Slow Real Wage Growth during the Industrial Revolution: Productivity Paradox or Pro-Rich Growth?

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Abstract

I examine the implications of technological change for productivity, real wages and factor shares during the industrial revolution using recently available data. This shows that real GDP per worker grew faster than real consumption earnings but labour's share of national income changed little as real product wages grew at a similar rate to labour productivity in the medium term. The period saw modest TFP growth which limited the growth both of real wages and of labour productivity. Economists looking for an historical example of rapid labour-saving technological progress having a seriously adverse impact on labour's share must look elsewhere.

Keywords: Engels' pause; factor shares; industrial revolution; labour productivity; real wages.

JEL Classification: N13; O33; O47.

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1. Introduction

The term 'Industrial revolution' is often used to describe economic development in Britain between the 1760s and the 1830s. It is well-known that real wages increased very slowly during this period of acceleration in technological progress which is often seen as an era when the share of wages in national income was under downward pressure in an early example of workers being replaced by machines. Engels (1887) excoriated 'the industrialists, who grow rich on the misery of the mass of wage earners' and Allen (2009) coined the phrase 'Engels' Pause' to describe the early decades of the 19th century.

This episode has attracted renewed interest from economists in the context of worries about the impact of artificial intelligence (AI) and robotics on the labour market. Informed by Allen's account of Engels' Pause, recent contributions by Frey (2019) and Acemoglu and Restrepo (2019) both draw attention to what they see as a long wait for the innovations of the industrial revolution to benefit workers during which labour's share of national income fell while highlighting the possibility that today a similar experience may be under way.

If the industrial revolution is to be used as a template for thinking about the implications of AI, it is important to do so while using the best available estimates of real wage and productivity growth. The publication of Broadberry et al. (2015) has improved the dataset in several respects compared with that which was available at the time of Allen (2009). Annual estimates of real GDP and the GDP deflator and better estimates of labour productivity are now available with which Engels' Pause can be re-visited.

The heart of the matter is to compare the growth of real wages with that of labour productivity. In this paper, this is implemented using these new estimates. Real wages can now be measured either in terms of real consumption earnings or real product earnings. The former will be appropriate for examining workers' standards of living but the latter should be the basis for deriving trends in factor shares.

The main results of this new analysis are as follows. First, real wages grew more slowly than real GDP per worker during the industrial revolution. However, the discrepancy was much less than has been claimed such that in 1820 the former had risen by about 12% since 1770 and the latter by about 16%. Second, labour productivity grew quite slowly prior to 1830 averaging a little below 0.4% per year in the 60 years after 1770. Nevertheless, in the context of demographic pressure this was a very good outcome by pre-industrial standards. Third, as relative prices changed and manufactures became cheaper relative to food, over the long run real product wages grew somewhat faster than real consumption earnings. Fourth, the share of profits in GDP rose over time from 17.2% in 1770 to 29.5% in 1860 but this was associated with a decline in the share of land rents and the share of labour was little changed. Fifth, looked at through the lens of growth accounting the evidence is of total factor productivity (TFP) growth accelerating only gradually to about 0.8% per year during 1830 to 1860 with the steam age only materializing after 1830.

In sum, this looks more like a story of paradoxically slow productivity growth than of pro-rich growth. The story of the industrial revolution is definitely not one of a new general-purpose technology boosting productivity growth at the expense of a big shift in the distribution of income which is the current fear about AI.

2. Literature Review

Economists have recently been heavily engaged in looking for explanations of the declining share of labour in national income in recent decades in advanced economies. These might see the industrial revolution as a precursor or, mutatis mutandis, they might seem to apply to the industrial revolution. Theoretical models have been developed in which technological progress can lead either to a phase in which real product wages fall before eventually increasing (Berg et al., 2018) or to an outcome in which real wages grow more slowly than labour productivity (Acemoglu and Restrepo, 2019). In the latter case, the initial impact of a new technology like AI is to displace labour but over time growth creates new demands for labour as productivity goes up and capital deepening takes place and new tasks are created in which labour has a comparative advantage over machines although labour market adjustments may be slow. There have also been empirical papers which attribute a substantial part of the recent decline in labour's share to technological change through its implications for the automation of routine tasks and/or the substitution of cheaper capital for labour (Abdih and Danninger, 2017; Karabarbounis and Neiman, 2014; IMF, 2017).

