THE SECRET HISTORY OF THE INDUSTRIAL REVOLUTION

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

Sir Robert Filmer (1653).

When was the decisive break from the pre-industrial world of slow technological advance and stagnant living standards to the modern world of constant technological progress and steadily improving living standards? Most historians have assigned the dawn of the modern world to England in 1770. There has followed a long debate about the cause of the Industrial Revolution. Here I argue that there was no significant break in 1770 from the earlier world. That break only occurred later in the nineteenth century. Instead the Industrial Revolution was most likely the last of a series of localized growth spurts stretching back to the Middle Ages, as in the Netherlands from 1500 to 1660, and northern Italy in the fourteenth century. Accidents of demand, demography, trade, and geography made this spurt seem different than what had come before – but it was really more of the same.

Introduction

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

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

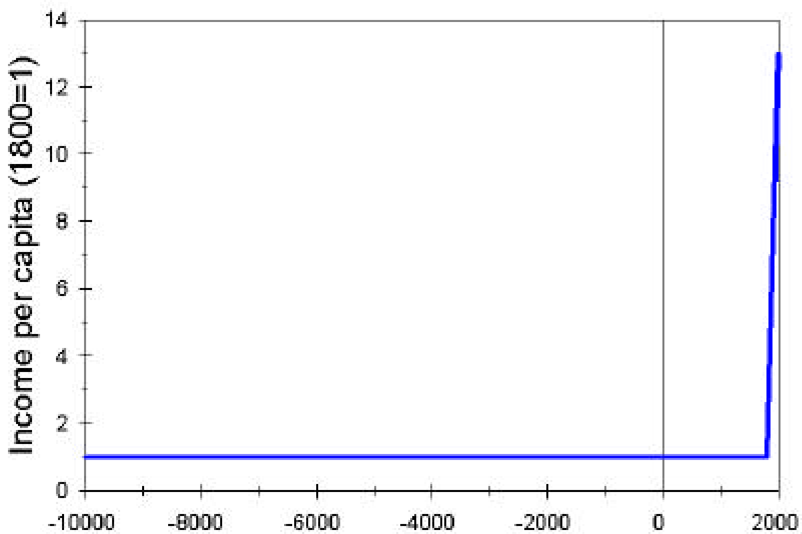
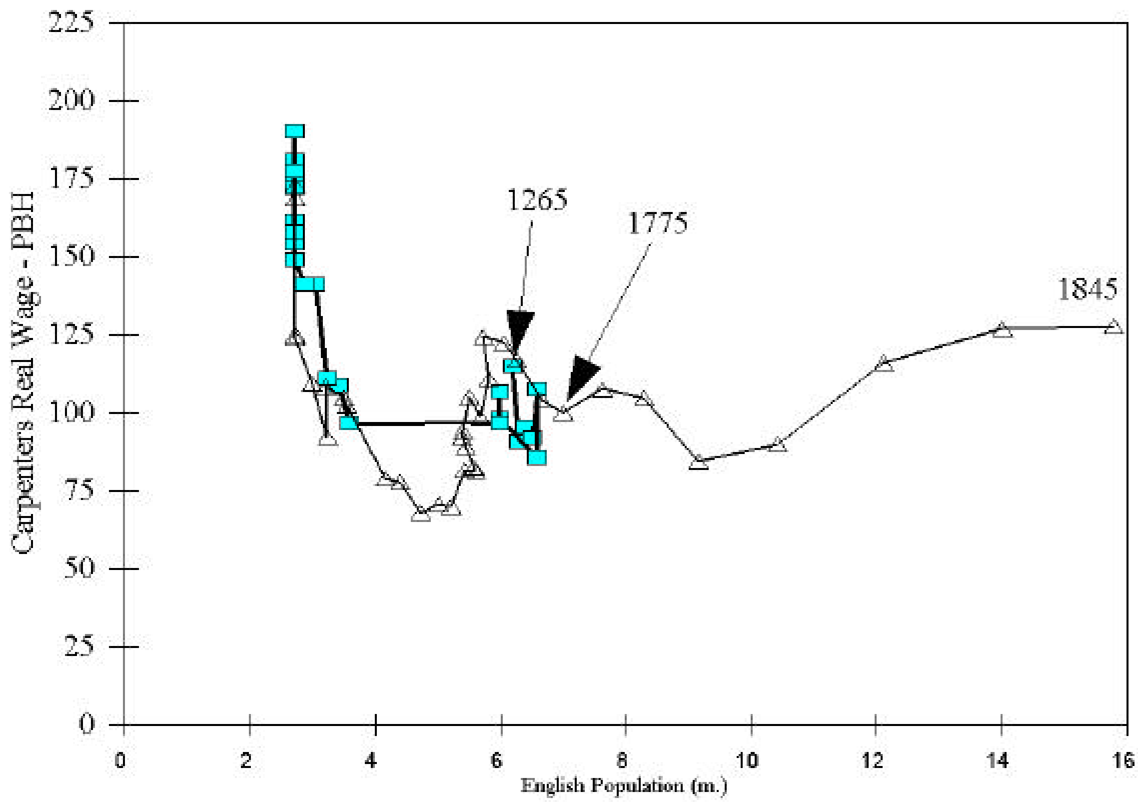


Figure 2, which shows English population in millions by decade from 1260-9 to 1840-9, and the real wages of craftsmen as measured by Phelps-Brown and Hopkins clearly suggests that something dramatic happened in the English economy between 1770 and 1860 after 500 years of stasis. Before 1770 population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

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



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

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

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

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

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

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

The arguments of the paper can be summarized in the ten points below

1. Growth of real output per capita, and of productivity was much slower in the Industrial Revolution than previous estimates have suggested. Even moderate rates of growth of output per person, by modern standards, did not appear till the 1870s.

2. Output per capita grew as rapidly in the bad old days of the Stuart monarchs and the Civil War in the seventeenth century as in the Industrial Revolution.

3. Pre-industrial England was a much wealthier economy than has previously been realized. Per capita real GDP in the 1760s, for example, was similar to that of Egypt and Indonesia in 1992. English per capita income was double that of Nigeria and Kenya, and four times that of Chad or Malawi.

4. Since per capita income in England in the late eighteenth century was more than half its level in the 1900s, when English per capita incomes are estimated by some scholars to have been nearly ten times those of India and China, Ken Pomeranz must be wrong to conjecture that incomes per capita were equivalent in the advanced parts of Asia with those of Europe in 1800.

5. The modest productivity growth rates of the Industrial Revolution owed mostly to productivity gains in one sector, textile manufacture.

6. It was accidents of demand, demography, and trade that allowed innovations in this sector to have a much bigger impact than previous innovations of similar magnitude in terms of productivity gains.

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

7. The southern two thirds of England saw almost no growth in output per capita or productivity growth in the Industrial Revolution.

8. Manual worker's real incomes in the Industrial Revolution period rose much more than did real output per capita, because of the consumption bundle they consumed, and because of the decline in real property incomes per person.

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

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

Estimating Output in England, 1260 to 1869

The strategy employed here is first to estimate the sum of all nominal incomes in the English economy from 1260 to 1869, then calculate real incomes by deflating using a GDP price deflator. Nominal incomes will be composed principally of five elements – wages and salaries, farmland rents, house rents, income from ownership of equipment and working capital and indirect taxes collected by local authorities and the national government.

Wages and salaries.

To derive estimates of total wage earnings over this long period I use just three series that we can measure relatively well. To measure farm wages I use day wages for male agricultural laborers. To measure wages in non-farm employments I take the average of the wages of building laborers and craftsmen. These nominal wages will on average be much higher than for farm workers because there is a premium of building laborers typically over farm laborers, and because I assume that a half of non-farm workers are skilled. The ratio of the wage of building craftsmen to building workers gives some information on the skill premium in the labor market. The ratio of building wages to agricultural wages tells us about the wage gap between rural and urban employments. Table 1 shows the resulting wage estimates.

After 1350 the wage structure was pretty stable over this long period, as figure 3 shows. In the figure the ratio of the day wages of building craftsmen to building laborers is shown, along with the ratio of the day wages of building laborers to farm laborers. As already noted by Phelps-Brown and Hopkins the ratio of craft wages to laborers wages in building changed little. The ratio of the wages of the mainly urban building workers relative to farm wages does show gains over these years as England became more urbanized. This means that in measuring nominal incomes for the labor force as a whole we need to estimate the share of the population employed in agriculture since the average wage level will depend on the allocation of labor between the sectors. Table 1 also shows the assumptions I made about the percentage of the population employed in agriculture. For 1801 and later we have census records to guide us in this. For the earlier years I have to make informed guesses. I have assumed, based on the estimated levels of real incomes, that before 1600 the share of the population employed in farming was always 60 percent.

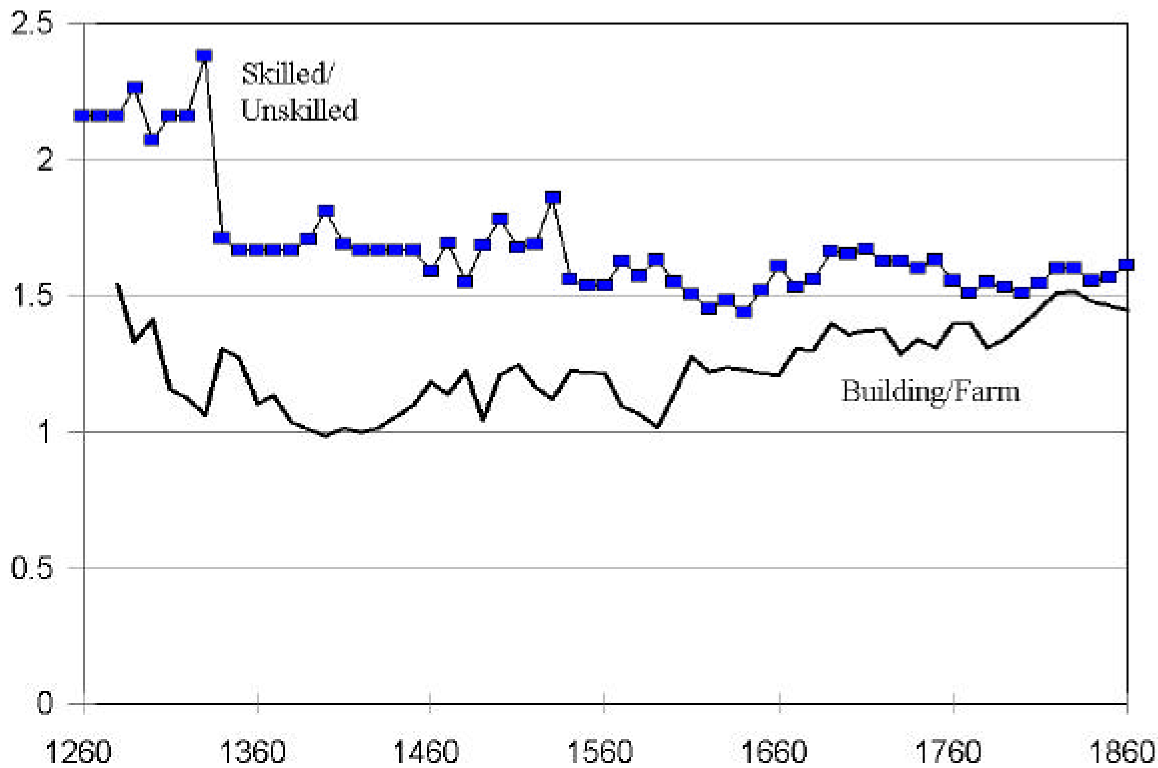
Table 1: English Wages, 1260-1869

Decade	Urban Craftsman Wage (d. per day)	Urban Laborer Wage (d. per day)	Farm Labor Wage (d. per day)	Assumed Share Farm	Overall Male Wage (d. per day)	Overall Wage (Feinstein) (d. per day)
1260-9	3.05	1.41	1.18	0.60	1.60	
1270-9	2.94	1.36		0.60	1.60	
1280-9	3.54	1.64	1.06	0.60	1.67	
1290-9	3.32	1.47	1.10	0.60	1.62	
1300-9	3.38	1.64	1.16	0.60	1.70	
1310-9	3.97	1.84	1.59	0.60	2.12	
1320-9	3.84	1.78	1.58	0.60	2.07	
1330-9	3.67	1.54	1.45	0.60	1.91	
1340-9	3.40	1.98	1.52	0.60	1.99	
1350-9	4.63	2.78	2.18	0.60	2.79	
1360-9	4.85	2.91	2.64	0.60	3.14	
1370-9	5.12	3.07	2.71	0.60	3.26	
1380-9	4.89	2.93	2.83	0.60	3.27	
1390-9	4.71	2.76	2.74	0.60	3.14	
1400-9	5.39	2.98	3.02	0.60	3.49	
1410-9	5.42	3.21	3.17	0.60	3.63	
1420-9	5.31	3.19	3.20	0.60	3.62	
1430-9	5.62	3.37	3.33	0.60	3.80	
1440-9	5.99	3.59	3.40	0.60	3.96	
1450-9	6.02	3.61	3.30	0.60	3.90	
1460-9	5.70	3.59	3.03	0.60	3.68	
1470-9	6.02	3.56	3.13	0.60	3.79	
1480-9	5.79	3.74	3.05	0.60	3.74	
1490-9	5.91	3.51	3.37	0.60	3.90	
1500-9	6.07	3.41	2.83	0.60	3.59	
1510-9	5.98	3.57	2.87	0.60	3.63	
1520-9	6.15	3.64	3.13	0.60	3.84	
1530-9	6.79	3.65	3.25	0.60	4.04	
1540-9	7.10	4.55	3.72	0.60	4.56	
1550-9	8.62	5.61	4.60	0.60	5.61	
1560-9	9.89	6.44	5.29	0.60	6.44	
1570-9	10.29	6.33	5.80	0.60	6.80	
1580-9	10.71	6.81	6.40	0.60	7.34	

