivity long before the breakthrough in cotton textiles, and that there was no sign of any connection between this earlier agricultural advance and industrial progress. Also the breakthrough in textiles seems much more an isolated event in the economy, and not just one of a host of technically unconnected changes.

APPENDIX: A CHALLENGE TO PESSIMISM

It is argued above that the Industrial Revolution only touched a few of the industrial sectors of the economy, textiles and iron and steel, which employed less than 15% of the labor force by 1850. Large sections of the economy, and indeed large areas of southern England, witnessed no productivity gain in this period. As Peter Temin notes in a recent article "This new school of thought sees the Industrial Revolution as a much narrower phenomenon, as the result of technical change in a few industries. The new industries, obviously, were cotton and iron. All others were mired in pre-modern backwardness."

Temin has disputed the assertion that productivity growth in the rest of industry was non-existent on the basis of British trade statistics. If we just look at British trade overall we see the pattern shown in table 13.

TABLE 13: BRITISH EXPORT SHARES, BY DECLARED VALUE, 1794-1856 (%)

	1794-96	1814-16	1834-36	1854-56
Manufacturing/Total	86	82	91	81
Cotton and Wool/Manufacturing	45	70	70	57
Iron/Manufacturing	11	2	2	7
Other/Manufacturing	44	28	28	36

Sources: Davis, The Industrial Revolution and British Overseas Trade, pp. 95-101.

Manufactures other than cotton or wool textiles and iron continued to be a very large share of manufactured exports. Indeed the share of the advanced sectors of textiles and iron in total exports showed no significant gain between 1794 and 1854. There were large volumes of other manufactures still being exported in the 1850s. Table 14 shows what individual goods were the most important exports of Britain after cotton, wool, linen, and iron and steel. They are listed by the value of the exports. What is impressive is the wide range of other manufactures that are still being exported in 1850. Prominent among these

TABLE 14: EXPORTS OF MANUFACTURES OTHER THAN YARN, CLOTH OR IRON GOODS BY VALUE, 1850-2

Product	(£)
Hardwares and Cutlery	2,556,441
Brass and Copper Manufactures	1,830,793
Haberdashery and Millinery	1,463,191
Earthenware	975,855
Machinery and Mill-work	970,077
Tin and Pewter Wares and Tin Plates	904,275
Apparel, Slops and Negro Clothing	892,105
Beer and Ale	513,044
Arms and Ammunition	505,096
Stationary	373,987
Apothecary Wares	354,962
Lead and Shot	339,773
Glass	296,331
Plate, Plated Ware, Jewellery and Watches	286,738
Soap and Candles	275,200
Painters' Colours and Materials	237,880
Books	234,190
Cabinet and Upholstery Wares	155,407
Cordage	155,127
Hats	141,084
Leather Saddlery and Harness	121,401
Musical Instruments	85,006
Umbrellas and Parasols	72,928
Carriages of all sorts	57,018
Spirits	52,843
Fishing Tackles	41,607
Mathematical and Optical Instruments	34,289
Spelter, Wrought and Unwrought	22,097
Bread and Biscuit	15,529
Tobacco (Manufactured) and Snuff	14,762

Notes: These figures are for Britain and Ireland together.

Source: Parliamentary Papers, 1852 (196) XXVIII.1, quoted in Temin (1997).

TABLE 15: IMPORTS OTHER THAN TEXTILE AND IRON PRODUCTS BY VALUE, 1850-2 (£)

Product	Value of Imports
Raw Cotton	23,670,472
Sugar	10,762,045
Tea and Coffee	9,276,680
Corn, Meal and Flour	9,167,600
Silk	5,163,865
Flax and Hemp	4,114,264
Hides, Skins, and Furs	2,366,502
Wool	2,049,348
Cochineal	1,909,848
Oil	1,793,320
Madder, Madder Root, and Garancine	1,687,568
Tallow and Lard	1,592,679
Guano	1,476,940
Indigo	1,191,495
Wood and Timber	1,153,477
Dye and Hardwoods	1,104,308
Butter and Cheese	1,003,779
Spelter (zinc)	**957,540**
Wines	**927,721**
Spirits	**902,351**
Pork, Bacon and Hams	892,841
Currants and Raisins	730,362
Seeds	719,017
Rice	668,585
Potatoes	562,595
Copper, Unwrought and part Wrought	**477,778**
Spices: Cinnamon etc	474,697
Brimstone (Sulphur)	383,691
Tobacco	367,685
Saltpetre and Cubic Nitre	355,564
Gum	298,147
Oil Seed Cakes	296,993
Glass	**270,110**
Bark and Cork	266,904
Ashes, Pearl and Pot	238,077
Turpentine	213,561
Bones of Animals and Fish	209,326
Quicksilver (Mercury)	**201,669**
Tin	**200,801**
Sago	178,329
Watches and Clocks	**169,589**
Lead, Pig and Sheet	**169,024**
Borax	164,565
Terra Japonica and Cutch	150,035
Hair or Goats' Wool, Manufactures of	**148,473**
Cocoa, etc, and Chocolate	145,973
Tar	142,819