Frey (2019) sees the experience of the British industrial revolution as a warning light in the context of developments in AI. He describes a great divergence within Britain as wages stagnated, profits surged, and income inequality skyrocketed. The gains of progress went overwhelmingly to the industrialists as the profits share of national income doubled in the first four decades of the 19th century while labour's share decline. Between 1780 and 1840 output per worker rose by 46% but real wages by only 12%. His emphasis is on a prolonged period of pro-rich growth.

This last estimate taken from Allen (2009) is, of course, the key to the fall in labour's share which is the essence of Engels' Pause. The 12% rise in real wages which is quoted is based on estimates of real consumption earnings made by Feinstein (1998). These have gained quite wide acceptance, for example, they are the preferred series used by Thomas and Dimsdale (2017, table A48, column B). They were not, however, the estimate used by Allen who used Feinstein's index of money wages but deflated them with his own cost of living index (Allen, 2007) which modified the story a bit and resulted in an 18% gain between 1780 and 1840. In fact, the evolution of real consumption wages in this period has been controversial for many years with a variety of different indices of money earnings and the cost of living being proposed.[1]

Allen's estimate that real GDP per worker rose by 46% between 1780 and 1840 was derived using the growth estimates in Crafts and Harley (1992) and national accounts estimates by Feinstein (1978). The correct figure is in fact 39% if this method is used.[2] Output per worker growth was significantly faster than the growth of real consumption earnings but not by as much as has been suggested by Frey (2019). Improved estimates are now possible using the work of Broadberry et al. (2015). This provides revisions to real GDP growth between the benchmark years in Crafts and Harley (1992) but also breaks new ground by providing annual estimates for both real and nominal GDP and the GDP deflator. In fact, growth of real output per worker in the medium term is not very different from Crafts and Harley but the additional detail allows a new look at Engels' Pause.[3] In effect, Broadberry et al. (2015)

[1] Two recent estimates are by Clark (2010) and by Humphries and Weisdorf (2019). They show considerably bigger increases in real consumption earnings between 1780 and 1840, at 46.5% and 35.0%, respectively.

[2] Crafts and Harley's estimates imply that output per worker grew at 0.38% per year between 1780 and 1830. Feinstein gives an estimate of GDP in 1830 of £310 million at 1851-60 prices and then extrapolates this to 1860 using Deane (1968). Based on Deane's estimates, this gives an estimate for output growth between 1830 and 1840 of 2.77% per year and output per worker at 1.45% per year. In total then output per worker in 1840 would have been 39.0% of the 1780 level.

[3] According to the new estimates, output per worker in 1840 was 38.4% above the 1780 level (see Table 2).

provided firmer evidence that the earlier estimates of labour productivity growth at 1.3% per year during 1800-30 by Deane and Cole (1962) were much too high.

3. Growth of Real GDP/Worker and Real Wages

In this section, comparisons are made between the growth of real earnings and of labour productivity from a date which might be regarded as representing the onset of the industrial revolution to the middle of the 19th century. 1770 is the year after Arkwright's water frame and James Watt's steam engine were patented and is also the year that Feinstein's real wage index (and Allen's refinement of it) commences so it is an obvious starting point for this analysis.

In Tables 1 and 2, the labour productivity growth estimates gathered from the Thomas and Dimsdale (2017) spreadsheet are those of Broadberry et al. (2015), the real consumption earnings are the series constructed by Allen (2007) using earnings from Feinstein (1998) deflated by a cost of living index constructed by Allen while the real product wages is a new series constructed by deflating earnings from Feinstein (1998) by the GDP deflator from Broadberry et al. (2015).[4] Others may prefer to use more optimistic estimates of real wages but the present exercise will establish whether Allen's widely-cited findings still hold good when the earnings estimates are retained but placed in the context of Broadberry et al's dataset.[5]

The estimates reported in Table 1 show real consumption earnings growing more slowly than real GDP per worker from 1770 to 1800 and from 1800 to 1830 by about 0.13 and 0.16 percentage points per year, respectively. It is interesting to note that the difference in 1800-1830 would have been about 1 percentage point per year greater if Deane and Cole's estimate of labour productivity growth was still accepted. Between 1830 and 1860 real consumption earnings grew faster than real GDP per worker by 0.09 percentage points per year.