Decade	Urban Craftsman Wage (d. per day)	Urban Laborer Wage (d. per day)	Farm Labor Wage (d. per day)	Assumed Share Farm	Overall Male Wage (d. per day)	Overall Wage (Feinstein) (d. per day)
1590-9	10.97	6.72	6.62	0.60	7.51	
1600-9	12.00	7.74	6.82	0.60	8.04	
1610-9	13.35	8.88	6.96	0.59	8.66	
1620-9	13.65	9.40	7.71	0.58	9.31	
1630-9	14.85	10.03	8.11	0.57	9.97	
1640-9	16.37	11.37	9.26	0.56	11.29	
1650-9	18.95	12.48	10.26	0.55	12.71	
1660-9	19.58	12.16	10.05	0.54	12.73	
1670-9	20.42	13.31	10.20	0.53	13.33	
1680-9	21.24	13.62	10.50	0.52	13.83	
1690-9	22.76	13.69	9.80	0.51	13.93	
1700-9	22.52	13.64	10.05	0.50	14.06	
1710-9	23.13	13.85	10.10	0.48	14.46	
1720-9	22.92	14.09	10.25	0.45	14.79	
1730-9	22.91	14.08	10.95	0.43	15.25	
1740-9	23.31	14.57	10.90	0.43	15.48	
1750-9	23.32	14.31	10.95	0.43	15.43	
1760-9	24.62	15.84	11.35	0.43	16.41	
1770-9	25.89	17.13	12.25	0.43	17.53	13.5
1780-9	26.89	17.38	13.30	0.43	18.33	14.5
1790-9	31.03	20.24	15.10	0.40	21.46	18.2
1800-9	40.40	26.78	19.20	0.36	28.41	24.5
1810-9	50.81	32.90	22.65	0.35	35.15	26.6
1820-9	47.83	29.89	19.80	0.33	32.53	22.6
1830-9	47.50	29.75	19.65	0.31	32.82	22.5
1840-9	47.09	30.28	20.50	0.28	33.59	23.9
1850-9	49.43	31.52	21.55	0.27	35.42	26.1
1860-9	55.08	34.15	23.60	0.23	39.78	29.5

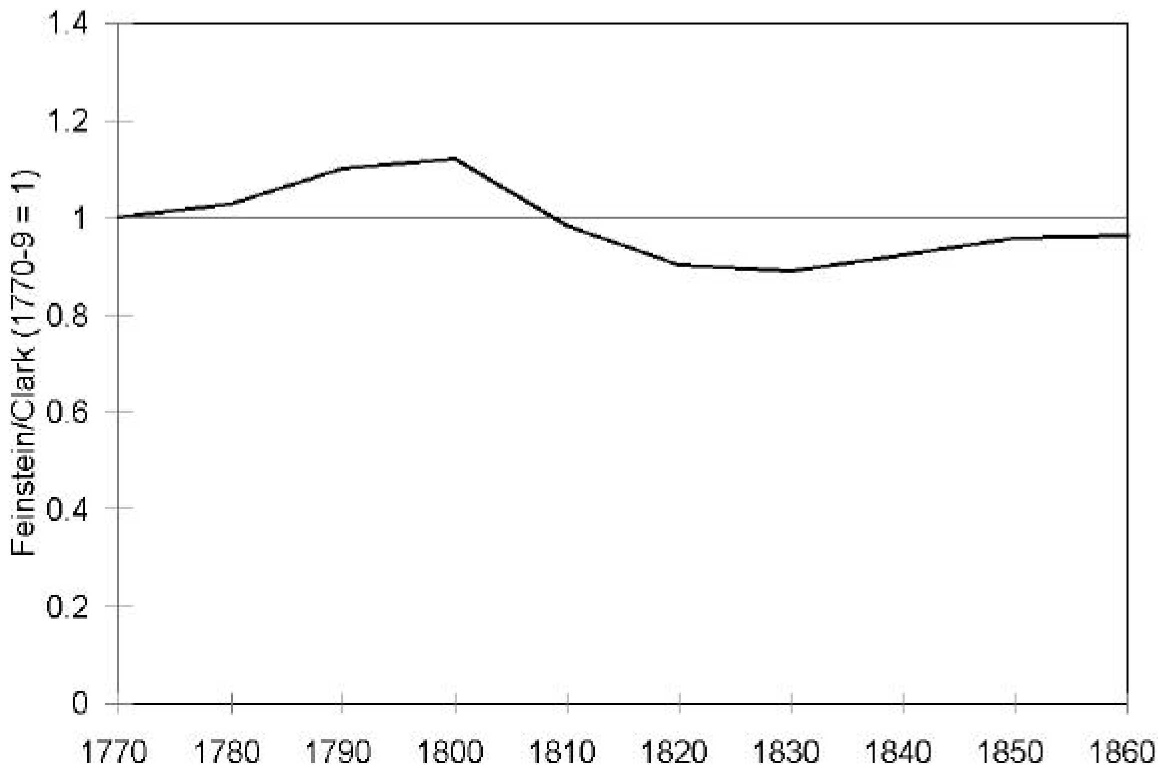
Notes: The level of the wages in any year does not matter since the purpose here only is to create an index of wage movements.

Figure 3: Relative Wages Skilled/Unskilled and Urban/Rural, 1260-1869



Source: Table 1.

Figure 4: Feinstein's Wage Index Relative to Clark, 1770-9 to 1860-9



Sources: Table 1, Feinstein (1998).

For comparison the more comprehensive wage measures of Feinstein that includes female workers, and many more occupations, for the years 1770-1869 are also shown. As can be seen generally the two wage measures move together for these years. My nominal wage series rises 121% between 1770-9 and 1860-9, compared to 118% for Feinstein. Figure 4 shows Feinstein's estimated wage index compared to mine for the decades 1770-9 to 1860-9. There are some deviations. But since I am using better measures of farm and building wages than Feinstein the deviations need not indicate a failure of this approach.[2] It does suggest that projecting back before 1770 with this simple measure should work relatively well. Also it shows that the unexpected results I get for the Industrial Revolution period owe little to the nominal wage series used.

Property Income.

I estimate of property income as the sum of the rental value of housing, public houses and shops, the rental value of farmland, and other forms of property income such as mineral rents, payments on turnpike mortgages, and canal and rail payments to capital owners. Table 2 shows estimates of population, and of implied farmland and building rental values from 1640 to 1869. The estimates for the years after 1841 are from the property tax returns and for "houses" include commercial property. The earlier data is inferred from the movement of rents on housing as derived above and on charity owned farmland. They are adjusted to be at the same level as the Property Tax data after 1840. The total rental value of "housing" is inferred as the rental value

[2] Feinstein's wage sources are generally weak for the years before 1820. Thus my building wage series deviates by about 20 percent from his in terms of the long term rise from 1770 to 1869.

per dwelling, multiplied by the estimated stock of non-farm houses.[3] Circa 1700 land rental values are almost four times house rental value. By 1860 land rental values are only about 75 percent of house rental values.[4] As land declined as a source of property income, other real assets became much more important, and show up in the accounts of charities. These included mineral rents, turnpike mortgages, canal bonds and shares, and railway bonds and shares. For the years after 1842 we get tax data on the extent of these rents. For the years before I can approximate the rental earnings from the transport and mining sectors using various sources that are poorer the further back I go. But it does not matter much to the estimate of rental income per capita, since these sources of rental income only become important in the nineteenth century. The fourth column of table 2 shows these estimated other rental incomes. Even when we add in these other sources which increase rapidly in the mid nineteenth century with the arrival of the railroads and the growth of coal mining, the overall trend in the Industrial Revolution period is for nominal property incomes to increase very little. Thus while from 1760-9 to 1860-9 nominal wage income per person more than doubled, nominal property income per person increased by 50% or less.

The numbers in table 2 omit other sources of rental income that it is very difficult to derive information on: farmer's capital, and manufacturing and commercial capital for example. But based on Feinstein's estimates of net domestic assets in 1860 the rentals reported in table 9 represent the returns on 82 percent of private domestic assets in 1850, and 78 percent in 1760.[5]

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

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

[5] Feinstein, "Appendix", pp. 437, 439, 464-5.

Thus the inclusion of the rents on these other assets is unlikely to change the overall conclusion that rental incomes per capita grew less quickly than wage income in the Industrial Revolution period because of the decline in farmland rents per capita.

The final two columns in table 2 show the sums collected in indirect taxes. For the national government we have counted here customs and excise charges. There were also taxes by local governments that also functioned as indirect taxes (taxes collected before the wage or property incomes listed in our sources). Thus both land and house occupiers had to pay local rates, which rates have to be added to property income to get the total amount of property income generated. The total amount of poor rate payments for the years before 1812 where official figures are not available was estimated from the records of 24 parishes in Bedford, Cambridge, Dorset, Essex and Warwick.

Table 2: English Property Incomes, 1260-1869

Decade	Land and Farmhouse rental values (£. m)	Houses, Shops etc. Rental values (£. M)	Mines, Canals, Railways etc. (£. m)	Property Income per Capita (£.)	Local Rates (£. m)	Indirect Taxes (£. m)
1260-9	2.08	*0.42*	*0.00*	0.40	*0.00*	*0.00*
1270-9	1.72	*0.41*	*0.00*	0.34	*0.00*	*0.00*
1280-9	1.93	*0.50*	*0.00*	0.38	*0.00*	*0.00*
1290-9	2.14	*0.48*	*0.00*	0.40	*0.00*	*0.00*
1300-9	2.29	*0.48*	*0.00*	0.42	*0.00*	*0.00*
1310-9	2.34	*0.54*	*0.00*	0.44	*0.00*	*0.00*
1320-9	2.57	*0.45*	*0.00*	0.50	*0.00*	*0.00*
1330-9	2.45	*0.40*	*0.00*	0.47	*0.00*	*0.00*
1340-9	2.10	*0.39*	*0.00*	0.42	*0.00*	*0.00*
1350-9	2.07	*0.31*	*0.00*	0.66	*0.00*	*0.00*
1360-9	2.31	*0.29*	*0.00*	0.76	*0.00*	*0.00*
1370-9	2.17	*0.28*	*0.00*	0.75	*0.00*	*0.00*
1380-9	2.41	*0.23*	*0.00*	0.86	*0.00*	*0.00*
1390-9	2.06	*0.20*	*0.00*	0.78	*0.00*	*0.00*
1400-9	1.97	*0.21*	*0.00*	0.80	*0.00*	*0.00*
1410-9	1.90	*0.22*	*0.00*	0.78	*0.00*	*0.00*
1420-9	1.73	*0.21*	*0.00*	0.71	*0.00*	*0.00*
1430-9	1.85	*0.23*	*0.00*	0.76	*0.00*	*0.00*
1440-9	1.78	*0.24*	*0.00*	0.74	*0.00*	*0.00*
1450-9	1.78	*0.24*	*0.00*	0.74	*0.00*	*0.00*
1460-9	1.82	*0.23*	*0.00*	0.76	*0.00*	*0.00*
1470-9	1.36	*0.24*	*0.00*	0.59	*0.00*	*0.00*
1480-9	1.58	*0.24*	*0.00*	0.67	*0.00*	*0.00*
1490-9	1.56	*0.23*	*0.00*	0.66	*0.00*	*0.00*
1500-9	1.61	*0.24*	*0.00*	0.68	*0.00*	*0.00*
1510-9	1.61	*0.24*	*0.00*	0.68	*0.00*	*0.00*
1520-9	1.61	*0.26*	*0.00*	0.69	*0.00*	*0.00*
1530-9	1.61	*0.28*	*0.00*	0.69	*0.00*	*0.00*
1540-9	2.41	*0.38*	*0.00*	0.93	*0.00*	*0.00*
1550-9	2.41	*0.54*	*0.00*	0.91	*0.00*	*0.00*
1560-9	3.08	*0.64*	*0.00*	1.16	*0.00*	0.17
1570-9	3.08	*0.78*	*0.00*	1.10	*0.00*	0.17
1580-9	4.80	*0.98*	*0.00*	1.63	*0.00*	0.17
1590-9	4.80	*1.42*	*0.00*	1.49	*0.00*	0.17

Decade	Land and Farmhouse rental values (£. m)	Houses, Shops etc. Rental values (£. M)	Mines, Canals, Railways etc. (£. m)	Property Income per Capita (£.)	Local Rates (£. m)	Indirect Taxes (£. m)
1600-9	12.03	1.81	*0.00*	3.14	*0.00*	0.17
1610-9	12.88	2.29	*0.00*	3.21	*0.00*	0.23
1620-9	12.68	2.79	*0.00*	3.08	*0.00*	0.28
1630-9	13.49	3.14	*0.00*	3.19	*0.00*	0.36
1640-9	14.47	4.28	*0.00*	3.46	0.13	0.37
1650-9	14.76	4.46	*0.00*	3.42	0.18	0.51
1660-9	16.62	4.43	*0.00*	3.77	0.20	0.53
1670-9	15.29	4.31	*0.00*	3.59	0.22	0.96
1680-9	15.90	4.41	*0.00*	3.76	0.33	0.96
1690-9	15.15	4.39	*0.00*	3.63	0.42	1.63
1700-9	15.07	4.51	0.17	3.59	0.48	2.47
1710-9	16.33	4.69	0.18	3.73	0.69	3.07
1720-9	17.54	5.01	0.20	3.91	0.81	3.60
1730-9	17.08	4.92	0.24	3.88	0.75	3.73
1740-9	15.76	5.03	0.28	3.48	1.05	3.64
1750-9	19.85	5.23	0.39	4.07	1.05	4.43
1760-9	19.89	5.88	0.56	3.95	1.36	5.96
1770-9	23.19	9.43	0.83	4.78	1.83	6.56
1780-9	22.99	8.57	1.05	4.28	2.44	8.35
1790-9	28.20	10.38	1.53	4.83	3.65	11.53
1800-9	38.97	17.53	2.25	6.41	5.30	23.23
1810-9	49.79	24.57	3.15	7.43	7.94	30.58
1820-9	43.47	30.21	3.18	6.34	7.51	31.03
1830-9	41.34	35.19	4.04	5.75	6.97	27.53
1840-9	42.34	36.98	7.06	5.16	7.02	27.86
1850-9	41.94	43.44	11.45	5.14	7.50	30.20
1860-9	46.31	60.18	19.29	5.95	9.47	32.22

Notes: Numbers in italics are those estimated indirectly, or not at all. All rental incomes from 1842 on are from the Property Tax returns. Land and house rents are from the Charity Commission reports. "Houses" here include public houses, shops, and other commercial property. The rents of commercial properties are assumed to be the same relative to houses for the years before 1842. Rental incomes from coal mining, canals and turnpikes was approximated for the years before 1842 from the sources listed.

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

Nominal GDP

In table 3 I set out by decade a very rough calculation of gross domestic income per capita for England and Wales between 1260-9 and 1869 calculated by the income approach. The second column shows calculated wage income on two assumptions: the average days worked per year were the same throughout, and the fraction of women in employment did not change (I make no assumption here about the length of the work day. I shall give some evidence on this below). The total estimated wage income is fixed in the decade 1860-9 using Leone Levi's estimate for 1866 of wage and salary earnings. His wage estimates are close to those of Feinstein's for the same year. The third column shows calculated property income including local taxes levied on property occupiers. The fourth column shows all indirect taxes from table 2. These numbers are summed in column 5 to give all income except the return on the working capital of farmers, manufacturers and traders, and entrepreneurial returns. But it does cover a very large share of GDP. Column seven shows nominal GDP calculated by Deane and Cole from 1801 on. Since they calculated this for Britain I reduce it to a total for England and Wales assuming GDP per capita was the same in Scotland as in England and Wales. For the benchmark decade of the 1860s the GDP I calculate is 92 percent of the full GDP reported by Deane and Cole. I thus inflate all my nominal GDP estimates by 9% to allow for these missing returns, and assume that they were a constant share of GDP over time. This gives the last column of the table.

