THE INDUSTRIAL REVOLUTION AS A DEMOGRAPHIC EVENT

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INTRODUCTION

Figure 1, which shows English population in millions by half century from 1250 to 1850, and the real wages of carpenters as calculated by Phelps Brown and Hopkins, clearly suggests that something dramatic happened in the English economy between 1750-99 and 1800-49. Before 1750 population and wages had seemingly been inversely linked along the same curve for 500 years. If population rose, real wages fell. But between 1750 and 1850 the population of England nearly tripled with no loss in wages. The Industrial Revolution may not have improved living standards immediately, but it seemingly still represented a dramatic break with the past. Something very unexpected happened.

The latest empirical work measuring and analyzing the Industrial Revolution by Crafts and Harley is shown in Table 1. Though their estimates tend to somewhat more pessimistic than the previous generation they still argue for a 6.5 fold increase in output between 1700 and 1860, and a near doubling of output per worker. Crafts also argues that back in 1700 agriculture had labor productivity only about half that of the rest of the economy. Between then and 1860 this disparity was eliminated, so that by 1861 output per worker in agriculture was nearly as high as the rest of the economy. Thus agriculture was a sector of the economy with unusually rapid labor productivity growth in the Industrial Revolution era. If we assume that output per unit of capital was constant over these years then the numbers in table 1 imply that the productivity of the economy grew by about 90% from 1700 to 1861.

Figure 1: Population and Real Wages, 1250-1850
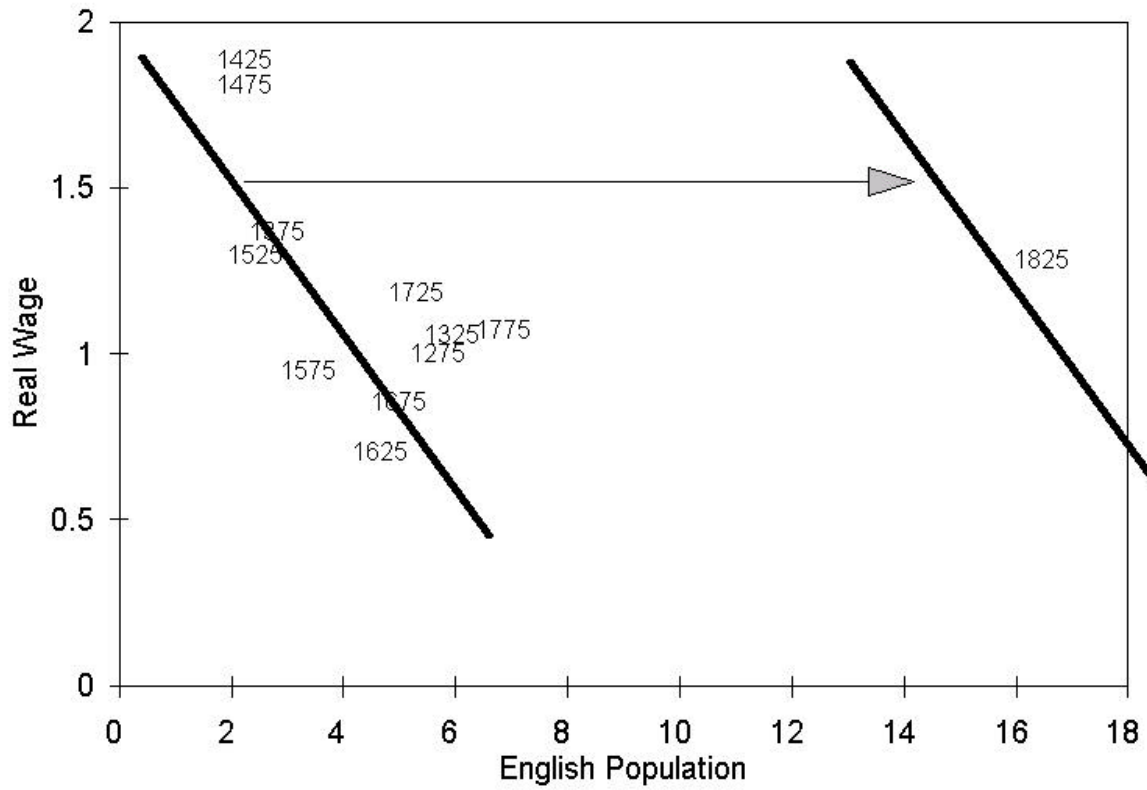
TABLE 1: ESTIMATED OUTPUT LEVELS, 1700-1860

Period	1700	1760	1801	1831	1861
GNP	100	151	230	406	750
GNP/N	100	120	130	151	198
Agriculture's assumed share in GNP(%)	37	37	26	23	18
Agriculture's share in Employment (%)	56	48	36	32	19
Relative output/worker (Farm/non-farm)	.46	.64	.62	.63	.93

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

In this paper I will argue the following points:

(1)	Crafts' and others assumptions about agricultural productivity growth in the Industrial Revolution period are wildly optimistic. Agriculture experienced very slow productivity growth in this period, no faster than the average for the rest of the economy. Agricultural output grew more slowly than the population, the deficiency being made up from massive imports of food and raw materials, and from domestic coal mines.

(2)	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. 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 given the way output growth is calculated in the Industrial Revolution period, removing the agricultural revolution 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 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.

(3)   Once revisions are made for the slower growth of agriculture, and for the general effects this has on estimates of growth in the IR period, the overall growth of national income from 1700 to 1860 drops from the 650% of Table 1, to 440%.