The pattern of growth of real product wages was somewhat different. Prior to 1800 it was below the growth of output per worker but subsequently the opposite was the case. Real product wages grew faster than real consumption earnings throughout the first half of the 19th century. Since the same index of money wage earnings is used for both series this is entirely the result of changes in relative prices which result in differences in the rate of change of the cost of living index and the GDP deflator.

In Table 2, the evolution of these three series is compared in terms of their levels at 10-yearly intervals. Looking at the data in this way emphasizes that the big point about the early stages of the industrial revolution is how slowly both productivity and living standards rose rather than the discrepancy between their growth rates. In 1820, after 50 years, real GDP per worker had risen by only 15.9% compared with 11.6% for real consumption earnings. After 1820, real consumption earnings did not keep up with labour productivity but by 1850 the gap had narrowed and was once again quite small.

[4] Feinstein's estimates (and therefore Allen's) are for earnings rather than wage rates (1998, pp. 631-633) and therefore are suitable to compare with GDP for the purpose of deriving labour's share of national income. Strictly speaking, these are estimates of weekly average manual earnings but Feinstein's discussion of hours worked (p. 649), the absence of paid holidays in this period and Feinstein's verdict that there was broad stability in earnings relativities (1988a, p.728) imply that these estimates are an acceptable index of annual earnings over the long run.

[5] There is no good reason to think that the wage data from either Clark (2010) or Humphries and Weisdorf (2019) are to be preferred. As might be expected, it is the case that using the alternative money wage series would give higher values for labour's share as the first half of the 19th century unfolds. Clark's own calculations are reported in Table 4 and see Figure 3 in Humphries and Weisdorf for their calculation which shows labour's share at 0.7 in mid-century.

In 1830 and 1840 the increase in real GDP per worker since 1770 was 1.7 and 1.6 times that of real consumption earnings, respectively rather than the 3.8 times that Frey headlined.

For real product wages, the post-1820 story is rather different. In 1830 they were almost level with real GDP per worker and by 1850 were ahead. In that year, real product wages were 65.3% above the level of 1780 whereas for real GDP per worker the figure was 54.3%. Since in each case the earnings series is that of Feinstein (1998), the difference in the trajectories of real product wages and real consumption earnings is entirely due to the discrepancy between movements in the GDP deflator and the cost-of-living index. In turn, this is very largely due to the different behaviour of the prices of food (relatively highly weighted in the cost-of-living index) and industrial goods (relatively highly weighted in the GDP deflator).[6] A key underlying factor was the unevenness of technological progress across different sectors of the economy.

Although an increase of only 11.6% in real consumption earnings by 1820 may seem a very disappointing outcome, it needs to be put into context. The rate of population growth increased from about 0.36% per year between 1700 and 1770 to 1.13% per year between 1770 and 1820. Estimated models of economic-demographic interactions find that the maximum population growth rate that the pre-industrial-revolution economy could sustain while maintaining constant real wages was a little under 0.5% per year (Crafts and Mills, 2009; Lee and Anderson, 2002). If, as Crafts and Mills estimated, the elasticity of wages with respect to population was about -0.7, then the additional 35% population in 1820 on top of the number with maximum sustainable population growth would have been predicted to have reduced real wages by about 25% in earlier times. Looked at in this way the small increase in real wages was really quite a good outcome.

4. Factor Shares

In this section, new estimates of the share of labour in national income during the industrial revolution are presented. These are derived using the estimates of real product wages reported in Table 2. It can be expected that they will look rather different from earlier estimates based on real consumption earnings. There are also implications for capital's share which is the residual share left over after accounting for wages and rents.

Labour's share of national income (LS) can be defined as $wL/pY = (w/p)/(Y/L)$ where w is money wages, p is the GDP deflator, L is labour input and Y is real GDP. Given an estimate of the share of labour in a base year, the share in other years can be calculated using the ratio of real product wages divided by base year real wages to GDP per worker divided by base year GDP per worker, i.e.

$$LS_t = LS_0[(w/p)_t/(w/p)_0]/[(Y/L)_t]/(Y/L)_0] \quad (1)$$

This formula should be implemented using real product wages not real consumption earnings. This is now possible using the estimates of the GDP deflator in Broadberry et al. (2015) but these were, of course, not available to Allen (2009) who had to use real consumption earnings instead.[7] This was unfortunate because, as was outlined above, the evolution of these two series differs appreciably.