Table 3: National Income, England and Wales, 1700-1869

Decade	Wages and Salaries (£. m)	Property Income+taxes on occupiers (£. m)	Indirect Taxes (£. m)	Nominal GDP (£. M)	GDP (Deane and Cole) (£. m)	Nominal GDP adjusted for missing capital income (£. m)
1260-9	4.9	2.51	*0.00*	7.40		8.05
1270-9	5.0	2.13	*0.00*	7.09		7.72
1280-9	5.3	2.43	*0.00*	7.70		8.38
1290-9	5.2	2.62	*0.00*	7.81		8.50
1300-9	5.5	2.78	*0.00*	8.30		9.04
1310-9	6.9	2.87	*0.00*	9.75		10.61
1320-9	6.1	3.02	*0.00*	9.14		9.95
1330-9	5.6	2.85	*0.00*	8.50		9.25
1340-9	5.9	2.50	*0.00*	8.36		9.11
1350-9	4.9	2.38	*0.00*	7.32		7.97
1360-9	5.3	2.60	*0.00*	7.88		8.58
1370-9	5.2	2.44	*0.00*	7.65		8.33
1380-9	4.9	2.64	*0.00*	7.56		8.23
1390-9	4.5	2.26	*0.00*	6.71		7.30
1400-9	4.7	2.17	*0.00*	6.84		7.45
1410-9	4.9	2.11	*0.00*	6.97		7.59
1420-9	4.8	1.94	*0.00*	6.79		7.39
1430-9	5.1	2.07	*0.00*	7.16		7.79
1440-9	5.3	2.02	*0.00*	7.31		7.96
1450-9	5.2	2.02	*0.00*	7.25		7.89
1460-9	4.9	2.06	*0.00*	6.98		7.60
1470-9	5.1	1.60	*0.00*	6.68		7.27
1480-9	5.0	1.82	*0.00*	6.82		7.42
1490-9	5.2	1.80	*0.00*	7.03		7.65
1500-9	4.8	1.85	*0.00*	6.65		7.24
1510-9	4.9	1.85	*0.00*	6.71		7.30
1520-9	5.1	1.87	*0.00*	7.01		7.63
1530-9	5.4	1.89	*0.00*	7.30		7.95
1540-9	6.7	2.79	*0.00*	9.51		10.35
1550-9	8.9	2.96	*0.00*	11.90		12.96
1560-9	10.2	3.72	0.17	14.07		15.32
1570-9	11.7	3.86	0.17	15.75		17.15
1580-9	12.8	5.79	0.17	18.81		20.47

Decade	Wages and Salaries (£. m)	Property Income+taxes on occupiers (£. m)	Indirect Taxes (£. m)	Nominal GDP (£. M)	GDP (Deane and Cole) (£. m)	Nominal GDP adjusted for missing capital income (£. m)
1590-9	15.4	6.22	0.17	21.79		23.72
1600-9	17.4	13.84	0.17	31.42		34.21
1610-9	20.2	15.18	0.23	35.58		38.74
1620-9	23.0	15.47	0.28	38.75		42.18
1630-9	25.6	16.63	0.36	42.55		46.32
1640-9	30.1	18.88	0.37	49.39		53.77
1650-9	35.1	19.39	0.51	55.02		59.90
1660-9	35.0	21.25	0.53	56.75		61.78
1670-9	35.8	19.81	0.96	56.57		61.59
1680-9	36.8	20.63	0.96	58.35		63.53
1690-9	36.9	19.97	1.63	58.53		63.71
1700-9	38.1	20.24	2.47	60.85		66.24
1710-9	40.5	21.90	3.07	65.47		71.28
1720-9	42.4	23.57	3.60	69.53		75.70
1730-9	43.0	22.97	3.73	69.68		75.85
1740-9	46.1	22.12	3.64	71.88		78.25
1750-9	47.6	26.53	4.43	78.52		85.48
1760-9	53.9	27.69	5.96	87.54		95.30
1770-9	60.4	35.28	6.56	102.25		111.32
1780-9	68.7	35.05	8.35	112.14		122.08
1790-9	87.6	43.75	11.53	142.91		155.58
1800-9	128.2	64.05	23.23	215.51	217	234.62
1810-9	180.4	85.45	30.58	296.46	250	322.74
1820-9	194.0	84.36	31.03	309.35	259	336.78
1830-9	226.4	87.53	27.53	341.47	319	371.75
1840-9	276.7	93.40	27.86	397.99	403	433.28
1850-9	328.2	104.33	30.20	462.78	485	503.81
1860-9	414.0	135.24	32.22	581.45	633	633.00

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

Sources: Deane and Cole, British, p. 166. Tax receipts are from Mitchell, Abstract, pp. 386-8, 392-3, 410. The other sources are as for tables 1 and 2.

Comparing my estimates in the last column with Deane and Coles' in the second last column we see that even though the incomes were equalized for 1860-9, for every decade before then I find more nominal income, sometimes as in the 1810s as much as 30 percent more. How can I derive such radically different estimates of nominal income? Deane and Cole derived information on all incomes other than wages primarily from the statistics of the income and property tax levied in 1803-1815 and 1842-1861. There is a long gap in the tax information from 1816-1841 because in these years there was no income or property tax. Further the legislation ending the first tax at the end of the Napoleonic Wars called for destruction of all the tax records to prevent the information in them being used to aid the reimposition of an income tax. The income tax was reimposed in essentially the same form as for the years 1803-1815 in 1842. This later tax seems to have been fully assessed. The assessed value of land, for example, was high compared to other information on rents in the years after 1842. Deane and Cole thus naturally assumed full assessment of most income categories under the earlier period of income taxation. Using the benchmarks this gave them for 1801 and 1811 they interpolated incomes in the years 1821 and 1831 from ancillary information.

Unfortunately there is good evidence that the first experiment with an income tax in 1803-1815 did not produce full assessment of most property incomes, and that indeed the underassessment was substantial. For I have been able to construct a rental series on farmland in England from 1500 to 1912, and on housing from 1640 to 1912 which suggests strongly that the earlier tax assessments undervalued rental values. The charity rent series suggest an under assessment in the tax returns of 1806-9 of 32 percent for houses and 36 percent for land. For 1810-14 the underassessment is 41 percent for houses and 38 percent for land.[6] The discussions

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

on the Income Tax of 1801-1814 are silent on the question of how the authors know incomes were assessed in full.[7] Though the tax was based on assessing the annual values of property, the years 1790-1815 saw rapid growth in house and land rental values. Many properties were let on leases of 21 years or longer, so the even if the assessments were made according to the rules the assessed value for taxes would be well below market rental values.

When Nick Crafts published his revised growth estimates for Industrial Revolution England in 1985 he was troubled primarily by Deane and Coles choice of a price index for the years before 1831, and so accepted their income and price estimates as reliable for the years 1831 and later. Table 4 shows these nominal income estimates. The Deane and Cole estimate of a nominal income of £284 m. (on an England and Wales basis) for 1831 is about 20% too low based on the estimates of tables 2 and 3 above.

The GDP Deflator.

To convert nominal GDP into real output we need a GDP deflator. This is the most troubling part of our calculation. For the GDP deflator should cover only domestically produced goods, or only the domestic component of production. Thus in cotton textile production it should cover only the value added in manufacturing since all the raw cotton was imported. For food it should cover only the domestically produced share of various foods. Thus the raw material for sugar was imported but then it was refined in Britain. But while we have prices series for most goods consumed in quantity by working class consumers, we are missing price series for more high income commodities such as house wares, furniture, books, firearms, and

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

clocks. The prices that are readily available tend to be those for raw materials, and in particular for imported raw materials.

Deane and Cole relied on the Rousseaux index of 1938 to calculate real GDP. But Rousseaux uses mainly wholesale prices, and the unit values of imports of agricultural commodities and industrial raw materials. It is clearly not the right price index. Table 4 also shows the Rousseaux price index for these years. Its very high level in 1801 and 1811 helped produce the very low real income estimates of Deane and Cole for 1801 and 1811.

To construct a better GDP deflator I use the price series listed in table 5. The price for the last decade the good appears in is set to 100. The farm price listed is an index of the prices of sixteen English farm outputs weighted by their relative shares in the value of output in the 1860s. The goods whose prices are relatively high in the earlier years are the ones that experienced the relatively greater productivity advance. Cotton and linen cloth, for example, cost about twelve times as much in the years before 1350 as did farm products than in the 1860s. The overall price level is formed as a geometric average of the individual price series with the weights being updated decade by decade. That is, if p_{it} is the price index for each commodity i in year t, and a_i is the expenditure share of commodity i, then the overall price level in each year, p_t is calculated as,

$$p_t = \prod_i p_{it}^{a_i}$$

This implies that if the relative price of an item such as housing increases consumers adapt by reducing relative purchases of the item to the degree that the share of expenditures on each item remains constant.

Table 4: Deane and Coles' Nominal Income and Prices, 1801-1871

Period	Deane and Cole Nominal National Income (£ m.)	Rousseaux Price Index (1860-1869 = 100)
1801	196	142
1811	254	152
1821	243	92
1831	284	92
1841	379	97
1851	441	90
1861	560	100
1871	762	99

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

Table 5: The Price Series in the GDP Deflator

Period	Farm	Beer /Cider	Coal	Light	Hous-ing	Service, Govt., Etc.	Shoes	Cotton /linen	Wool cloth	Manufact-ured goods	Invest-ment	Iron Exports
Weight, 1760	0.51	0.03	0.01	0.01	0.07	0.19	0.04	0.025	0.04	0.08	0.00	0.00
Weight, 1860	**0.27**	**0.05**	**0.03**	**0.02**	**0.11**	**0.21**	**0.05**	**0.07**	**0.04**	**0.00**	**0.12**	**0.03**
1260-9	7	6			8	4		116		13		
1270-9	9	6			7	4		87		10		
1280-9	8	6		19	9	5		88		9		
1290-9	9	5		13	8	4		123		9		
1300-9	10	7		26	8	5		130		12		
1310-9	13	7		26	9	5		160		19		
1320-9	13	7		25	8	5		162		10		
1330-9	11	6		24	7	5		133		15		
1340-9	11	6		23	7	6		132		11		
1350-9	12	8		26	9	8		346		23		
1360-9	13	9		28	9	9		292		23		
1370-9	14	9		26	9	9		289		23		
1380-9	11	6		23	8	9		223		20		
1390-9	11	6		21	8	8		231	22	21		
1400-9	11	6		20	8	9		189	23	20		
1410-9	11	8		19	9	9		187	24	26		
1420-9	10	6		20	9	9		189	22	28		
1430-9	11	7		19	9	10		165	23	27		
1440-9	10	8		19	10	11		162	24	25		
1450-9	10	8	21	15	10	11		161	23	21		
1460-9	10	11	22	17	9	11		173	24	23		
1470-9	10	16	29	14	10	10		172	24	20		
1480-9	10	7	15	17	10	11		155	25	20		
1490-9	10	8	19	13	10	10		158	25	21		
1500-9	11	7	15	14	10	10		158	25	15		
1510-9	11	8	17	15	10	10		153	25	21		
1520-9	13	9	27	15	10	11		151	24	24		
1530-9	14	8	23	17	11	11		153	25	27		
1540-9	17	10	23	20	12	13		149	27	24		
1550-9	26	11	36	32	15	16	19	181	38	32		
1560-9	27	14	27	39	17	19	26	228	52	44		
1570-9	28	11	39	38	16	19	41	271	55	41		
1580-9	32	12	39	42	21	20	44	331	56	38		
1590-9	41	20	52	50	20	20	37	324	60	41		
1600-9	42	22	54	53	24	23	43	342	70	53		
1610-9	49	25	60	58	26	26	49	329	74	62		
1620-9	49	28	63	60	28	28	48	364	75	69		
1630-9	57	33	75	66	28	29	49	361	79	69		
1640-9	57	31	96	71	34	33	49	295	81	72		
1650-9	57	27	93	69	34	37	57	299	83	85		
1660-9	56	35	96	71	34	36	63	366	80	79		

Period	Farm	Beer /Cider	Coal	Light	Hous-ing	Service, Govt., Etc.	Shoes	Cotton /linen	Wool cloth	Manufact-ured goods	Invest-ment	Iron Exports
1670-9	55	35	96	65	34	39	60	394	75	103		
1680-9	54	39	83	61	36	40	65	357	75	81		
1690-9	58	41	114	68	36	40	67	370	80	108		
1700-9	52	43	117	63	36	40	65	382	86	104		
1710-9	56	43	112	76	36	41	75	410	83	131		
1720-9	55	45	108	73	32	41	82	408	82	126		
1730-9	51	48	107	68	32	41	87	394	77	65		
1740-9	53	48	117	82	27	43	86	406	78	99		
1750-9	57	48	120	80	27	42	87	402	75	116		
1760-9	60	48	119	86	37	46	87	386	72	136		167
1770-9	68	58	127	91	40	50	88	360	73	130	48	167
1780-9	71	62	134	95	44	51	85	409	72	100	54	187
1790-9	87	63	154	104	49	59	95	357	77		65	178
1800-9	124	85	198	134	73	78	117	288	85		90	219
1810-9	136	98	202	146	87	96	112	266	95		109	190
1820-9	99	100	164	89	89	88	110	150	89		98	139
1830-9	92	82	122	93	92	87	107	103	91		96	115
1840-9	91	75	91	92	81	89	100	71	95		97	103
1850-9	91	91	98	105	87	92		69	89		95	109
1860-9	100	100	100	100	100	100		100	100		100	100

Notes:

Since prices of different goods were moving in very different ways the weighting of the elements of the price series is very important. Weights were derived in part with guidance from the 1851 census of occupations, and in part from estimates of the share of housing rents and government expenditures on goods and services. Table 5 shows the weights adopted for the 1760s and 1860s. Table 6 shows the distribution of workers, measured in adult male equivalents, in 1851. Table 6 reveals, for example, that personal service was an important part of the economy, even in 1851. Servants of every description, innkeepers, hairdressers, washerwomen, clergy, doctors, gamekeepers, and teachers formed 13.2% of the labor force. But the government was also an important actor, with 2.3% of employees in 1851. In the absence of better information I have assumed that the cost of government services was indexed by the wage rate. Finally clothing can be separated into two components: the manufacture of thread and cloth, and the fashioning of the final articles of clothing. In 1851 while 11.0% of the labor force was engaged in the manufacture of cloth and yarn, a further 5.7% were engaged in transforming this cloth into clothing and selling it to consumers. Since there is no indication of any productivity advance in this area I have again assumed that the price of clothing manufacture is again indexed by the wage rate. This explains why a full 21% of the economy in the 1860s is allocated to "services."