Animals, living	138,607
Beef	122,855
Embroidery and Needlework	**114,999**
Copper Ore and Regulus	113,166
Safflower	94,911
Boots, Shoes and Calashes, and Boot Fronts	**94,779**
Lace, Thread, and Cushion or Pillow Lace	**82,816**
Leather Gloves	**81,441**
Shumac	80,320
Oranges and Lemons	74,845
Rhubarb	70,912
Valonia	66,799
Horse hair	63,159
Fish, of British taking	60,405
Almonds of all sorts	59,705
Pimento	57,222
Liquorice	54,153
Senna	53,452
Rags, &c. for Paper	49,140
Bees' Wax	46,160
Teeth, Elephants'	44,661
Bristles	44,048
Cassia Lignea	43,735
Books	**33,865**
Annatto	25,468
Isinglass	24,685
Figs	22,812
Barilla and Alkali	2,122

Notes: The numbers in bold type are those for imports of manufactured products.

Source: Parliamentary Papers, 1852 (196) XXVIII.1, as quoted in Temin (1997).

are hardware and cutlery, pottery, clothing, hats and umbrellas, beer, arms, stationary and books, soap and candles, and furniture.

If we look at imports as in table 15 what we find in contrast is that all the significant imports were of food or raw materials (manufactured imports are shown in bold type). Thus in the table of total imports (aside from textiles and iron products) of £93.2 m. per year, food and raw materials were £88.4 m., and manufactures only £4.8 m. But manufactures include £0.93 m. for wines, which could not be easily produced in Britain, and £0.90 m. for "spirits" which again may be produced abroad as a way of sharply reducing the transport costs of the raw materials. In contrast exports of manufactures other than textiles and iron totalled a much more impressive £14.0 m.

Thus, though Britain had a huge markets for boots and shoes in 1850, with 30 million people to be shod, the total imports of boots and shoes were a mere £94,779, which is dwarfed by imports of sugar at £10,762,045, and even by imports of currents at £559,919. Similarly there were no significant pottery imports, despite exports of £975,855 of earthenware goods. Hats were exported, but not imported. Similarly though £2,366,502 of hides, skins, and furs were imported to be manufactured into leather products, very few manufactured leather products such as leather gloves (£81,441**)** were imported.

Temin argues that the failure of Britain and Ireland to import any significant quantities of manufactured goods reveals there must have been widespread technological improvement in other manufacturing in Britain. For suppose that Britain had technical advances only in textiles. Then the cost of production in textiles should be less than for other areas of manufacturing in Britain than in the rest of the world. Britain should thus start exporting textile products. But exports and imports don't depend on the absolute costs in one country relative to another, they depend on comparative costs. In particular suppose that Britain produced two manufactured products, textiles and pottery, both of which used only labor. Suppose that each required in Britain one unit of labor per unit of output. Suppose also that in other countries the labor requirements were respectively 10 units and 1 unit of labor. I.e.

Table 16: Labor Requirements per Unit of Output

	Britain	Other Countries
Textiles	1	10
Pottery	1	1

Ricardo showed that in this case what will happen with free trade is that Britain will both export textiles, and import pottery. For trade depends not on absolute advantage, but on comparative advantage. Thus if the Industrial Revolution improved only the textile sector in Britain, then it would imply not just exports of textiles, but corresponding imports of other manufactured goods. This trade would continue until the relative price of textiles and pottery was the same in the rest of the world as in Britain. No textiles would be produced elsewhere, and no pottery in Britain.

We can generalize this result to the case where there are many different goods which experience different amounts of technical advance in Britain as follows. Suppose these are N manufactured goods. The technology of each country can be described by the labor needed to produce each of the N goods. Let the labor requirement to produce the ith good in Britain be a_i, where a_i is the number of hours of British labor needed to produce a single unit of the ith good. In this case $1/a_i$ is the output per worker hour in industry i, which is the efficiency in Britain of industry i.

Let a^*_i correspondingly represent the hours of labor needed to produce the nth good in the rest of the world. A low number a^*_i means a higher level of efficiency in producing the good abroad, since $(1/ a^*_i)$ is the output per worker hour in industry i abroad, which is the efficiency abroad of industry i.