I take 1800 as the baseline year and assign a value of 55.8% for labour's share. This is the average of the years 1791-1800 in Allen's (2009) dataset and is very close to the 56.6% share which Allen (2019) obtained through analysis of Colquhoun's social table for 1798. Working forwards to 1860 as described generates an estimate of 62.0% for labour's share which is close to the estimate given by

[6] More details can be found in the appendix to this paper.

[7] Since, understandably, Frey (2019) relied on Allen as the basis for his account of trends in factor shares, in effect, he also used real consumption earnings rather than real product wages.

Matthews et al. (1982) of 57.8% for 1856.[8] The new estimates for labour's share are not very different from those made by Clark (2010) from the income side until the second quarter of the 19th century when in most years they are somewhat lower (Table 4).

Tepper and Borowiecki's (2015) review of various estimates of the share of land rent in national income endorses those made by Allen for his 2009 paper so I use them again here. There is no direct way of estimating the share of capital every ten years and it is derived as national income minus the shares of land and labour. The rate of profit is then inferred by dividing capital's share by the capital to output ratio. The estimate of 17.2% obtained for 1860 is close to the rate of 15.6% in Matthews et al. (1982).

The new estimates for labour's share in Table 3 tell a different story from the one constructed by Allen (2009) which is reported in Table 4. There is no decline in labour's share in the first half of the 19th century but rather a modest increase from the levels of the late 18th century. There is a substantial rise in the share of profits but not on the same scale as found by Allen (2009). Arithmetically, over the long run, the increase in profits' share is the counterpart of the decrease in the share of land rents in national income. The rate of profit derived in Table 3 rises steadily over time but by rather less than the increase to over 20% by the mid-19th century that Allen (2009) estimated.

It may still be appropriate to use the phrase 'Engels' Pause' to describe the trajectory of labour's share but, according to these estimates, it is better applied to the late 18th century when it was both shorter and shallower than economists have been led to believe. Allen's (2009) estimates of a steady decline in the share of labour in national income from 55.8% of national income in 1800 and to 44.4% in 1860 are at odds with all the other estimates in Tables 3 and 4.

5. TFP Growth

The Industrial Revolution was a time of famous inventions including those of Richard Arkwright, Henry Cort, Samuel Crompton, George Stephenson, and James Watt. Watt invented the (improved) steam engine, thus inaugurating what is generally thought to be one of the most important general-purpose technologies ever. Prima facie, this 'wave of invention' seems to suggest that TFP growth and labour productivity growth would both speed up dramatically. It is perhaps natural then to suppose, as did Engels, that if real wages grew only slowly this means that the fruits of economic growth went to the rich.

Growth accounting can provide a reality check on this proposition. It is helpful to examine estimates using both the primal and dual methods. The national income identity is

$$Y = \pi K + wL + rN \quad (2)$$

where K is capital, π is the rate of profit, L is labour, w is the wage rate, N is land and r is the land rental rate. So, taking logarithms and differentiating with respect to time

$$\Delta Y/Y = s_K(\Delta\pi/\pi + \Delta K/K) + s_L(\Delta w/w + \Delta L/L) + s_N(\Delta r/r + \Delta N/N) \quad (3)$$

where s_K, s_L, and s_N are the factor shares of capital, labour and land, respectively. Rearranging (3) gives

$$\Delta Y/Y - s_K\Delta K/K - s_L\Delta L/L - s_N\Delta N/N = s_K\Delta\pi/\pi + s_L\Delta w/w + s_N\Delta r/r \quad (4)$$

[8] The 1840 estimate of 59.2% is also close to the estimate of 56.6% for 1846 based on Smee's social table reported by Allen (2019), see Table 4.

The left hand side of (4) is the primal formula for TFP growth which is the rate of output growth minus the rate of growth of total factor inputs while the right hand side is the dual formula for TFP growth which is the sum of the factor-share-weighted factor rewards. These formulae are implemented in Tables 5 and 6, respectively, using the data from which Table 3 was derived together with generally accepted estimates of capital stock, land input, and real rents which are consistent with those data.