Table 6: Distribution of Occupations, 1851

Region	England and Wales	England and Wales (%)	North (20+)	North (20+) (%)	South (20+)	South (20+) (%)
All Occupations	6,313,053		1,572,140		3,773,383	
Cotton and Linen Textiles	353,075	**5.6**	198,922	**12.7**	57,243	**1.5**
Worsted	114,178	**1.8**	46,652	**3.0**	36,922	**1.0**
Wool Textiles	120,822	**1.9**	66,348	**4.2**	29,295	**0.8**
Silk Textiles	86,380	**1.4**	27,450	**1.7**	38,266	**1.0**
All Textile Manufacture	694,363	**11.0**	344,970	**21.9**	172,208	**4.6**
Clothing Manufacture	357,907	**5.7**	80,389	**5.1**	220,769	**5.9**
Coal	191,193	**3.0**	71,705	**4.6**	83,808	**2.2**
Iron and Steel	204,646	**3.2**	58,172	**3.7**	115,880	**3.1**
Shoe Manufacture	292389	**4.6**	67763	**4.3**	194767	**5.2**
Agriculture	1,685,498	**26.7**	296,460	**18.9**	1,144,365	**30.3**
Services	832,386	**13.2**	148,678	**9.5**	530,008	**14.0**
Government	147,956	**2.3**	23,241	**1.5**	119,502	**3.2**

Notes: Workers in adult male equivalents based on relative wages of men, women, boys and girls. "Services" includes domestic servants, teachers and governesses, laundresses, clergy, lawyers, doctors, gamekeepers, musicians, innkeepers, chimney sweeps, hairdressers, nurses, among other occupations.

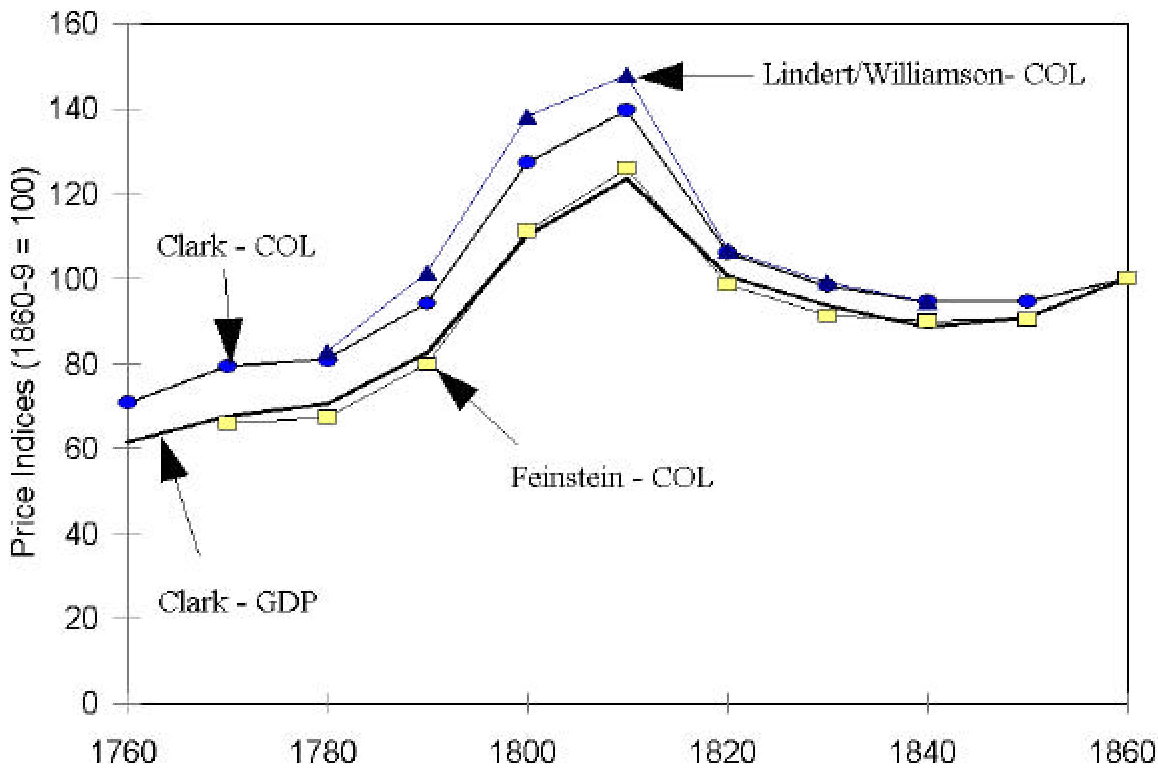
With the data listed above we get the GDP price deflator shown in table 7. Also shown is a separate price index calculated for the expenditures of manual workers, and the Feinstein price index for manual workers. Figure 5 shows the three price indices for the years 1760-9 to 1860-9, with 1860-9 set at 100, as well as the 1985 cost of living index of Lindert and Williamson. My GDP deflator by coincidence is very close to the cost of living deflator constructed by Feinstein for manual workers, even though the indexes were constructed with a different weighting scheme, and they give very different weightings to different commodities. Thus the workers cost of living index includes sugar and tea, imported goods that do not appear at all in the GDP deflator. Also while the GDP deflator assumes that in the 1860s 21% of output was produced using just labor with no productivity advance in these sectors, the Feinstein worker cost of living index assumes workers consume no services. The cost of living index I construct, however, shows significantly less price increase over the Industrial Revolution than my GDP price index, and is close to that of Lindert and Williamson. Clark (2001) explores the reasons why this index is more optimistic on living standards than is Feinstein's. Workers costs of living rise less rapidly than prices in the economy as a whole in part because the food they consume was heavily composed of imported grains, sugar and tea - commodities whose prices rose less quickly than those of domestic farm output. From 1760-9 to 1860-9 the price of domestic farm output increased by 67% as a whole, but wheat prices rose only 36% because of large foreign imports while beef prices rose by 106%, beef being less transportable. Wheat consumed as bread constituted about one third of working class budgets, however, while for richer consumers wheat would be a much smaller share and beef a larger share.

Table 7: Real GDP per Capita and Wages, England and Wales, 1260-1869

Decade	GDP Deflator	Working Class Cost of Living	Feinstein Cost of Living	Real GDP per Capita	Real Manual Day Wages	Feinstein – Real Wages
1260-9	7.5			57.9		
1270-9	8.5			48.5		
1280-9	8.2			53.5		
1290-9	8.6			50.4		
1300-9	9.5			48.0		
1310-9	12.3			43.5		
1320-9	11.6			47.7		
1330-9	10.3			50.1		
1340-9	10.2			49.5		
1350-9	13.1			56.6		
1360-9	13.3			63.0		
1370-9	14.2			60.4		
1380-9	11.4			78.8		
1390-9	11.3			74.7		
1400-9	11.7			78.2		
1410-9	12.2			76.2		
1420-9	11.3			80.5		
1430-9	11.6			82.4		
1440-9	11.3			86.2		
1450-9	11.1			87.1		
1460-9	11.1			83.8		
1470-9	10.9			82.2		
1480-9	11.0			82.5		
1490-9	11.3			83.3		
1500-9	11.4			78.1		
1510-9	12.0			74.5		
1520-9	13.5			69.5		
1530-9	14.3			68.4		
1540-9	16.7			69.1		
1550-9	24.3			55.1		
1560-9	26.9			59.3		
1570-9	27.7			59.0		
1580-9	31.3			61.4		
1590-9	37.5			50.7		
1600-9	40.0			64.9		
1610-9	45.9			59.6		
1620-9	46.4			60.5		

Decade	GDP Deflator	Working Class Cost of Living	Feinstein Cost of Living	Real GDP per Capita	Real Manual Day Wages	Feinstein – Real Wages
1630-9	52.5			56.6		
1640-9	53.9			61.4		
1650-9	54.6			65.3		
1660-9	54.5			67.9		
1670-9	54.6			69.1		
1680-9	54.1			72.7		
1690-9	57.9			68.2		
1700-9	54.5			73.8		
1710-9	57.5			72.8		
1720-9	56.9			76.4		
1730-9	51.4			86.2		
1740-9	54.9			78.7		
1750-9	57.4			79.4		
1760-9	61.7	70.9		77.3	58.2	
1770-9	67.8	79.4	66.0	78.3	55.5	66.8
1780-9	70.5	81.0	67.5	75.9	56.9	68.3
1790-9	82.6	94.2	79.8	75.8	57.3	67.6
1800-9	110.2	127.3	111.2	77.6	56.1	64.3
1810-9	123.6	139.6	125.9	83.6	63.3	70.2
1820-9	100.6	106.1	98.6	92.3	77.1	82.9
1830-9	93.7	98.4	91.3	94.6	83.9	90.3
1840-9	88.5	94.6	90.1	97.7	89.3	93.7
1850-9	90.7	94.6	90.4	98.5	94.1	98.5
1860-9	100.0	100.0	100.0	100.0	100.0	100.0

Figure 5: The Different Price Indices, 1760-1860



Note: Lindert and Williamson COL series set to 94.6 in the 1840s (same as Clark 1840s) since it does not run beyond 1851.

Sources: Feinstein (1998), Lindert and Williamson (1985).

Dividing nominal national income by the GDP deflator gives us real GDP. Table 7 reports real GDP per capita by decade as well as real day wages. Also reported are Feinstein's recent estimates of real day wages. Figure 6 shows the implied estimate of GDP per capita from 1610-9 to 1860-9, as well as real GDP per capita estimated by Feinstein for the years 1870-1914 spliced to this series. Growth of output per person was much less in the Industrial Revolution than even the pessimistic estimates of Crafts and Harley suggested. Figure 7 shows the new estimates for the Industrial Revolution years only compared to Deane and Cole and Crafts and Harleys' earlier estimates. The deviation of the new estimates from those of Crafts and Harley largely stems from the very slow growth estimated for the decades 1830-9 to 1860-9. For the years before 1831 Crafts and Harley show very similar amounts of growth to these estimates.

Output per person increased by only 29% from 1760 to 1860, or at a rate of 0.26% per year, compared to Craft's estimate of a 73% gain (0.54% per year). Compared to modern growth rates of output per person this is an order of magnitude slower. Also there is a clear acceleration in the rate of growth of output per person in the 1870s, after the end of the classic Industrial Revolution period. The growth rates of output per person in the Industrial Revolution are also not much faster than was achieved in the seventeenth century in the bad old days of the Stuart monarchs, the Civil War, and Cromwell. Output grew at 0.25% per year between 1580-1629 and the 1680s, the same as in the Industrial Revolution era. Indeed if we fit a long run trend line with growth of output at 0.20% per year from 1600 to 1869 then there is very little deviation all the way through, as the figure shows. Also if output had continued to grow at the trend rate of the Stuart monarchy all the way from 1600 to 1860-9 then income per capita would have been about 14% higher in the 1860s than was achieved. What shows up more is a late eighteenth century

Figure 6: Real GDP per Person, England, 1600-1914

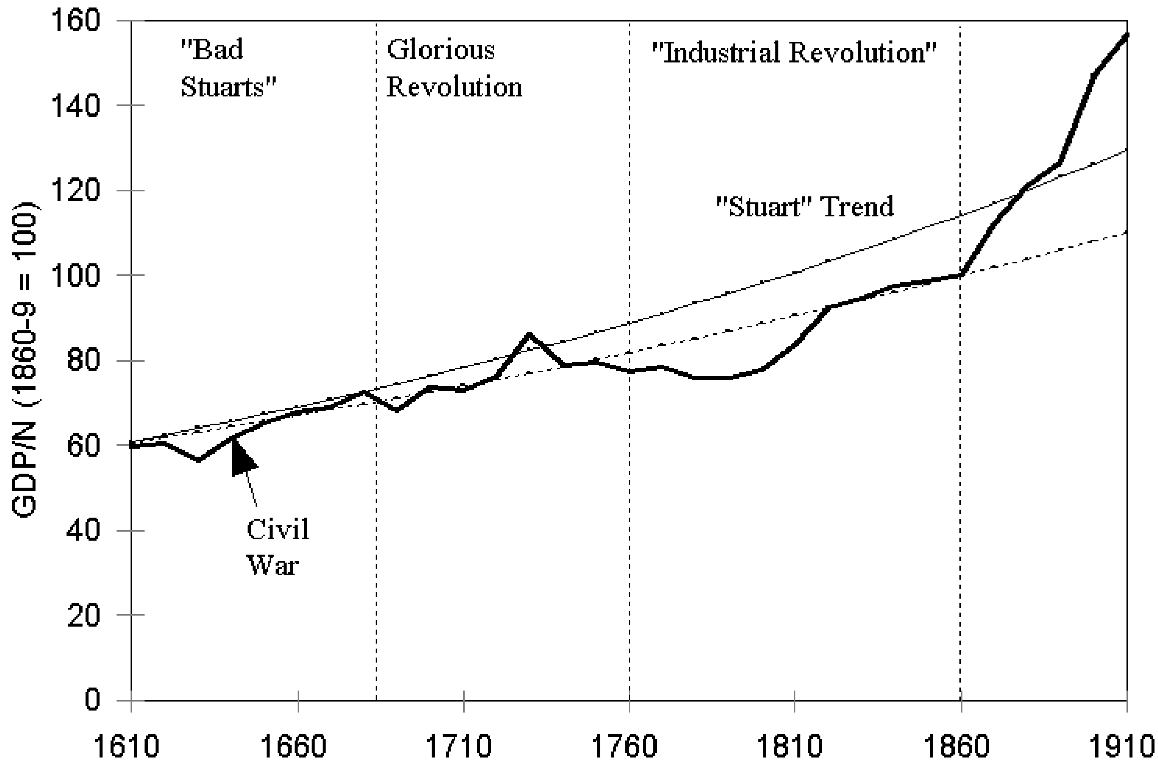
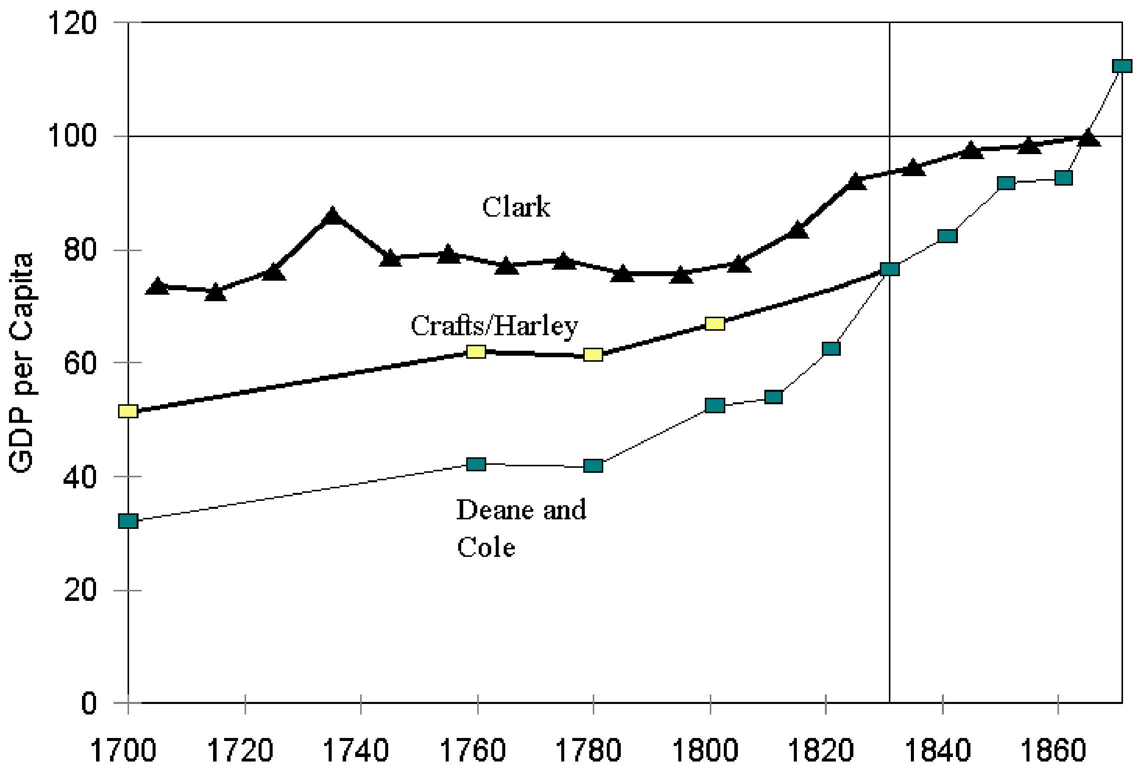