(4)   Had no technological change occurred in England in textiles between 1760 and 1860, England would have looked substantially similar in 1860. Assuming that at fixed terms of trade England could export manufactures and import food, then just as a result of population growth and a stagnant agricultural sector, industrial output would have expanded **twelve fold**. Employment in industry would have gone from 14% of the population to 48%. The country would have urbanized and industrialized. Living standards would have been lower in 1860, but much that we associate with the industrial revolution would have occurred anyway.

(5) This still leaves a puzzle as to why the experience of population growth in England in the years 1760-1860 was so different from previous population booms as in 1500-1630, and 1200-1300. Why did these earlier booms lead to large declines in wages, and not instead to the Industrial Revolution outcome of manufacturing exports and food imports? Real wages more than halved from 1475 to 1625 when population roughly doubled. Why wasn't this earlier population growth accommodated by increased manufacturing output and trade? I explore some

potential answers, but none are particularly satisfying. One is that developments in international trade had changed the tradeoff between wages and population at any particular locality such as England to make it much less steep by 1760. This possibility is portrayed in figure 2.

(6)   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.

Figure 2: Population and Real Wages, 1250-1850
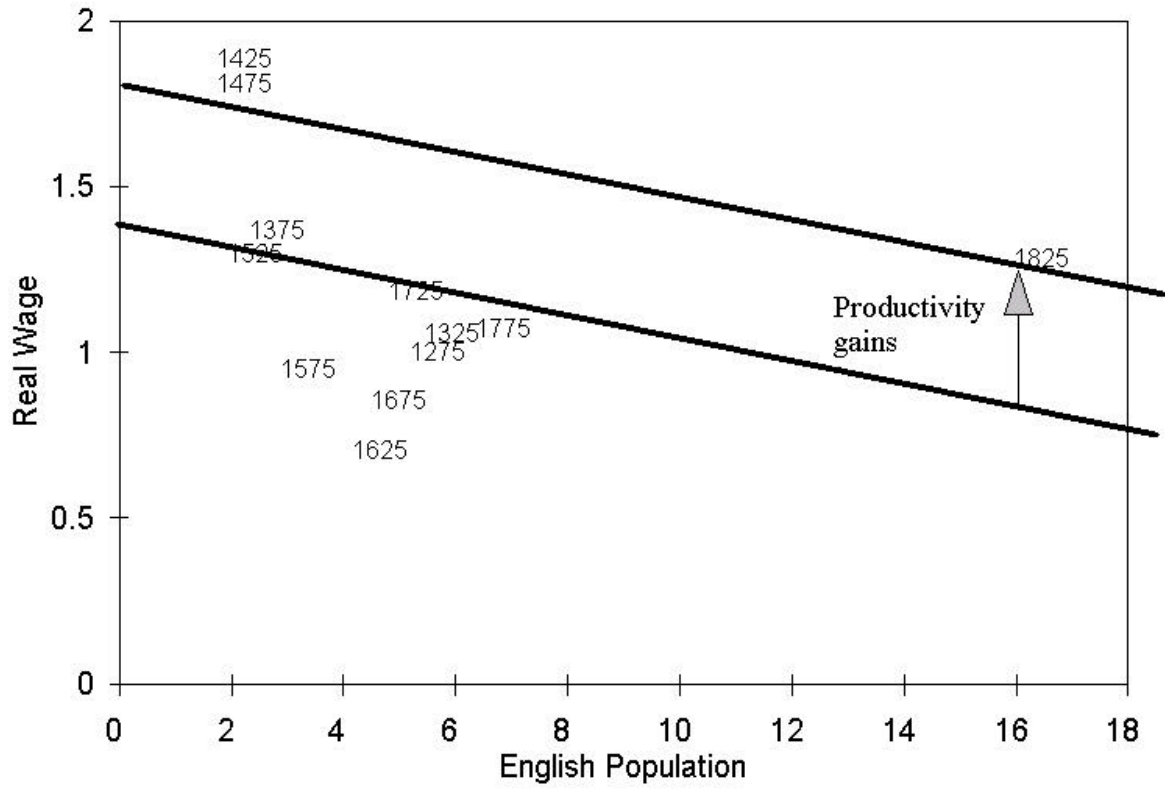
THE AGRICULTURAL REVOLUTION

The idea that an agricultural revolution accompanied the Industrial Revolution, and indeed contributed more to the overall productivity growth of the British economy in the years 1700 to 1850 than did the revolutionary changes in cotton textiles, still dominates thinking about the Industrial Revolution period.[1] Table 2 shows, for example, some recent estimates of productivity growth in English agriculture between 1700 and 1860. The authors vary in where exactly they place the productivity growth, but all find productivity more than doubled between 1700 and 1850, just at the time of the Industrial Revolution.

It is important to understand that none of these estimates of productivity growth in agriculture are derived from direct estimates of outputs and inputs. Such figures do not exist for the years before 1860. Instead people believe in an agricultural revolution mainly because of three things that happened in the economy as a whole: growing population, rising incomes, and urbanization. The population of Britain increased from 6.5 m. in 1700 to almost 21 m. by 1851. Since domestic agriculture still fed four out of five Britons in 1850, the population it fed increased 150% from 1700 to 1851. Since both output per person and real wages are widely believed to have increased in Britain after 1800, that should have boosted food consumption even more since at higher incomes people consume more food. In studies of the value of food consumed compared to income for groups of workers at particular times in the late eighteenth and nineteenth centuries it has been found that consumption per capita, c, is well predicted by a function of the form, $c = a.(w/p)^\varepsilon$, where w/p is real income, and ε is the elasticity of demand for food, which seems to be about 0.65.   Since even relatively pessimistic estimates such as the

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[1] Knick Harley, for example, attributes to agriculture more than one third of all the productivity growth in the Industrial Revolution. See Harley (1983).