The striking feature of the primal growth accounting estimates in Table 5 is that TFP growth was modest rather than spectacular, especially before 1830. A similar picture is apparent from the dual growth accounting estimates in Table 6, although here the TFP growth rates are somewhat faster. The data are evidently imperfect since there is a discrepancy between the two methods of estimating TFP growth rates but in either case the message is that famous inventions did not immediately promote a dramatic acceleration of TFP growth during the industrial revolution.

Three key points can be taken from Tables 5 and 6. First, modest TFP growth was a major reason for underwhelming labour productivity growth before 1830. Second, as the dual formula makes clear, TFP growth is what is available for increases in the returns to factors of production – if TFP growth is slow, real wage rates are unlikely to rise rapidly. Third, especially given its large factor-share weight, slow real wage growth underpins the plausibility of an estimate of modest TFP growth.

How can the paradox of famous inventions but modest TFP growth be resolved? First, the impact of technological progress was very uneven. Agriculture and most of the service sector other than transport was largely unaffected. Sectors which we think of as the embodiment of the industrial revolution, namely, textiles, metals and machine-making accounted for less than a third of industrial employment – or 13.4% of total employment - even in 1851 (Shaw-Taylor, 2009), while much industrial employment was still in 'traditional' sectors. Second, the process of technological advance was characterized by many incremental improvements and learning to realize the potential of the original inventions. This took time in an era where scientific and technological capabilities were still weak by later standards.

Steam power offers an excellent example. The estimates in Table 7 show that its impact on productivity growth before 1830 was trivial – as was made clear by the detailed quantitative research of von Tunzelmann (1978) and Kanefsky (1979). In 1830, only about 165,000 horsepower were in use, the steam engine capital share was 0.4% and the Domar weight for steam engines was 1.7% (Crafts, 2004). The cost effectiveness and diffusion of steam power was held back by the high coal consumption of the original low-pressure engines and the move to high pressure – which benefited not only factories but railways and steam ships - was not generally accomplished until the second half of the 19th century.[9] The science of the steam engine was not well understood and the price of steam power fell very slowly compared with that of computers in modern times, especially before about 1850. The maximum impact of steam power on British productivity growth was delayed until the third quarter of the 19th century – nearly 100 years after James Watt's patent. This is a classic example of a general-purpose technology which had a large impact on productivity but only after a long lag (Crafts, 2004). If Engels' Pause was in the late 18th century, it certainly did not occur in the steam age.

6. Discussion

[9] Nuvolari and Verspagen (2009) concluded that technological progress in steam engine technology in the early nineteenth century was a localized and path-dependent learning process with very limited transfer of knowledge and practice across geographic regions and limited scientific understanding. So, although there was quite good progress with high-pressure steam engines in Cornish mining, this did not impact on Lancashire textiles.

As we have seen, the industrial revolution is not a template for studying the impact of technological change that gives a rapid and substantial boost to productivity at the expense of a significant and prolonged decline in labour's share of national income. The experience of the industrial revolution is more one of productivity paradox than pro-rich growth.[10] Nevertheless, it does mark a transition to modern economic growth based on sustained technological progress which is the hallmark of the post-industrial revolution West.

As Mokyr (2002) has emphasized, the key feature of the Industrial Revolution is that the process of innovation did not run into diminishing returns and fizzle out. A growing use of (primitive) scientific methods investigated what works and developed and made accessible useful knowledge which could promote further technological advance. Increased innovative capacity promoted micro inventions to capitalize on breakthroughs and led to the increase of TFP growth to an unprecedented 0.8% per year after 1830. The harbinger of this was a big increase in 'less than top quality' patents from the 1820s onwards (Nuvolari and Tartari, 2011).[11]

The modest increase in labour's share of national income reported in Table 3 does not mean that the displacement effects highlighted by Acemoglu and Restrepo (2019) were absent. On the contrary, for some workers the impact of mechanization was devastating. The most notorious example is that of the handloom weavers who initially gained a lot from the prior mechanization of spinning but were then swept away by the invention of the power loom. They numbered 37,000 in 1780, 240,000 in 1820 but only 43,000 in 1850 (Allen, 2018). Their money wages were 75d per week in 1770, 276d in 1805 (the peak year) but were back to 75d by 1830 (Wood, 1910). In another well-known episode, the 'Captain Swing' riots (1830-2), the evidence is that these were a response to the diffusion of labour-saving threshing machines which wiped out winter earnings for many agricultural labourers (Caprettini and Voth, 2020).