Figure 7: Real GDP per Person, England, 1700-1869 – Estimates Compared



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

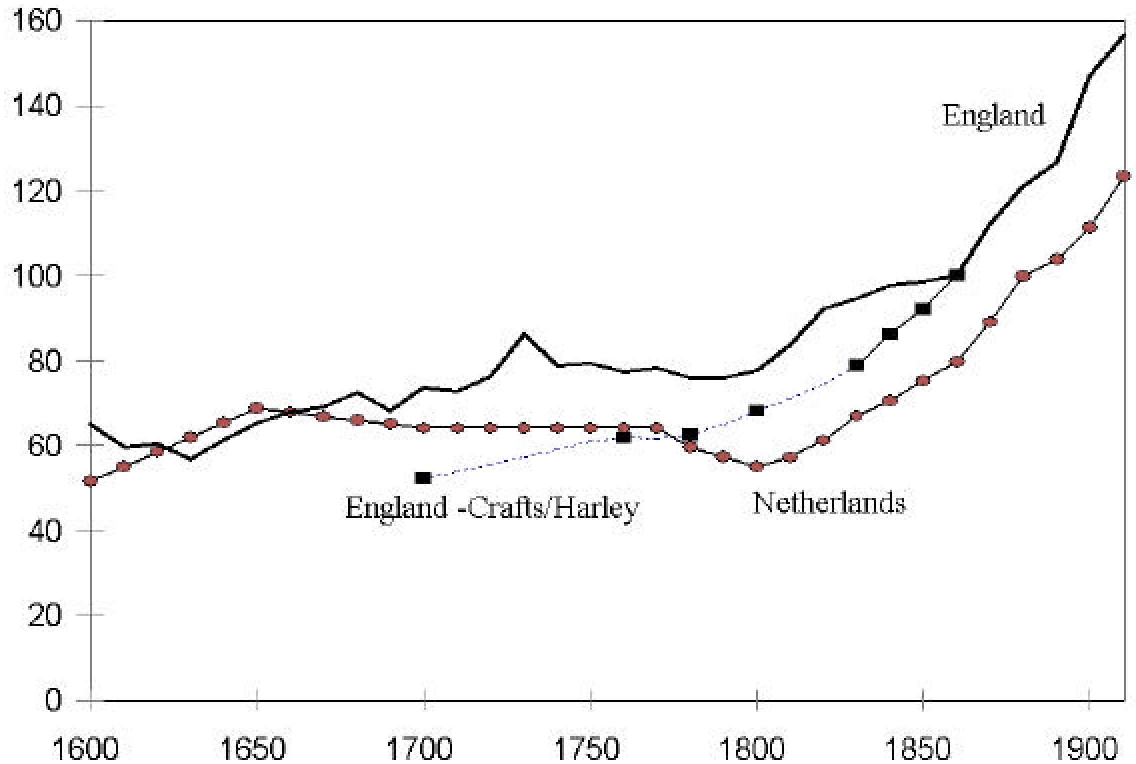
Source: Deane and Cole, British, pp. 78, 166, 170. Crafts and Harley, "Output Growth," p. 715, Crafts, British, p. 45.

pause in the growth of income per capita followed by some catch up in the early nineteenth century.

One way to test the plausibility of these numbers is to consider what they imply for English real GDP per capita relative to Dutch GDP. Recently Smits, Horlings and van Zanden have estimated Dutch GDP from 1807 to 1913. De Vries has tentatively carried these estimates back to 1600. Figure 8 shows the combined estimate of real Dutch GDP per person compared to my estimates of real English GDP per person, and the Crafts/Harley estimates. I have assumed that Dutch real GDP per capita in 1913 was 79 percent that of England, based on Prados (2000). If the Crafts/Harley view of the Industrial Revolution is correct then Dutch GDP per capita was nearly 25 percent greater than English in 1700. There was a steady erosion in the relative position of the Netherlands till the 1810s, when Dutch GDP per person is only 80 percent of English. England passes the Netherlands in GDP per capita only circa 1780. But from the 1810s till 1913 England and the Netherlands have the same rate of real GDP growth, so that there is no further widening of the English advantage. Thus the eighteenth century is the period when England grew unusually fast compared to the Netherlands.

The implication of the new estimates developed here is that the English actually overtook the Dutch in terms of output per capita in the 1660s, and that by the 1750s Dutch output per capita had fallen to about 82 percent of English. England made substantial gains relative to the Netherlands in the Napoleonic War years so that by the 1820s Dutch output per capita was down to 66 percent of English, but in the next forty years the Netherlands grew faster than England so that by the 1860s the gap had narrowed to 80 percent.

Figure 8: English versus Dutch GDP per capital, 1600-1913

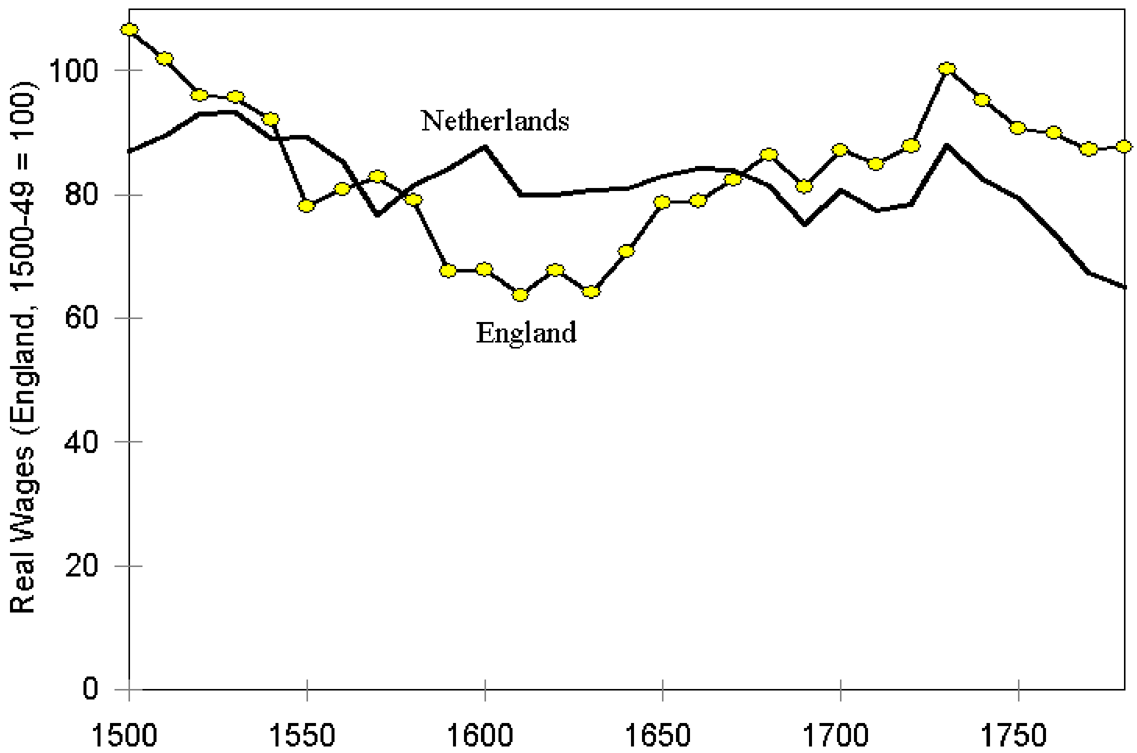


The new estimates of GDP developed here can be shown to accord with that we know of real wages in England and the Netherlands from 1500 to 1780, while the old estimates are implausible in light of the real wage evidence. Figure 9 shows, for example, the calculated real wage of Dutch versus English building craftsmen from 1500 to 1789 by decade. The English real wage is calculated by converting the nominal wage into purchasing power in terms of GDP. The Dutch real wage was calculated by converting the Dutch and English nominal wages into their silver equivalents, and assuming that an ounce of silver purchased the same amount of goods in each economy. For this reason the wage series were not continued into the years 1780-1819 even though the Dutch data exists, since in most of those years the English had suspended the convertibility of the currency.

Dutch real wages overtake English in the 1550s, and remain higher than the English until the 1670s. In the first half of the seventeenth century Dutch wages were nearly 25 percent higher than English. But by the 1680s the substantial rise in English real wages had carried them beyond the Dutch. In the first half of the eighteenth century English real wages were about 12 percent higher than the Dutch. By the 1780s when the Crafts/Harley/Deane/Cole view would put England and Dutch GDP per person at about the same level Dutch wages are estimated to be 74 percent of English. Since these wage comparisons are based on the purchasing power of silver being equal between the two economies, there is certainly some margin for error. But the error would have to substantial indeed to make possible the old view of the Industrial Revolution.[8]

[8] de Vries and van der Woude report English real wages as being substantially below Dutch wages all the way from the 1540s to the 1800s, which would be consistent with the Crafts/Harley/Deane/Cole view. Indeed they show English wages from 1600 to 1700 at only about half the level of the Western Netherlands. But this is based on the Phelps-Brown and Hopkins series for building wages which has many deficiencies in these years.

Figure 9: English and Dutch Building Craftsmen Real Wages, 1500-1789



Note: Dutch wages are the average of those for the East and West Netherlands reported by Jan De Vries and Ad van der Woude. I assumed that there was one master craftsman form every two journeymen.

Sources: Table 1. De Vries and van der Woude (1997).

The real GDP per capita estimates can be carried back all the way to 1260-9, though with increasingly fragile assumptions having to be made about some elements such as the population or house rentals. Estimated GDP per capita in the very long run is shown in figure 10. The figure shows that if we want to define growth epochs just on the basis of the growth of GDP per capita then there seem to be two transitions in the data. A transition from almost no long run growth of income per capita in the years 1260 to 1600, to a period of modest growth rates of GDP per capita in 1600 to 1860, and a transition towards modern growth rates of GDP per capita in 1860.

These revised GDP figures also imply that relative to many modern economies England was a relatively rich economy in the pre-industrial period. Table 8 shows the estimated GDP per capita of England in 1992 $ compared with some other economies in 1992. Per capita real GDP in the 1760s, for example, was similar to that of Egypt and Indonesia in 1992. English per capita income was double that of Nigeria and Kenya, and four times that of Chad or Malawi.

Focusing on GDP per capita as an indicator of growth ignores the important role of population relative to a limited land base in determining income in the pre-industrial world. It was the collapse of population after the onset of the Black Death in 1349 which seemingly explains the high levels of income in the years 1350-1500. Figure 11 shows real GDP per capita relative to population. All the observations from 1260-9 to 1630-9 can plausibly be regarded as showing an economy with a fixed technology and varying supplies of labor relative to land. Thereafter the economy deviates increasingly from this pre-industrial tradeoff, with the deviation beginning in the seventeenth century. Now the Industrial Revolution period looks more promising as representing a significant break from the past. From the 1800s on there are increasingly large steps away from the old trade off. The rise in GDP per capita is modest, but it