The ratio of the labor needed to produce good I in other countries and in Britain is a^*_i/a_i, which measures British efficiency relative to efficiency abroad. The goods can be re-ordered by this ratio, starting with the good for which the relative quantity of foreign labor needed for production is the highest (so the ratio, a^*_N/a_N, is the lowest).

$$a^*_1/a_1 > a^*_2/a_2 > \ldots > a^*_N/a_N$$

1 is thus the industry in which Britain had the highest relative efficiency. The pattern of trade is determined by the relative costs of producing goods in the Britain versus other countries. Let w be the British wage; w^*, the wage in the rest of the world. Then the cost of producing good i in Britain is $w \times a_i$, while the cost abroad is $w^* \times a^*_i$. Any good for which $w^* \times a^*_i > w \times a_i$ will be produced in Britain because its production costs are cheaper in Britain. This implies that any good for which

$$a^*_i/a_i > w/w^*,$$

or in effect

$$\frac{BritishEfficiency}{ForeignEfficiency} > \frac{BritishWages}{ForeignWages}$$

will be produced in Britain. All other goods get produced abroad.

Where the cutoff comes between exports and imports depends on the level of wages in Britain relative to the rest of the world. The higher are British wages, the higher the relative efficiency of a British industry has to be to allow exports of goods. Since British wages in 1850 were higher than those of all competitors this implies that any manufactured good which was produced at the same efficiency in Britain as abroad would be imported.

Consider now the effect of technical change in Britain in the Industrial Revolution. Suppose at the same time there was no technical change outside of Britain, that is, no change in labor productivity in the other countries. The improvements in productivity in textiles would increase British wages relative to those of the rest of the world. Textiles would now be exported, but some industrial products in those industries which experienced no technical change would start to be imported, as British wages rose. If other manufacturing goods saw no gain in productivity in the industrial revolution period, then since British wages in this period increased by at least 80% we should expect them to begin to face severe competition from abroad.

Since tables 14 and 15 suggest that still in 1850 almost all British manufactures were exported rather than imported Temin concludes that there must have been substantial productivity advance in the rest of the manufacturing sector also. In one of those few cases where we see manufactured imports exceeding exports, such as for watches and clocks, it had already been noticed by historians that there had been a failure in this case by the British industry to make advances. Since productivity stagnated in the British industry it had become an import industry by mid-century. Since other manufacturing areas remained exporters, they must have seen productivity advance. It follows therefore that other British manufactures were not inefficient and stagnant, or at least, they were not all so backward. The spirit that motivated cotton manufactures extended also to activities as varied as hardware and haberdashery, arms and apparel.

Temin concludes that there must have been more technical progress outside the famous revolutionized industries to produce the results shown here. A corollary of Temin's article is that overall productivity growth in Britain in 1770 to 1850 was much faster than the aggregate figures suggest, so that the

Industrial Revolution must have been more impressive than recent calculations suggests.

Is Temin's conclusion correct? Temin's argument makes three basic assumptions:

1. Labor is the only input.
2. There is free trade in all goods.
3. Technical progress in Britain does not diffuse quickly to the rest of the world.

The conclusions Temin wishes to draw follow nicely from his assumptions, so the crucial issue is the assumptions. Let us consider each of them.

LABOR IS THE ONLY INPUT. For manufacturing I do not think this is a particularly restrictive assumption, given the widespread international trade in the raw materials required for manufacturing, many of which were imported into Britain. But for agricultural the use of land in production means that we cannot say anything about productivity growth from trade flows without considering that constraint. Suppose, for example, the agricultural area of Britain had been 1 acre and not 29 million acres. Then we could have had productivity growth in agriculture at 10% per year and still have observed food imports. So this first assumption requires that we can only discuss the relative productivity growth of "footloose" manufactures. Given that Britain was constrained to import large amounts of food by 1850, the question is now why it did not pay for these only with exports of the revolutionized sectors - textiles and iron and steel?

TRADE BARRIERS. Suppose that either (a) barriers to exports of textiles exist or (b) Britain completely saturates the market for machine-made textiles in other countries by 1850. Then it might be forced to pay for food imports by exporting other manufactured products, even though they had witnessed no technological advance given the dense population of Britain and Ireland. The only constraint that would then arise would be that the wages of British labor could not rise relative to foreign competitors. Otherwise the non-revolutionized British products would cost more than the international competitors. This would say that the gains from technical progress in Britain in the Industrial Revolution could mainly accrue to workers in other countries in the form of cheaper textiles exported from Britain without much gain going to British workers.

In practice there were many trade barriers in the textile market in the 1850s. Markets in countries such as France, Germany, Russia and the USA were heavily protected by tariffs against British goods.

KNOWLEDGE DIFFUSION. Suppose that while the efficiency advances in British industry were confined mainly to textiles, the efficiency gains which were based on knowledge spread quickly to the rest of the world. There were textile mills in many other countries by 1850 including France, Belgium, the Netherlands, Switzerland, Germany and the US. Thus Britain did gain some comparative advantage in textiles, but not anything like the advantage Craft's figures for productivity growth in Britain alone would imply. In this case any gains Britain made in income per capita relative to other countries in the Industrial Revolution period were achieved by better X-efficiency rather than by better technical knowledge. Suppose Britain was in 1770 a relatively efficient producer of a whole range of traditional products, including textiles. It could be that in 1850 it had the same relative advantage across the board, based on some national level of manufacturing competence.