TABLE 2: ESTIMATED PRODUCTIVITY LEVELS, 1700-1860

Period	1700	1760	1800	1850	1860
Crafts	100	135	146	234	259
Allen	100	-	182	234	-
Overton	100	-	142	208	-

Notes: The estimates of Crafts refer to Britain after 1801, England and Wales before, those of Allen to England and Wales, and of Overton to England only. Crafts estimates after 1831 derive from those of Deane and Cole. The productivity estimates ascribed to Overton are derived from his estimates of land and labor productivity giving land and labor equal weight.

Sources: Crafts (1985), pp. 41-4, 84; Deane and Cole (1967), p 166; Allen (1994), p. 111; Overton (1996), p. 86.

recent ones of Charles Feinstein suggest a 43% gain in real incomes between 1770 and 1850, total agricultural output would thus have increase by 220% between 1700 and 1850.[2] The cultivated area seemingly increased little between 1700 to 1850 so yields per acre should have tripled.

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[2] Feinstein (1997). Assuming real incomes in 1780 were the same as in 1700.

There has been equivalent optimism about increases in output per worker. The census of population gives estimates of the share of the work force in agriculture from 1801 onwards, though the earlier figures are very imprecise. These suggest that the share of the adult male labor force in agriculture was 25% in 1851, and 36% in 1801. Before 1801 there are no census figures, so the labor in agriculture must be deduced from other considerations. E. A. Wrigley uses urbanization rates as a guide and concluded 55% of the labor force was in agriculture in 1700. Crafts uses information on occupations gathered from probate inventories by Lindert to get a similar figure of 56% of workers in agriculture in England in 1700.[3] These considerations imply an adult male labor force in agriculture of about 0.9 million in 1700, and 1.0 million in 1861. Thus the swelling food production was largely achieved without greater labor inputs, so that output per worker grew as much as 170% between 1700 and 1860. Once these large increases in output per acre and output per worker are concluded, it follows that overall productivity in agriculture increased in the way shown in table 1.

Backing up this indirect route to the agricultural revolution, Deane and Cole exploit another possible source of information, which is measures of the amount of income generated by the agricultural sector. To this end they use records of land rents generated by the property taxes of 1806 to 1814 and 1842 on, combined with estimates of the earnings of agricultural workers. This allows them to calculate estimated income in agriculture as shown in table 3 below. Dividing this nominal income by a price index for all agricultural products, they conclude that total output doubled between 1801 and 1861, again suggesting impressive productivity growth.[4]

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[3] Wrigley (1985). Lindert (1980). Crafts (1985), p. 15. Allen estimates the labor force in agriculture in the eighteenth century by estimating the distribution of farm sizes in 1700 and 1750, and then fitting to these farm sizes calculations from Arthur Young's tours circa 1770 of the likely labor inputs per acre at different farm sizes. He concludes labor inputs in 1700 were somewhat greater than Crafts assumes.

[4] Deane and Cole (1967). This index unfortunately includes such goods as tea, coffee, sugar, rice, olive oil, tobacco, pepper, cinnamon, rum, and whale oil which were not produced on British farms.

WHY THERE WAS NO AGRICULTURAL REVOLUTION

The evidence that the long hypothesized agricultural revolution never took place comes in two forms. The first is that while input and output numbers are lacking 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 3 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

$$g_A = \alpha \cdot g_r + \beta \cdot g_w + \gamma \cdot g_s - g_p$$

$$= \alpha \cdot g_{r/p} + \beta \cdot g_{w/p} + \gamma \cdot g_{s/p}$$

FIGURE 3: REAL RENTS, WAGES AND RETURN ON CAPITAL
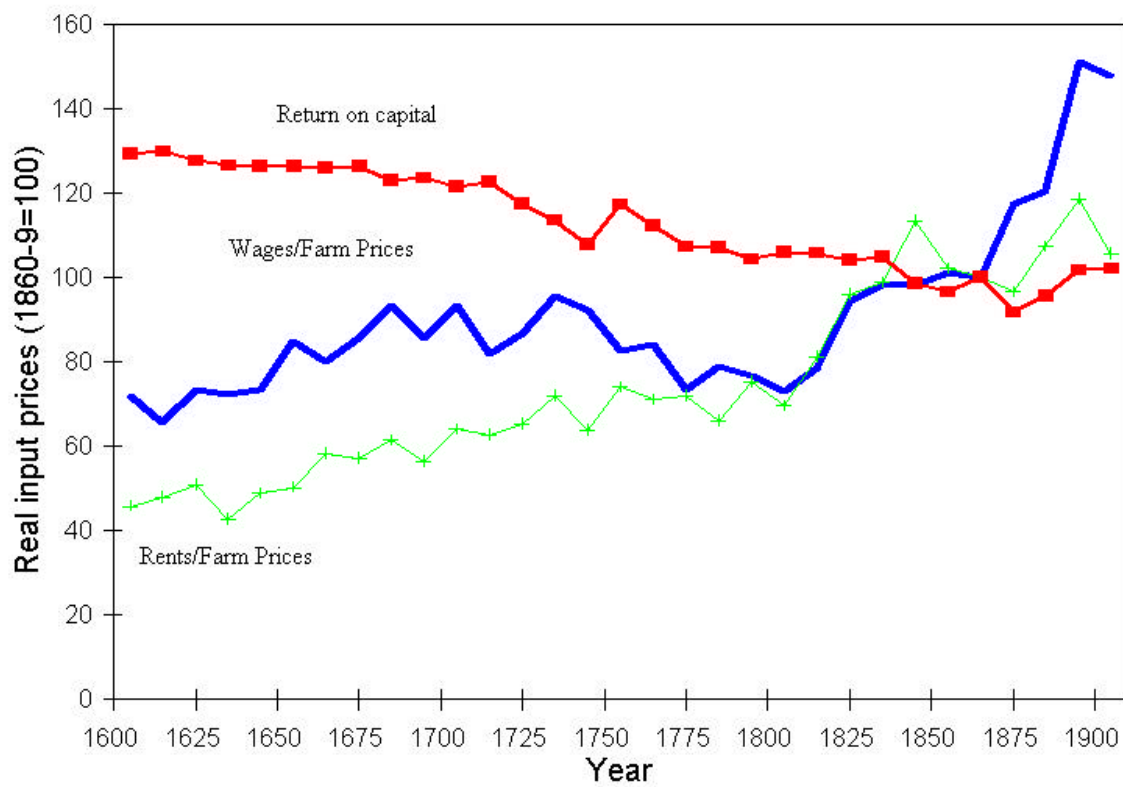
Sources: Return on capital, Clark (1998a). Rents, Charity Commission reports. Wages, Clark (1998b). Prices, see text.