Figure 10: Real GDP per Person, England, 1260-1914

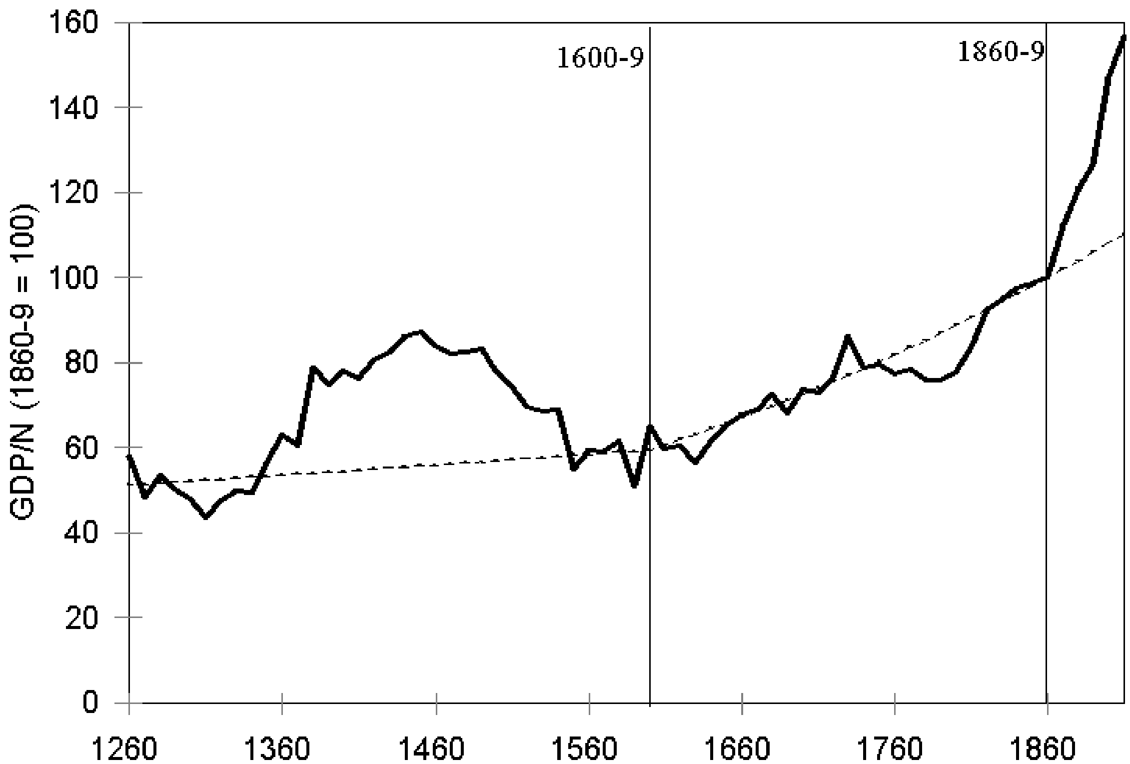
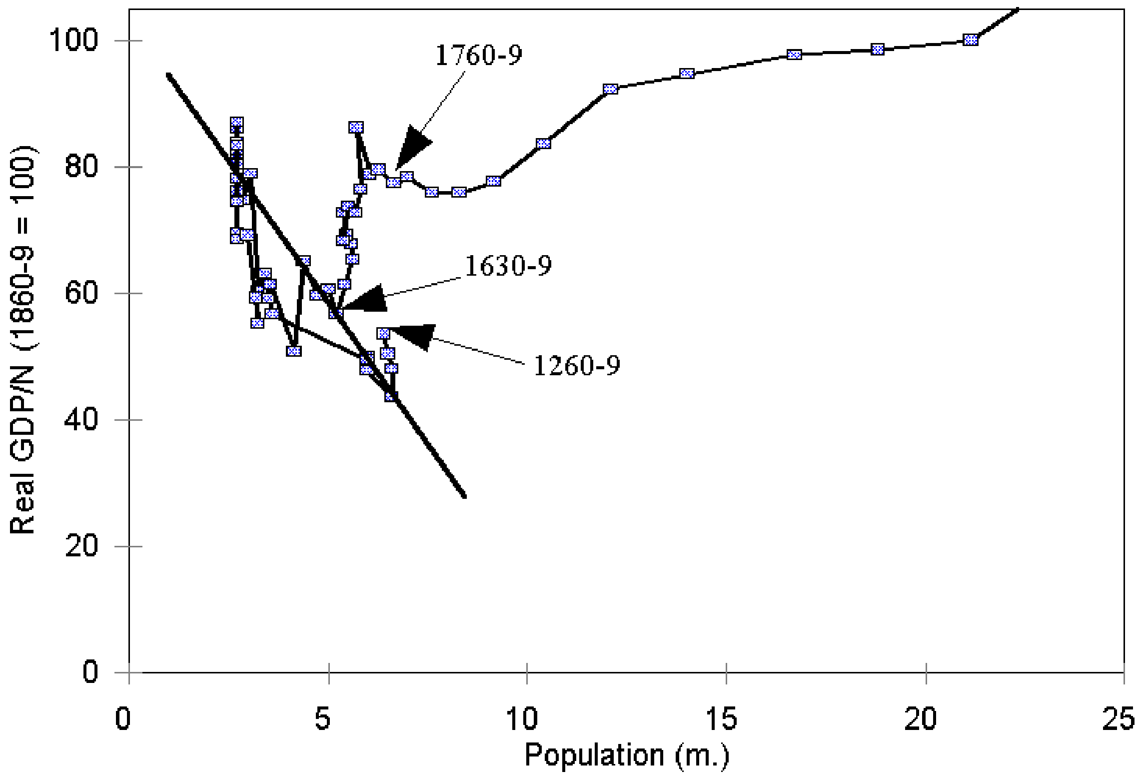


Table 8: GDP per Capita in England Relative to Modern Economies.

Country	Year	Income per capita (1992 $)
UK	**1992**	**16,302**
Mexico	1992	7,867
Bulgaria	1992	6,774
Iran	1992	4,161
South Africa	1992	3,885
England	**1860s**	**2,982**
Indonesia	1992	2,601
England	**1400s**	**2,382**
England	**1760s**	**2,359**
Egypt	1992	2,274
Bolivia	1992	2,066
India	1992	1,633
England	**1300s**	**1,464**
Ghana	1992	1,249
Kenya	1992	1,176
Nigeria	1992	1,132
Malawi	1992	607
Chad	1992	504

Figure 11: GDP per Capita relative to Population



is the ability to maintain or increase GDP per capita in the face of large population increases that is remarkable. Below, however, I will argue that this appearance of a dramatic break from the past owes not to more rapid technological advance mainly, but to the unusual circumstances of the demographic boom in England.

Total Factor Productivity

Did England experience unusual total factor productivity growth in the period after 1760, even if it did not achieve levels of output per capita growth that were any greater than what had come before? Productivity growth in principal is straightforwardly estimable once we know both the costs of the inputs of capital, labor and land and the average price of output. The level of productivity will then be

$$A = \prod_j \left(\frac{w_j}{p} \right)^{q_j}$$

where ωj is the cost of input j, and θj is the share of input j in total costs and *p* is the output price index. The rate of productivity growth is similarly

$$g_A = \sum_j q_j \frac{\dot{w}_j}{w_j} - \frac{\dot{p}}{p} \quad .$$

Complications arise, however, first in the form of taxes. Indirect taxes will drive a wedge between input and output prices. We can deal with this by reducing prices proportionate to the share of indirect taxes in national income. Taxes on land occupiers will again drive a wedge between costs and output prices. In this case we again can just reduce output prices proportionately. Table 9 shows these indirect taxes as a share of income in each year from 1600 to 1869 and the corresponding adjusted output price index.

The shares of labor and land in national income are also shown for each decade in the table. By the 1860s land rents as a share have fallen to a very small level. This implies that by the nineteenth century the drag of population on incomes will be very weak, as a result of food imports that stopped land rents from showing the rise that Ricardo expected.

The next complication comes in the form of land rents. If all land rents were payments to the site value there would be no issue here. But in practice a lot of rent paid in English agriculture, perhaps as much as 40% of land rents, was for capital improvements to the land – houses, barns, fences and investments in soil fertility. If we treat all land rent as site value rent then we will tend to overestimate productivity growth. In table 9 below I estimate productivity gains under the assumption that all land rents are payments to site value, but this should represent an overestimate of the likely productivity gains.

Finally we need to consider whether the hours of work per day changed over this period. Joachim Voth reports estimated hours worked per day to be relatively constant over the years 1760-1830. I, however, find distinct signs of a decline in work hours per day for building workers between the 1750s and the 1860s. Building contractors sometimes charge for labor by the hour as well as by the day. This allows us to calculate the implied number of hours per day, using the method outlined in Clark and van der Werf (1998). These hours estimates, given in table 10, show a clear decline in hours from 12 per day beginning in the 1790s to 10 or less in the 1860s. That implies that the true labor costs in the economy rose by about 20% relative to the day wage index if we assume the trend for building workers was general. In table 9 I have thus

Table 9: Total Factor Productivity, England, 1600-1869

Decade	Indirect taxes as share of GDP	Adjusted GDP deflator	Estimated day wage (10 hour day)	Labor Share in Income	Land Share in Income	TFP (all land rents site value)
1580-9	0.009	33.3	6.12	0.63	0.24	51.9
1590-9	0.007	39.9	6.26	0.65	0.20	44.7
1600-9	0.005	42.6	6.70	0.51	0.35	53.6
1610-9	0.006	48.9	7.22	0.52	0.33	50.3
1620-9	0.007	49.4	7.76	0.55	0.30	51.8
1630-9	0.008	55.7	8.31	0.56	0.29	49.0
1640-9	0.009	57.2	9.41	0.57	0.27	52.2
1650-9	0.011	57.7	10.60	0.59	0.25	55.7
1660-9	0.012	57.6	10.61	0.57	0.27	57.2
1670-9	0.019	57.3	11.11	0.59	0.25	57.8
1680-9	0.020	56.7	11.52	0.59	0.26	60.0
1690-9	0.032	60.0	11.61	0.60	0.25	56.3
1700-9	0.045	55.7	11.72	0.60	0.24	59.9
1710-9	0.053	58.3	12.05	0.60	0.24	60.1
1720-9	0.058	57.3	12.33	0.59	0.25	62.1
1730-9	0.059	51.7	12.71	0.60	0.24	68.1
1740-9	0.060	55.2	12.90	0.63	0.21	63.9
1750-9	0.064	57.5	12.86	0.59	0.25	64.8
1760-9	0.077	61.0	13.67	0.61	0.23	63.7
1770-9	0.075	67.1	14.61	0.59	0.23	63.5
1780-9	0.088	68.8	15.27	0.62	0.21	63.4
1790-9	0.098	79.8	18.19	0.62	0.20	65.5
1800-9	0.122	103.6	25.15	0.62	0.19	69.5
1810-9	0.119	116.5	34.12	0.63	0.18	80.5
1820-9	0.114	95.4	31.28	0.65	0.15	87.1
1830-9	0.093	91.0	32.82	0.67	0.12	93.7
1840-9	0.080	87.1	33.93	0.69	0.11	96.7
1850-9	0.075	89.9	36.14	0.70	0.09	98.9
1860-9	0.066	100.0	40.59	0.70	0.08	100.0

Table 10: Hours of Work per Day, Building Workers, 1800-1869

Decade	Towns	Observations	Simple average length of day (hours)	Average length of day (controlling for town and craft) (hours)
1750	1	2	12.0	12.0
1760	1	3	12.0	12.0
1770	-	-	-	-
1780	1	3	12.1	12.1
1790	1	8	11.8	11.8
1800	3	15	11.3	11.3
1810	4	20	10.3	10.3
1820	4	35	10.3	10.4
1830	5	21	9.9	10.0
1840	4	23	9.8	9.9
1850	5	24	9.7	9.8
1860	3	29	9.8	9.8

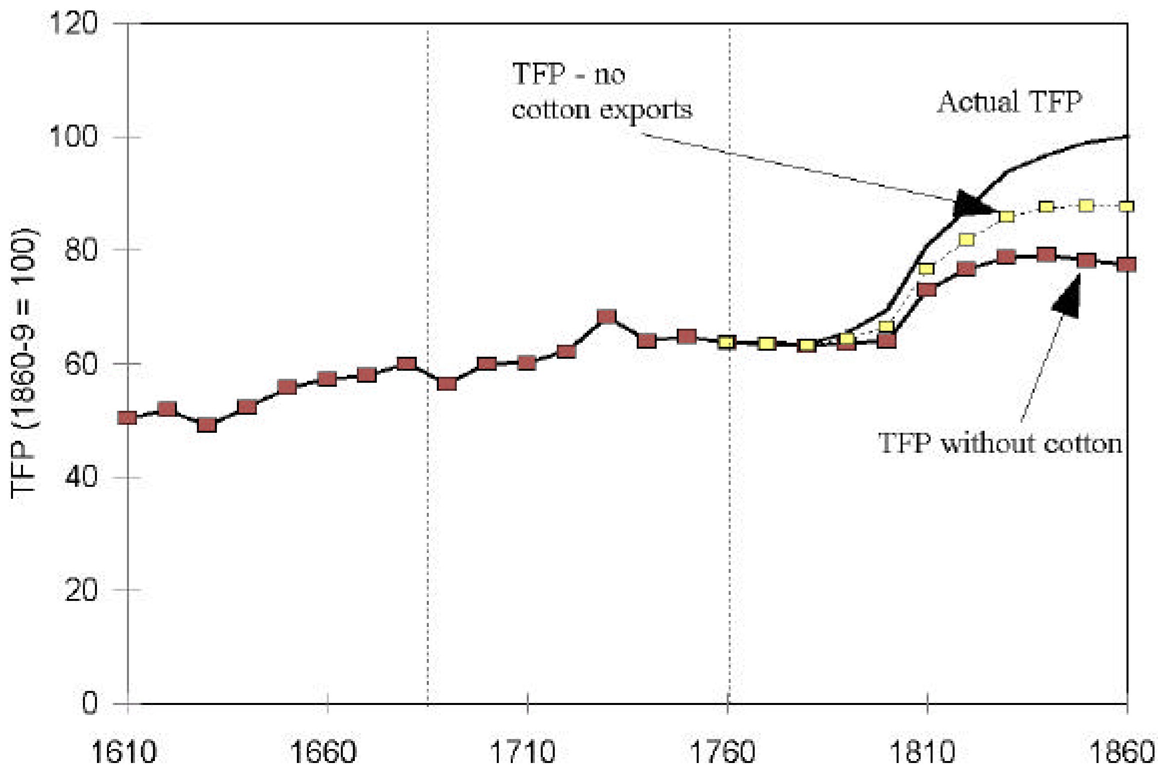
Note: The towns supplying observations are Barking, Bristol, Chelmsford, Colchester, Exeter, Hull, and Leicester.

Source: Bristol Record Office, Town Treasurer's Vouchers. Devon Record Office, Exeter Town Treasurers Vouchers. Essex Record Office, Quarter Session Vouchers. Leicester Record Office, Quarter Session Vouchers.

used a day wage series that normalizes hours to 10 per day, assuming that before 1790 all days were 12 hours. Since this is based just on observations on the hours per day of a few building craftsmen in Bristol and Exeter in the earlier years, and since Voth found to the contary new sign of any change in hours from the 1750s to the 1830s, the correction is somewhat speculative. It will, however, dispose me to find more productivity growth in the Industrial Revolution period than just assuming a constant length of day. If there was no decline in work hours per day then measured productivity in the economy would be about 12 percent in the 1860s relative to the years before 1790 than is estimated here.

The final column of table 9 shows the implied level of TFP in each year. This is portrayed also in figure 12. Productivity grows faster than GDP per capita in the Industrial Revolution era. Overall TFP increases by 49% with an annual growth rate of 0.40%. Crafts estimated total factor productivity increased by 109% (.58% per year) in the corresponding period. Also productivity growth in the Industrial Revolution is faster than under the Stuarts (where it is only 0.24% per year). But notice that while Crafts and others find a nice buildup of productivity growth from low levels in the late eighteenth century to the highest levels by the mid-nineteenth century, so that the Industrial Revolution seems to be a train getting into motion slowly but nevertheless running nicely by the end, I do not find that here. Instead the productivity growth is concentrated in the years 1800-9 to 1830-9. The growth rate of productivity between 1830-9 and 1860-9 is estimated at a mere 0.28% per year, little above the Stuart record.

Figure 12: Overall TFP in England, 1610-1860



The Meaning of Industrial Revolution Productivity Growth

Those wedded to the old idea of the Industrial Revolution as the defining break in human history may now think that at last they have found a place to take their stand, a rock however small to give some footing. This I think is a mistake. For we can easily show that the more rapid productivity growth of the Industrial Revolution era owes a lot to the accidental fact that English population was growing unusually fast in this period relative to other European economies.

The aggregate productivity growth rate is just the sum of the productivity growth rates of individual sectors weighted by their share in national outputs. Thus

$$g_A = \sum_j q_j g_{Aj}$$

where ?j is the share of national income derived from sector j, and g_{Aj} is the productivity growth rate in sector j. The cotton textile industry experienced very rapid productivity growth in the Industrial Revolution era, as figure 13 shows. The estimated total factor productivity in spinning and weaving cotton cloth increased 22 fold from the 1770s to the 1860s, implying an annual productivity growth rate of 3.1% per year. Table 11 shows the numbers necessary to calculate the contribution of cotton, and the associated industries of linen (assumed to have the same productivity growth as cottons) and woolens to overall TFP growth. As can be seen the estimated contribution of these industries is a productivity growth rate per year at the national level of 0.26% out of 0.40%. Thus nearly two thirds of the productivity growth rate can be explained by essentially one set of innovations, and by industries that employed less than 10% of the labor force in 1851. The great mass of the economy, including agriculture, construction,

Figure 13: Cotton Spinning and Weaving Productivity, 1770-1869

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

Table 11: The Contributions of Cotton and Wool Textiles to National Productivity Growth

Period	Cotton Productivity Growth Rate (%)	Cotton, Linen Share of GDP	Contribution to National Productivity Growth Rate (%)	Woolen Productivity Growth Rate (%)	Woolen Share of GDP	Contribution to National Productivity Growth Rate (%)	Total Contribution (%)
1765-1775	0.00	0.013	0.00	0.50	0.042	0.02	0.02
1775-1785	0.46	0.021	0.01	1.02	0.042	0.04	0.05
1785-1795	3.54	0.040	0.14	1.92	0.042	0.08	0.22
1795-1805	6.98	0.054	0.38	4.20	0.040	0.17	0.55
1805-1815	1.88	0.063	0.12	1.07	0.039	0.04	0.16
1815-1825	4.85	0.074	0.36	-1.59	0.037	-0.06	0.30
1825-1835	4.88	0.081	0.39	1.14	0.036	0.04	0.43
1835-1845	4.00	0.081	0.32	-1.21	0.036	-0.04	0.28
1845-1855	2.37	0.076	0.18	4.59	0.034	0.16	0.34
1855-1865	2.05	0.056	0.11	2.95	0.030	0.09	0.20
Overall	3.10	0.056	0.202	1.46	0.031	0.054	0.256

Sources: Cotton cloth prices, Harley (1997). Raw cotton prices, Mitchell and Deane (1971), pp. 490-1. Wages estimated from northern building wages.

services, and most manufacturing saw very little productivity increase. The gains in income per capita were thus the result of a lucky technological advance in one area. Had the textile revolution never happened overall productivity growth in Britain in the Industrial Revolution period would have been dramatically slower. This is shown in figure 10 where the path of TFP in the Industrial Revolution period with no textiles revolution is also shown.

Even with a textile revolution the effects of productivity growth in textiles on the TFP of the whole economy crucially depended on the ability of Britain to export these products on a large scale. Even though the share of cottons and woolens was never large, this share was only attained because of very substantial exports of cotton and woolen goods. Thus by the 1860s at least two thirds of English cotton goods output was exported, and about one third of woolens. These exports were traded in world markets for foods and raw materials demanded by England's rapidly growing population. Had these industries produced only for the home market then the productivity growth rate from 1765 to 1865 would have dropped by a third. Table 12 shows the calculated productivity growth rate from a purely domestic textile industry and Figure 10 also shows calculated TFP for the years 1610-9 to 1860-9 if we assume that textile products were consumed only within England. In 1760 British imports and exports were both a small share of GDP.

But this ability to export textiles was a purely adventitious thing. Textile products were tradable, and the growing population of Britain required large imports of food and raw materials which had to be paid for by manufacturing exports.

Table 12: The Contributions of Cotton and Wool Textiles to National Productivity Growth without Exports

Period	Cotton: consumption share of GDP	Contribution to National Productivity Growth Rate (%)	Woolens Consumption share of GDP	Contribution to National Productivity Growth Rate (%)	Total Contribution (%)
1765-1775	0.010	0.00	0.027	0.013	**0.01**
1775-1785	0.013	0.01	0.027	0.027	**0.03**
1785-1795	0.020	0.07	0.027	0.051	**0.12**
1795-1805	0.023	0.16	0.025	0.107	**0.27**
1805-1815	0.027	0.05	0.025	0.027	**0.08**
1815-1825	0.036	0.18	0.027	-0.042	**0.13**
1825-1835	0.042	0.20	0.027	0.031	**0.23**
1835-1845	0.040	0.16	0.027	-0.033	**0.13**
1845-1855	0.032	0.08	0.025	0.115	**0.19**
1855-1865	0.028	0.06	0.020	0.059	**0.12**
Overall	0.027	0.096	0.021	0.036	**0.131**

Productivity Growth through Technological Advance before 1760

The more rapid productivity growth in Britain after 1760 depended crucially on the accidental features of textile markets, and on Britain's need to export manufactures to pay for food and raw material imports. This will lead some to conclude that we can still identify a break between the static pre-industrial world and the modern world if we just move the break back in time to around 1600. After all there is no evidence of any aggregate productivity growth in the 300 years between 1260 and 1560. But I would argue that any attempt to find another breakpoint earlier between the old and the new worlds is fraught with difficulty. For the effects of individual technical advances on aggregate productivity depend crucially on such accidental factors as the size of the sector affected and the price elasticity of demand. The nature of technological advance is generally that some new idea leads to a long period of productivity advance in an industry as the consequences of the new technique are played out. If demand is price inelastic then reductions in prices created by the early phase of a technological advance will limit or even reduce the share of expenditure on the good, so reducing the general productivity gains from further advances. Advances in cotton textiles in the Industrial Revolution had big impacts because textiles were a substantial share of expenditure by the 1760s and demand was price elastic. The share of income spent on clothing if anything increased with the price declines of the Industrial Revolution. Even fairly broad categories of goods vary dramatically in their price elasticities. Thus for the modern USA we get:

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

Only a technological revolution in sectors with a price elasticity of demand close to or greater than one would have substantial long run impacts of the productivity growth rate of the economy. Suppose that prior to the Industrial Revolution innovations were occurring randomly across various sectors of the economy - innovations such as guns, spectacles, books, clocks, painting, new building techniques, improvements in shipping and navigation – but that just by chance all these innovations occurred in areas of small expenditure and/or low price elasticities of demand. Then the technological dynamism of the economy would not show up in terms of output per capita or in measured productivity.

Thus if we were to take a portrait or book illustration from England circa 1200 and compare it to one circa 1600 we would conclude that these were societies which had experienced dramatic technological advance. To see this just consider figures 14 and 15. The first is a book illustration from 1233, the second a formal portrait of a grandee in 1573. Even allowing for the somewhat different genres the advance in the ability to realistically portray people is very clear.

Similarly consider the introduction of the printed book by Gutenberg in 1445, again in the period where we can find no evidence of aggregate productivity growth, at least in England. We can measure output per worker using the prices of such standard texts as the Bible over long periods of time compared to the day wages of craftsmen, since the costs in printing were largely labor costs. Figure 16 shows this measure as we move from manuscript production in England to the printed book. Output per worker increased by roughly 30 fold from manuscript production in the fourteenth century till the early nineteenth century. This was greater than the productivity advances achieved in the cotton textile industry over the Industrial Revolution period, though it took place over a much longer period.

Figure 14: A Young Man Knighted, from Historia Major (Chronica Majora), 1233

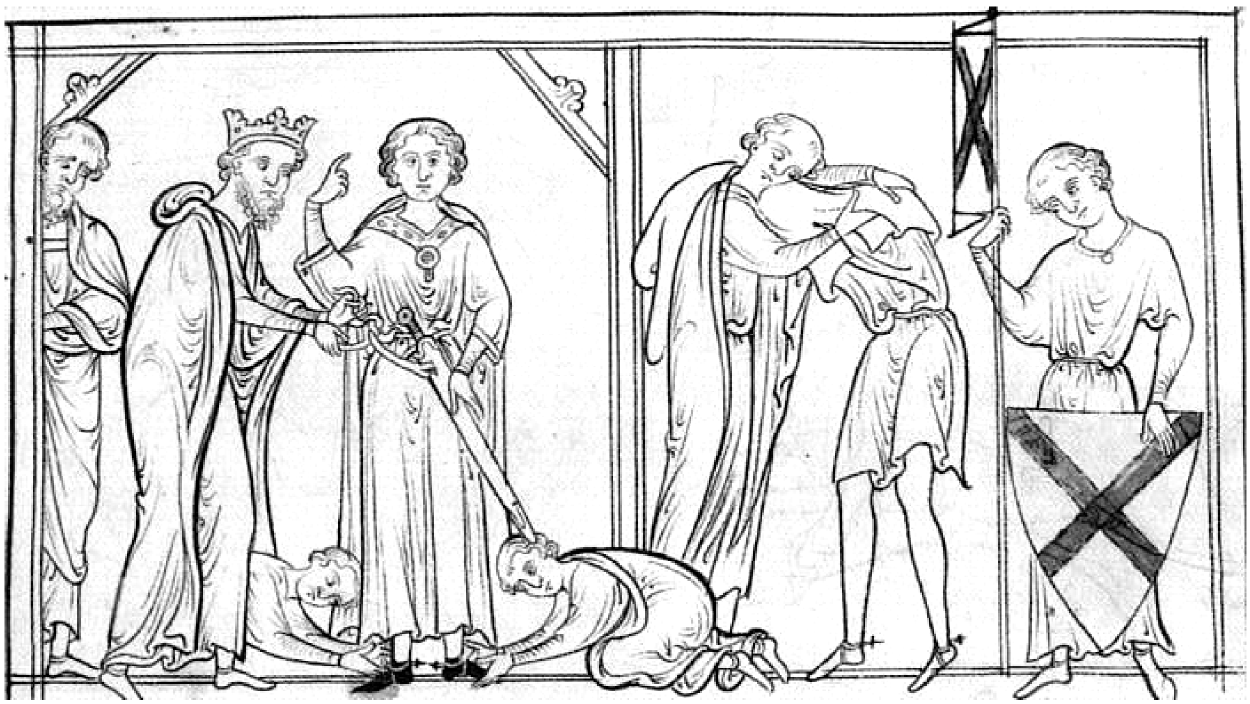
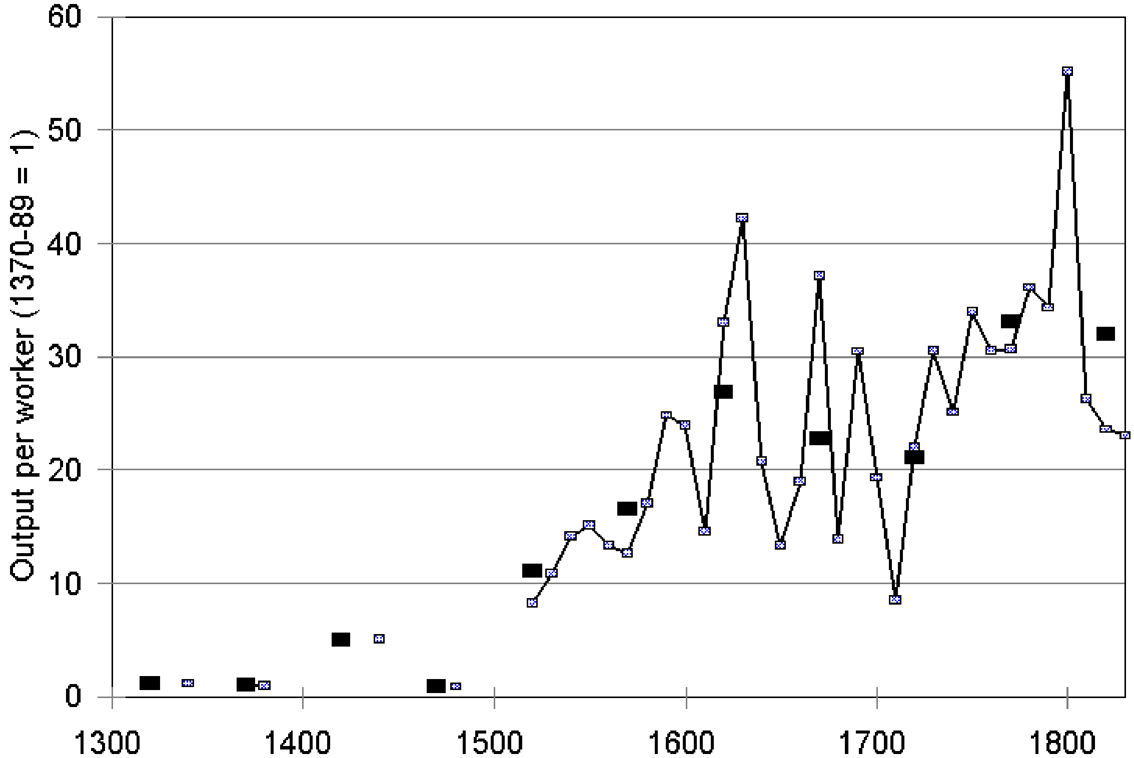


Figure 15: Portrait of Sir Thomas Kytson, 1573

Figure 16: Output per worker in printing, 1340-1839



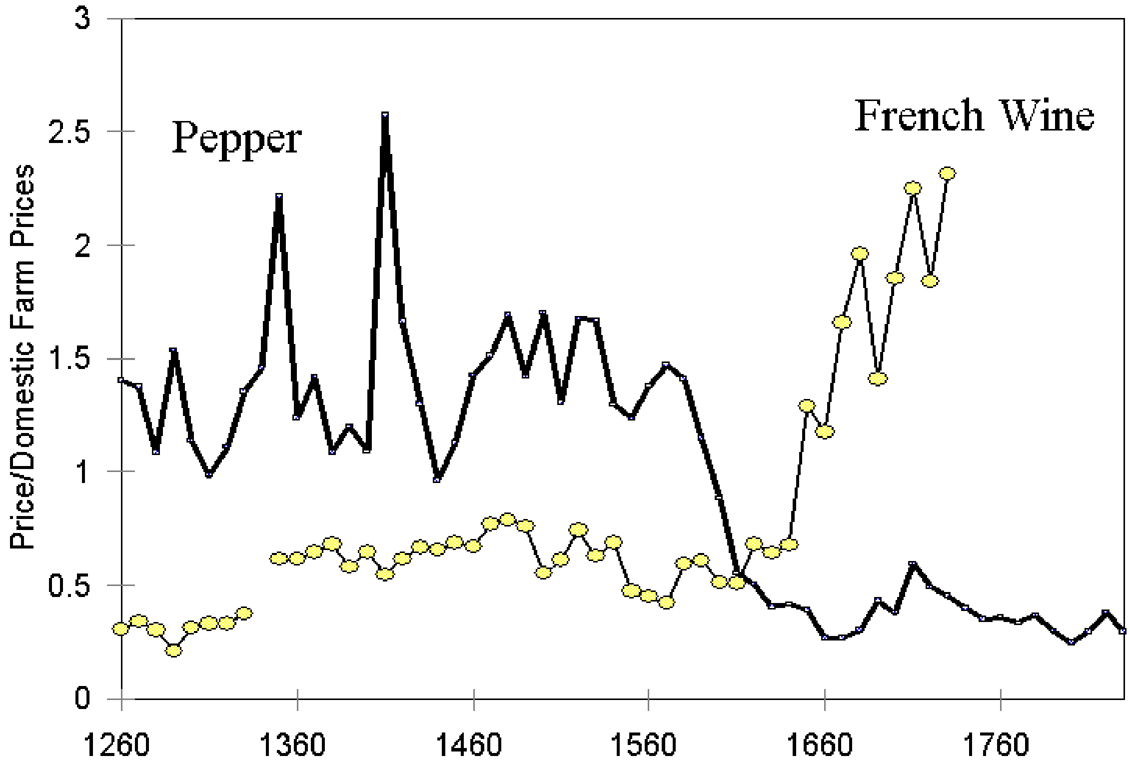
Notes: The measure of productivity used here treats paper as a basic input. The solid squares indicate the 50 year averages of productivity.