where α, β, 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. Figure 4 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.

What might have gone wrong with this calculation? There are five issues we need to consider:

(1) The single series with most influence on the calculation is the price series. The series used here is a weighted average of eight subseries (with the weights used in the years before 1858 given in brackets): wheat (.25), barley (.15), oats (.10), beef (.16), mutton (.16), butter (.06), cheese (.06), and wool (.06). 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.

FIGURE 2: PRODUCTIVITY GROWTH IN ENGLISH

AGRICULTURE
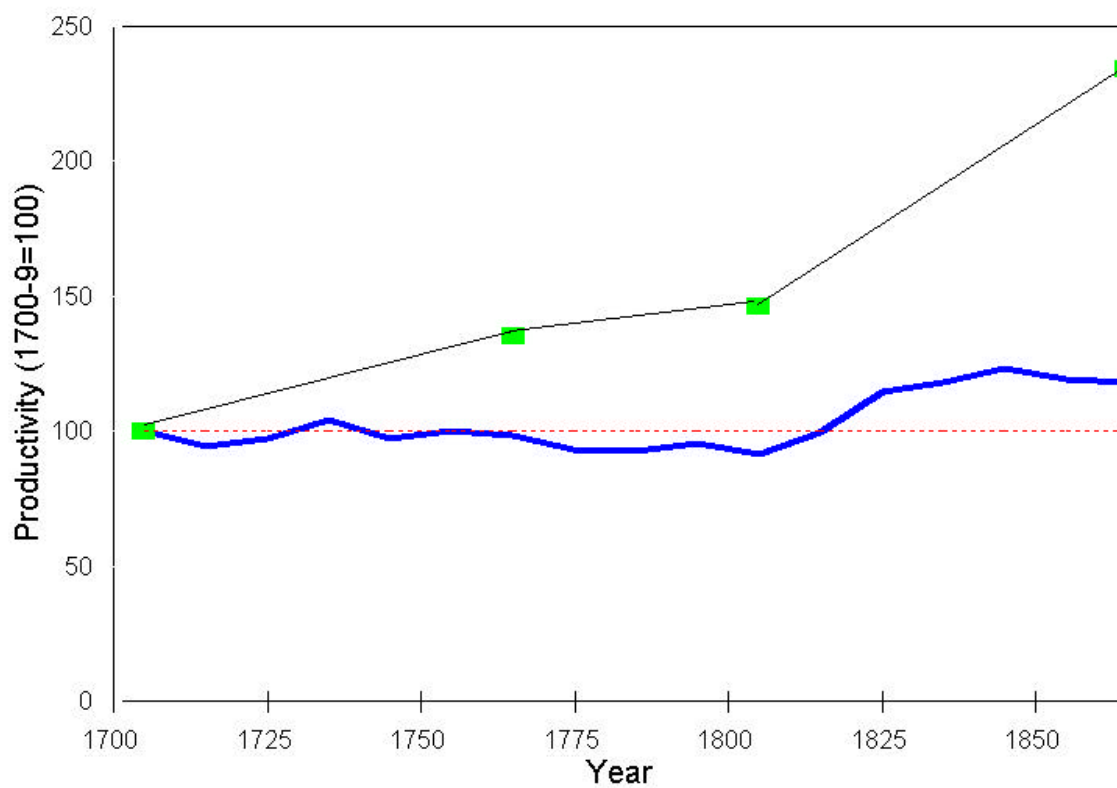
Notes: Crafts' productivity estimates from table 1 are given by the filled boxes. The solid line

shows productivity levels estimated from the series in figure 1.

(2) The rent series is for rent and tithe paid by the tenant. To calculate productivity we should also include all taxes paid by tenants. Tenants paid a variety of local taxes, most importantly the poor rate, and the size of this relative to rents probably increased over time. We do not have good estimates of the exact amount of poor rate levied on rural land owners per unit of rent and tithe.

(3) Rent per acre correlates strongly in all periods with the size of plots, being smaller the larger the plot. The rent series used here controls for this by calculating rent on a standard sized plot. Since we believe average plot sizes increased over time we may be overstating the aggregate rent rise over time, and hence productivity increases.

(4) If much new land was brought into cultivation between 1700 and 1860 then while the productivity of farming on any particular acre may have increased little, the productivity of the agricultural system as a whole may have increased much more. That is, the correct rent series to measure the productivity of the system would be the aggregate rental for all of England. Fortunately the rent series used here is constructed as the average rent per acre of all land, including "waste" land not under cultivation in earlier years. Such land was, however, only a few percent of the total agricultural area in 1700.

(5) The exercise assumes that labor hiring follows the rule that workers are hired until the wage equals the marginal product of labor. The rural labor market was more complicated than this. Labor demand was seasonal, with wages varying by season. Winter hiring of workers may represent just a strategy by farmers to ensure that they were available for the harvest and hay seasons. The winter wage may thus not index the marginal productivity of labor. Women are also believed to have had more employment in the years before 1770 than subsequently. received by the factors changed over time this could affect the measured productivity.

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(6) I do not have any estimate of the return on the management skills of farmers.

(7) Productivity is calculated using constant shares in income of the different factors over time. Since the factor cost series move in very different directions, if the shares of income

One way we can finesse some of these difficulties and also produce an estimate of total agricultural output is as follows. Total agricultural income will be:

$$\text{Income} = (\text{rents} + \text{tithes}) + (\text{poor rates} + \text{wage payments}) +$$
$$(\text{return on capital} + \text{farmer's profit})$$

If I can calculate the components of income, then I can derive real agricultural output which is what matters most directly for economic growth in the industrial revolution period.

I can calculate the aggregate rent and tithe in England from 1700 to 1861 using the rent series, and estimates of total land rental and tithe from the property tax of 1842 and later. We also know from the census of 1801 and later the total adult male labor force in agriculture. For 1700 I adopt Crafts' estimate of the labor force. These numbers are shown as the first column in Table 3. I also have an index of winter wages (meaning wages outside the harvest periods) from 1700 to 1861, but I need to convert that into total annual earnings. The 1834 Poor Law inquiry gives a fairly good estimate both of winter wages and of what an adult agricultural worker could earn annually in full employment. By the nineteenth century not all farm workers were employed throughout the year – they were supported by the poor rates at least part of the time. But what I assume is that each worker received a combination of direct wages from the farmer, and indirect wages through the poor rates, which equaled full time employment. That is, I assume that the poor rate payments of farmers all went to supplement the wages of workers, and

TABLE 3: NOMINAL AGRICULTURAL EARNINGS, ENGLAND, 1700-1861

Year	Male farm Workers (million)	Wages and Poor Relief (£. m.)	Rent and Tithe (£. m.)	Payments to capital, management (£. m.)	Nominal Income (£. m.)
1690-1709	0.897	15.3	13.6	9.4	38.3
1800-9	0.919	29.6	36.4	17.8	83.8
1810-9	1.024	38.1	45.6	22.4	106.1
1820-9	1.125	37.2	39.8	20.3	97.3
1830-9	1.199	38.7	38.4	20.4	97.5
1840-9	1.109	35.5	43.8	19.5	98.8
1850-9	1.137	39.0	41.1	19.1	99.2
1860-9	1.043	38.4	43.6	20.5	102.5

Sources: See text.

that this ensured effective full year employment for workers in all years. Thus column 2 in table 3 shows the sum of wages and payments to workers in poor rates, calculated by taking the winter wage as an index of wage levels. The 1851 census reveals 430,000 women and children who were living on farms or listed agricultural occupations. I assume that each of these women and children earned over the year one quarter of the male wage. That implies that all women and children in agriculture earned only 9.4% of male earnings in 1851. I assume the same was true for all years.

The return on capital and the farmer's profit above his or her labor earnings is assumed to be 20% of the value of output in the 1860s (based on farm accounts). For other years the

capital/output ratio is assumed the same as in the 1860s, and the earnings of capital are estimated as the return on capital plus 5% depreciation.

These figures imply that real output in English agriculture grew by only 42% from 1700 to 1861, compared to the estimate of Crafts of a 285% gain, as is shown in Table 4. The implied gains in output in table 4 imply a productivity growth in agriculture between 1700 and the 1860s of 22%, which is just a little more than was derived by the pure dual approach above. The numbers in Table 3 suggest also that the assumption of constant shares in output for labor and capital do not do too much violence to reality. Rent and tithe in the nineteenth century is about 13% more than wages and poor law payments. But back in 1700 these are estimated at 89% of wages and poor law payments. The assumption in the dual exercise above, derived from farm accounts, that they constituted an equal share of output on average balances them correctly.

ANCILLARY EVIDENCE

There is other evidence that can be brought to bear to show the plausibility of the picture painted above. Remember that the implied agricultural output suggested by the various agricultural "revolutionists" in 1700 is £15.7 m. (Crafts), £14.5 m. (Allen), and £17.6 m. (Overton). Estimated rent and tithe, customarily regarded in this period as being one third of output, alone almost equal this figure at £13.6 million. But we can find corroborating evidence for this figure in the details of the land tax, first imposed in 1693.

TABLE 4: NOMINAL AND REAL AGRICULTURAL OUTPUT, 1700-1861

Year	Nominal agricultural Income (£. m.) England	Real agricultural income (1700=100) England	Nominal agricultural Income (Deane and Cole) Britain	Real agricultural Income (1700=100) (Crafts/D+C) Britain
1700	38.3	100	-	100
1801	72.8	98	75.5	172
1811	95.0	103	107.5	-
1821	101.7	125	76.0	-
1831	97.4	143	79.5	245
1841	98.1	149	99.9	296
1851	99.0	148	106.5	368
1861	100.8	142	118.8	385

Sources: Deane and Cole (1967), p. 166. Real output before 1831 from Crafts (1985), p. 42. Thereafter from Deane and Cole.