Source: Clark and Levin (2001)

But the impact of these productivity gains in printing on the economy as a whole was unmeasurably small because the share of the economy devoted to printing always remained small despite the dramatic decline in the price of printed material. Thus in 1851 only 0.8% of the population was employed in the paper making and printing businesses. The share so employed when productivity growth in the industry was much more rapid in the seventeenth century would have been much smaller.

Another dramatic change in the years before 1600 was improvements in shipping and navigation which allowed access to the East by an all sea route. This was reflected in a dramatic fall in the sixteenth century in the price of eastern spices in England relative to local food stuffs. Figure 16 shows the price of pepper relative to domestic agricultural output in England from 1260 to 1829. The price of pepper relative to English farm output prices fell to about one fifth its earlier level between 1570 and 1660. Yet again though this decline represented a host of technical and organization changes the economic impact was negligible given the dietary habits of the English.

Figure 17: The Prices of Pepper and French Wine relative to Domestic Farm Products

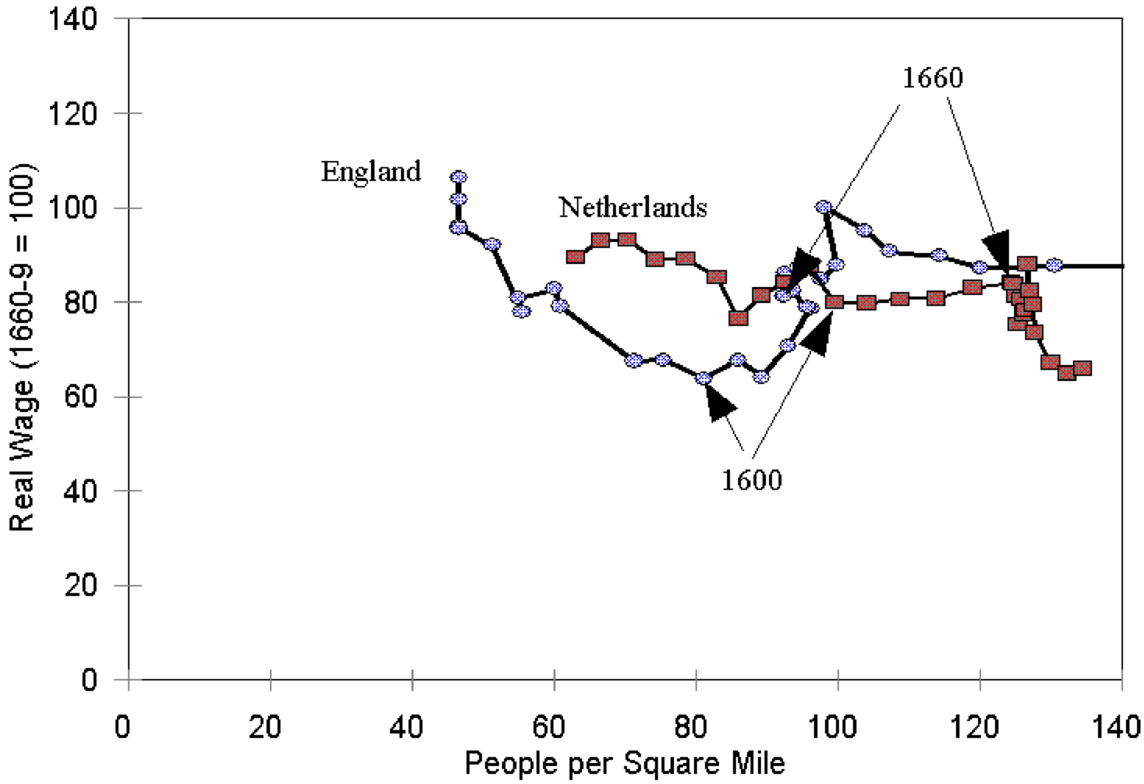


"Golden Age Holland." A Candidate for the First Industrial Revolution?

Not only did productivity growth in England begin before the classic dating of the Industrial Revolution, but the Netherlands is as good a candidate as England to have experienced the first Industrial Revolution if we want to place that at the point where sustained productivity growth began. Figure 18 shows for the decades from 1500-9 to 1780-9 real wages in the Netherlands compared to real wages in England, graphed this time versus population density. From 1500-9 to 1860-9 real wages fell modestly in the Netherlands. But at the same time population doubled. Thus the efficiency of the Dutch economy expanded greatly in these years. The amount of productivity growth necessary to stop real wages declining in these years depends on the share of income going to the fixed factor, land. If land received one third of income, then the Dutch economy between 1500 and 1660 saw about a 33 percent overall gain in efficiency, sustained over 160 years.

This efficiency growth is modest by even the standards of estimated efficiency gains in England in the years 1760-1860 (about 0.15% per year compared to an estimated 0.46% in England). But then English efficiency growth was very modest with respect to what came later. Those calling the British Industrial Revolution a unique moment in history have already conceded that we cannot characterize the Industrial Revolution in terms of the rate of increase in productivity growth rates. Instead what they have emphasized is the unique nature of sustained productivity growth coming from technological advances. But if the Netherlands had an earlier, more modest, version of the same phenomena why would we not characterize this as the real origins of the Industrial Revolution. As a result of the productivity growth of the "Golden Age" by 1600 the efficiency of the Dutch economy was 20-30% greater than that of England. The Netherlands was then able to support 20% more people per acre of land at a real wage level 30%

Figure 18: Wages versus Population, England and the Netherlands, 1500-1789



Source: Netherlands, De Vries, Jan and Ad van der Woude (1997), pp. 50, 609-631.

greater than in England. This is reflected in much higher urbanization rates of the Netherlands in these years. Thus de Vries and van der Woude estimate that at its peak between 1500 and 1815 45% of the population lived in urban areas. Correspondingly the share of the Dutch labor force employed in agriculture was probably less than 35% in 1675, about the same as in England in 1800.

It may be objected that this early Dutch efficiency growth did not last. By the 1660s the economy entered a point of stasis and even modest decline that lasted till the early nineteenth century, a period of 150 years. By the late eighteenth century the share of population in towns was falling, as were real wages. But we see a similar path occurring with England in the late nineteenth century. By then much of the technological dynamism of the world economy passed to the United States, and much of the productivity gains of the English economy owed to innovations created elsewhere. In just the same way Dutch GDP per capita grew as fast as English from the 1800s to the 1860s as a result of the spread of the technological advances of the British Industrial Revolution.

So if we want to locate the Industrial Revolution as the beginning of the era of sustained productivity growth then the Dutch have as good a case as the British. If we want to locate it in the era of very widespread productivity growth affecting large sectors of the economy, then the US in the after the 1870s is the best candidate.

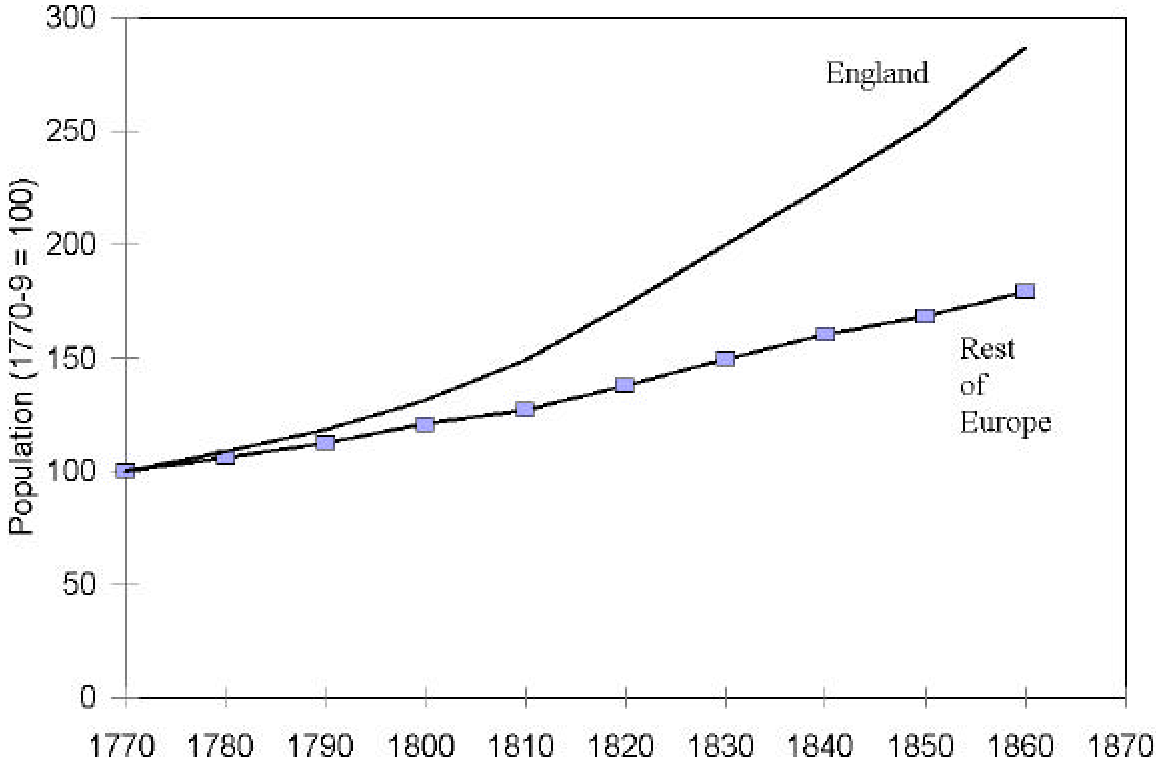
A Remaining Puzzle

One puzzle will remain for some readers, and that is the one presented by figure 10. How can it be that productivity growth was slow in the years 1760-1860 when the economy so clearly deviated from the old pre-1630 relationship between wages/output and population? That deviation first appears after 1630, but it continues and gathers force in the eighteenth and nineteenth century.

This puzzlement, however, comes from treating England as a closed economy. Suppose instead that free trade existed throughout the years 1200-1869. The internal grain market in England, for example, seems to have been integrated by the thirteenth century, and England had low transport costs to France and the Netherlands even in the middle ages. In that case wages and output in England will be determined not by the land/labor ratio in England, but by the land/labor ratio in Europe as a whole. The English land/labor ratio will predict real wages and real output only in so far as it moves in sympathy with the European land/labor ratio. Otherwise if England ends with more labor compared to land than other European economies it will not experience a decline in output per worker with a constant technology, but will trade labor intensive products in exchange for land intensive products from elsewhere.

In the years 1300 to 1750 there is a remarkable concordance in the population movements across Western Europe, and English wages, output per head and population are linked. But the Industrial Revolution was notable for England's rapid population growth compared to the rest of Europe, and in particular compared to the Netherlands and France. Figure 19 shows relative to 1770 how English population increased by 187% between 1770-9 and 1860-9 while a wide group of other European countries saw population increase by only 79%. Thus the land constraint did not operating as tightly as would be expected in the Industrial Revolution period.

Figure 19: Population in England and Western Europe Relative to 1770-9



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

At the same time the addition of the acreage of North America, and improvements in the transport system that brought grain and timber from the East and South to Western Europe effectively expanded the land base of the whole continent.

We can show how much the English land area was "expanded" by trade with other economies by the 1860s by comparing raw materials imports for domestic consumption with domestic farm output, as in Table 13. By the 1860s imports of food and raw materials had effectively expanded the land area of England by 123%. The population fed and clothed by English agriculture did not expand from 7.5 million to 21 million between 1760 and 1860 as figure 10 suggests, but instead grew from 7.5 to 9.6 million. However, even this calculation does not take into account the effect of the expansion of the coal industry in substituting for the use of land to produce energy in the pre-industrial economy through growth of wood and furze. In combination imports and the coal industry effectively tripled the land area of England by the 1860s. Thus the effective land/labor ratio did not decline from 1760 to 1860.

Thus England's economic growth looked so spectacularly different from the past after 1760 for three reasons: the demographic accident of the differential movement of population in England relative to the rest of Europe, the expansion of the land area effectively available to all of Europe through the opening up of the American Midwest and of the eastern Europe, and the expansion of the domestic coal industry. Observers of the period, such as Joel Mokyr, have argued there was little technical change in the coal industry before 1860, and that output growth was expansion along an unchanging supply curve. But in that case we should expect to observe rising real coal prices in the years 1760 to 1860. Real coal prices to consumers in fact fell relative to the general price level between 1760 and 1860, suggesting that the coal industry did experience productivity gains.

Table 13: Agricultural Consumption per Person in England, 1700s to 1860s.

	1700-9	1860-9
Population (millions)	5.16	19.97
English Farm net output (£ m.)	63.1	111.7
Net Food Imports (£ m.)	2.2	75.2
Net Raw Material Imports (£ m.)	-1.3	62.7
Domestic Coal Consumption (£ m.)	1.7	50.3
Total Food, Energy and Raw Material Consumption (£ m.)	65.7	309.9
Consumption per Person (£)	12.7	15.5
Predicted Consumption (£)	12.7	15.8

Notes: Cotton, wool, flax, and silk retained for home consumption are estimated by subtracting the raw material content of textile exports estimated using figures given in Deane and Cole (1962).

Sources: Coal production: Flynn (1984, p. 26) and Church (1986, pp. 19, 53, 85-97). Imports 1860-9: Mitchell (1988). Imports 1700-9: Schumpeter (1960, tables XV, XVII). Exports 1700-9: Schumpeter (1960, tables VII, IX, X, XII, XIII), Mitchell (1988), pp. 221-2).

Conclusion

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

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