The land tax assessment of 1693 valued land, houses and tithes in England outside most major towns at £8.3 m.[5] It is well known, however, that the land tax was heavily under-assessed in the north and in the west. So this £8.3 m figure would be very much a lower bound estimate of rents and tithes in the 1690s, though even this lower bound figure still constitutes 53% of Crafts' estimated agricultural output circa 1700. The peculiarities of the administration of the land tax allow us to use the charity observations to calculate what the corrected total of rents

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[5] This is from Browning (1953), pp. 318-21, where the tax yield is given separately for each of 61 towns, and for the counties outside these towns. The implied value of property in the towns was £0.85 m.

should be based on the land tax assessments. The assessed values of property and income in 1693, supposedly 20% of the rental value of real property, were used to set permanent county quotas of the land tax used from 1698 on. Within each county land tax commissioners allocated quotas of the tax to each parish or township. But these local quotas quickly became ossified in the early eighteenth century and subsequently remained unchanged. Within townships reallocation of the tax burden among land parcels could and did take place. But on average in rural parishes the land tax burden on a given piece of land in any year after 1710 would represent one fifth of the assessed rental value of the land in 1693. On many of the charity plots we have the land tax payments made after 1798 when the tax became fixed at the 20 percent rate. When I compare these assessed values with the actual rental value of the same charity land back in the years 1690 to 1729 I find that even in the south of the country the land tax assessment was only 66 percent of the rental value of land in these decades, and in the north the assessments were a mere 26 percent of the true value of land. Overall this would imply that if the land tax assessed all rent and tithe at close to £8.3 million in the 1690s, the true rental value of land and tithe was possibly as high as £14.6 million, almost as great as Crafts total implied output.

I assume in estimating the wage bill in 1700 that men worked a full year (or received poor law payments), and that women and children worked as much then as in 1860. The concept of the industrious revolution, recently introduced by de Vries, might seem to suggest that perhaps this labor force worked little, being unemployed for much of the year. Suppose, for example, that workers in 1700 worked only half the year on average, spending the rest of the time in taverns, playing cricket, writing poetry, or just sleeping. Now estimated output in 1700 would fall and output per worker would nearly double between 1700 and 1860. It would, however, imply that output per worker-hour in agriculture fell by 20% from 1700 to 1860. Given that

there was mechanization of threshing between these years, and threshing was perhaps a quarter of labor inputs earlier this seems highly implausible. Also the gains in grain yields should have produced at least modest labor savings.

Further, there is good evidence that the work habits of rural workers were not particularly different in 1700 than in 1850 or 1860. Workers seem to have worked as many hours per day - workers threshed as much grain per day of work in 1700 as in 1850. Accounts of the complete days worked per year by workers are difficult to find in the surviving farm accounts. But the evidence shows that even before 1750 some workers were putting in work years of nearly 300 days. Thus on the Harrold estate in Bedford over the account year 1647-8 four regular workers worked for this employer on average 291.5 days. Of the 21.5 idle days per worker (excluding Sundays), 14 were potentially common to all the workers and may reflect regular holidays (four of these were from the Christmas/New Years period). The other 7.5 were definitely idiosyncratic to individual workers. The household accounts of a curate in Cambridge in 1705-6 show that Thomas Watson, an agricultural laborer, worked 296.5 days for the curate in one year. On the Dryden estate in Northampton five regular workers who were employed in 1727-28 worked for this employer respectively 288, 264, 297, 296, and 300 days. For only 6 days in the year were all the workers absent implying that this was some kind of holiday. For example in Christmas week 1728 all the workers only worked 5 days.[6]

These estate and farm accounts, sparse though they are, do show that even long before the Industrial Revolution some rural workers were working 290 or more days per year. There was certainly no norm of short work weeks before 1770. Unless these regular employees were

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[6] Clark and van der Werf (1998).

very atypical agrarian workers as early as 1650 had labor inputs not unlike full time workers in the nineteenth century.

Another source of evidence on annual days worked is the annual earnings of full year employees relative to the average day wage. Workers paid by the year typically received a cash wage plus food and lodging. Where we are told the value of that food and lodging for the year we can infer the total value of compensation per year for annual workers. Assuming employers minimize labor costs this annual wage divided by the day wage will indicate the number of days worked per year by annual workers. In 1867-70 the ratio of annual to day wages is close to the 300 days that other estate account evidence suggests was the work year. Arthur Young's data for 1771 suggests a very similar picture of the agrarian work year, with no strong sign of a much lower expected yearly labor input. The data from one estate in Holkham in Norfolk in the 1730s, and from three wage assessments for the early eighteenth century again suggest that year round workers would be expected to work 300 close to 300 days per year. Again this is not much evidence, but it all points to a norm of a long work year as early as 1700.

These accounts also generally show much employment of irregular workers who work anything from one day to large chunks of the year. We do not know what these workers were doing the rest of the time – they may have been working for other employers, or working on their own holdings. But the fact that they were paid the same per day as the regular workers suggests that there was no special privilege attached to getting a year long job. And there was certainly work available for most of the year. If work was heavily seasonal, so that workers were only fully employed in the peak harvest periods, we would also expect the records of payments to workers would be concentrated also in summer. Instead, as table 4 shows, where the date of payments to workers is recorded in the years 1690 to 1729 these tend to be distributed fairly

evenly in the year, with only a modest July peak. Again the total payments made to workers each month show only modest evidence of a summer peak. Since hay and harvest wages were higher than in winter, the variation in days worked between July and the low payment months is small at best. The reason for this is clear when we look at the distribution for payments over the year by work type. While mowing and reaping were heavily concentrated in the summer months, activities like threshing and hedging, which were not so time sensitive, were concentrated in the winter months. Thus the peak month for threshing payments was December.

We thus see in these records of wage payments no indication that agricultural workers in 1700 behaved any differently in terms of days worked than those in 1850. Full time, year round work seems to have been the norm then as later. All this implies that output must indeed have grown by much less than everyone expects between 1700 and 1860, a mere 38%. There is no agricultural revolution.

TABLE 5: NUMBERS OF RECORDED WAGE PAYMENTS BY MONTH, 1690-1730

Month	All farm work		Threshing	Hedging, fencing and ditching
	Payments	Amount (£.)	Payments	Payments
January	173	103	43	18
February	208	89	41	22
March	211	168	50	21
April	229	78	33	35
May	224	68	24	21
June	195	79	14	7
July	244	157	13	10
August	166	134	7	10
September	219	74	21	8
October	205	90	27	15
November	196	77	48	12
December	204	91	52	16

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?

The answer, at least in part, lies in the fact that while Overton, Allen, Crafts, Harley and others who argue for an agricultural revolution based on population growth focus on agriculture as a producer of food, 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. 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 (Hatcher (1983, p. 68, p. 409)). By 1855, coal consumption per capita for domestic purposes had climbed to 0.73 tons per capita (Church (1983, p. 19)). 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.[7]

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.[8]

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.[9]

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[7] Assuming the trees were cut each 15 years. Wrigley (1988), p. 80, quotes the 10 acres per ton figure.
[8] 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).
[9] 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.

Table 6 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 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. Clark, Huberman and Lindert (1995) explore how the lack of growth of food consumption per capita might be possible in a period of income growth. 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 6: PRODUCTION AND IMPORTS OF FOOD, RAW MATERIALS AND ENERGY, 1700-1850

Period	Area	Population	Domestic Output Farm (£ m.)	Non-Farm (Coal) (£ m.)	Imports - Exports (£ m.)	Food, Energy, Raw Materials Per Capita (£)
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 estimated using figures given in Deane and Cole (1962).

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).

THE INDUSTRIAL REVOLUTION WITHOUT THE AGRICULTURAL REVOLUTION

These new estimates of agricultural output growth in the Industrial Revolution have 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 7 shows the revised growth estimates adjusting for slower agricultural growth as I have outlined.

The latest Crafts and Harley estimates of economic growth suggest that real income per person grew by 98% between 1700 and 1861, and by 64% from 1760 to 1861. Interestingly Feinstein's study of real incomes suggests that the incomes of wage earners rose by only 35-40% from 1770 to 1861, significantly slower than the overall rate of growth. It is also 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. This is in line with the view of O'Brien (1996) that what was unusual about British experience in this period was the elimination of surplus labor from the agricultural sector.

TABLE 7: NEW ESTIMATED OUTPUT LEVELS, 1700-1860

Period	1700	1760	1801	1831	1861
GNP	100	138	194	348	544
GNP/N	100	110	110	129	144
Agriculture's assumed share in GNP(%)	49	49	32	29	18
Relative output/worker (Farm/non-farm)	.75	1.04	.84	.87	.93

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

Using the new output estimates for agriculture I find three things. The first is that output growth in the Industrial Revolution period was even slower than Crafts et al. pessimistically estimate. Output per person increases by only 44% between 1700 and 1861, compared to Crafts et als. 98%. In the years 1760 to 1861 the gain is 31%, not the old 64%. 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.

These new figures are more in concordance with Feinstein's estimates of real wages from 1770 to 1861. Further 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.

It also appears from these new estimates of agricultural output that GNP growth did not accelerate in the last 30 years of the Industrial Revolution as Crafts and Harley estimate. Instead because there was seemingly no growth of agricultural output in this period, the overall growth rate of output is slower between 1831 and 1861 than in the years 1801 to 1831.

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 5, 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 5: LAND AND LABOR PRODUCTIVITY IN EUROPEAN AGRICULTURE, 1850-1870
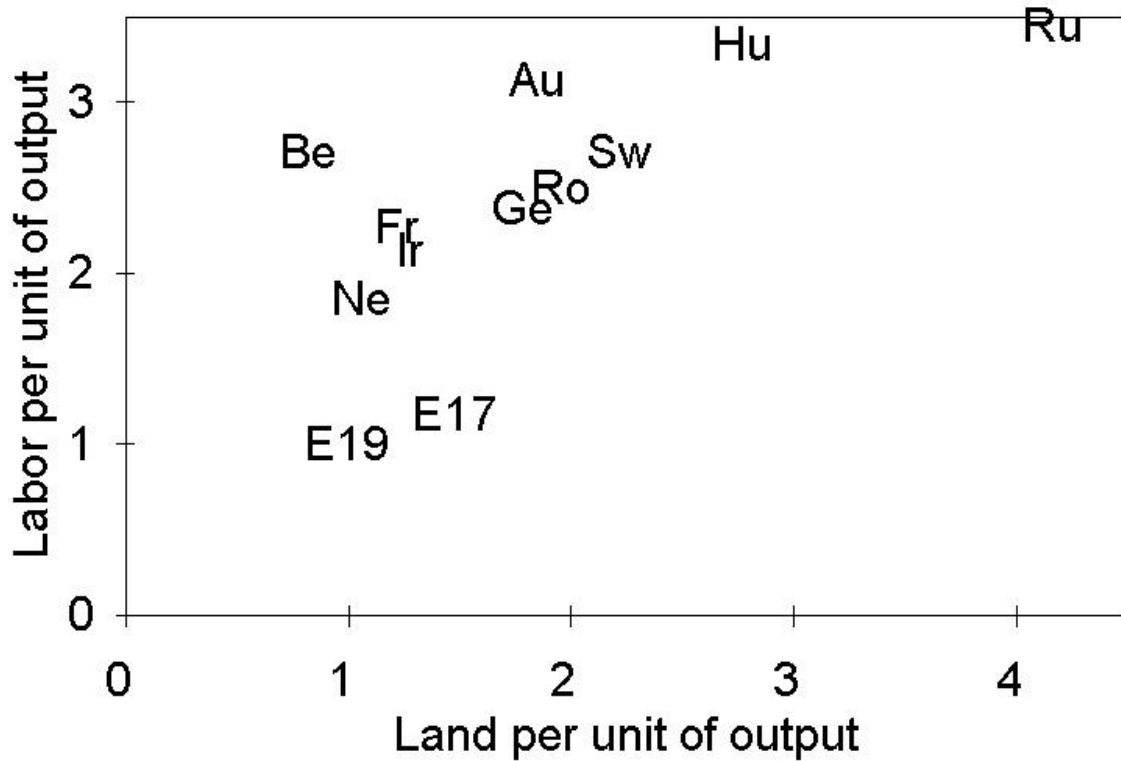
Note: "E19" is English agriculture in 1850. "E17" is English agriculture in 1700. "Ne" is the Netherlands, "Be" Belgium, "Fr" France, "Ir" Ireland, "Ge" Germany, "Ro" Romania, "Sw" Sweden, "Au" Austria, "Hu" Hungary, "Ru" Russia.

THE INDUSTRIAL REVOLUTION AS A DEMOGRAPHIC EVENT

The above revision portrays the Industrial Revolution as a much more limited event. Rapid productivity growth seems to have been confined to a few industrial sectors such as textiles. The bulk of the economy – agriculture, construction, retailing, and much of the manufacturing sector saw little productivity advance. This leads us to the question – what would have happened had Hargreaves, Arkwright, Crompton and the rest of their ilk not invented anything in textiles? How much different would the British economy have looked in 1860?

In a world without imports of food, it is clear what would have happened. As population grew both wages and average incomes per capita would have fallen rapidly, and expenditures on food as a share of total output would have increased. The industrial and urban share of the population would have decreased, and output in agriculture would have been increased by such techniques as the intensive spade cultivation of Ireland in the early nineteenth century, and by the reclamation of marginal lands. The Malthusian imperatives would have exerted themselves eventually, driving up the death rate and choking off the population growth.

But Britain was able to import food, and to pay with these imports, largely with exports of textiles but also with sales of other manufactured goods such as clothing, pottery, cutlery and stationary.[10] This trade using the technology of 1760 in textiles might have required somewhat lower wages among British workers, but there is no doubt of its possibility. If the tripling of population in England from 1760 to 1860 is viewed not as pushing on a resource base of 150,000 km^2 of land, but on a base of 9,600,000 km^2 for all of Europe where English population in 1750 was perhaps only 4% of total population then the population growth of 1760 to 1860 looks a lot less significant.

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[10] Temin (1997) gives a list of Britains major manufacturing exports in 1855.

The first thing to note is that the population growth of the years 1760 to 1860 seems to have been driven largely by changes in marital behavior that were exogenous to the economic system. Assuming that this population growth still took place between 1760 and 1860, the increased population would have to have found employment somewhere. The possibilities of increased agricultural employment seem to have been limited. By the 1830s, for example, many parishes in the south of England had surplus agricultural workers for whom little employment was found, even though the farmers had to pay to support them from the poor rates anyway. Thus population growth in England after 1760 implied industrialization. Employment in industry would have gone from 14% of the population to 48% (assuming that commerce, government and housing were always about 30% of GNP). Assuming just a constant output per worker in industry, and given the technology there is no reason why output per worker would have declined, this implies in turn that industrial output would have grown **twelve fold** from 1760 to 1860   Crafts and Harley estimate that industrial output, with the advantage of rapid technical advances in textiles, actually grew by 15 fold. Thus as long as Britain was able to export manufactures for farm products after 1760 we would expect to have seen industrialization, growing trade, and urbanization just as we saw with the revolution in textiles. The living standards of workers would certainly be lower in 1860, and perhaps considerably lower. The traditional textile industry of 1760 could still have supplied goods to exchange for agricultural imports. The quantities of textiles produced per worker would be much lower, but the terms of trade would presumably have been much better. As long as output per person stayed constant in England from 1760 to 1860 national income would have grown by 278% just from population growth alone.

The response to population growth of increasing industrial output and trade was not after all new in Europe. Between 1500 and 1650 the population of the Netherlands increased from about 950,000 to 1.9 million. Yet real wages fell by comparatively little from 1450-1500, only about 10-20%, and much less than in England in the same years even though the growth rate of population was similar. By 1675 the Netherlands was a highly urban society, with about 44% of the population living in towns, a far greater percentage than in England. It imported significant quantities of raw materials such as grain, timber, wine, wool, spices, and oil and exported manufactured goods, and trade services. Why do we not refer to this process in the Netherlands as the first "Industrial Revolution"? The answer is in part that the Netherlands subsequent to 1650 declined and even de-industrialized, and in part that there were no dramatic technical innovations associated with this process in the Netherlands. But if we now learn that English growth in output per head was much slower, that productivity advances in general were not the dominating feature, and that industrialization in England was perhaps through a similar process to the Netherlands then can we defend the English Industrial Revolution from the competition of its earlier Dutch counterpart?[11]

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[11] See de Vries and van der Woude (1997).

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