That said, the overall trajectory of the labour market saw a proliferation of new tasks and this was reflected in the expansion of lower-middle class occupations (Allen, 2019). 253,000 families (8.6%) were in this group in 1798 but 649,000 (15.4%) in 1846; workers comprised 61.1% of families in 1798 and 61.4% in 1846.

7. Conclusions

Looking at the industrial revolution with a view to finding a precedent for traumatic labour market shocks from labour-saving technological progress is misguided. The key characteristic of the industrial revolution is a gradual acceleration of productivity advance which eventually completes a transition to modern economic growth. This was not accompanied by a big decline in labour's share of national income and was not the pro-rich growth that Engels imagined.

Certainly, real consumption earnings growth was slower than the growth of labour productivity according to the comparisons made here but the difference is not as large as has been suggested. By 1840, real GDP per worker was 43.9% above the 1770 level whereas real consumption earnings had risen by 27.1%.

After initially falling behind, the growth of real product wages was more similar to that of real GDP per worker such that by 1840 they were 39.8% above the 1770 level. This implied that there was no long-

[10] Steam could be thought of as a precursor of Solow's ICT productivity paradox except that you couldn't see the steam age everywhere except in the productivity statistics in 1800.

[11] Nuvolari and Tartari (2011) assess the quality of patents on a quasi-citation basis. They find that 50% of the top 0.5% of patents in the period 1702 to 1841 had been granted by 1794 but 50% of all patents in this period came after 1823.

run tendency for labour's share of national income to fall significantly. The share of profits did increase markedly over time from 17.2% in 1770 to 29.5% in 1860 but this was accompanied by a matching decline in the share of land rents from 21.8% to 8.5% of national income. This was a redistribution between vieux riche and nouveau riche rather than between the poor and the rich.

References

Abdih, Y. and Danninger, S. (2017) What explains the decline of the U.S. labor share of income? An analysis of state and industry level data. IMF Working Paper, No. 17/167, Washington DC.

Acemoglu, D. and Restrepo, P. (2019) Artificial intelligence, automation and work, in A. Agrawal, J. Gans and A. Goldfarb (eds), *The Economics of Artificial Intelligence: an Agenda*, University of Chicago Press, Chicago, 197-236.

Allen, R.C. (2007) Pessimism preserved: real wages in the British industrial revolution. Oxford University Department of Economics, Working Paper, No. 314, Oxford.

Allen, R. C. (2009) Engels' pause: technical change, capital accumulation, and inequality in the British industrial revolution, *Explorations in Economic History*, 46, 418-35.

Allen, R.C. (2018) The hand-loom weaver and the power loom: a Schumpeterian perspective, *European Review of Economic History*, 22, 381-402.

Allen, R.C. (2019) Class structure and inequality during the industrial revolution: lessons from England's social tables, 1688-1867, *Economic History Review*, 72, 88-125.

Berg, A., Buffie, E.F. and Zanna, L-F. (2018) Should we fear the robot revolution? (The correct answer is yes), *Journal of Monetary Economics*, 97, 117-48.

Broadberry, S., Campbell, B., Klein, A., Overton, M. and van Leeuwen, B. (2015), *British Economic Growth, 1270-1870*. Cambridge University Press, Cambridge.

Caprettini, B. and Voth, H-J. (2020) Race against the machines: labor-saving technology and unrest in industrializing England, *American Economic Review: Insights*, 2, 305-20.

Clark, G. (2002) Land rental values and the agrarian economy: England and Wales, 1500-1914, *European Review of Economic History*, 6, 281-308.

Clark, G. (2010) The macroeconomic aggregates for England, 1260-2008, *Research in Economic History*, 27, 51-140.

Crafts, N. (2004) Steam as a general-purpose technology: a growth accounting perspective, *Economic Journal*, 114, 338-51.

Crafts N. and Harley, C. K. (1992) Output growth and the British industrial revolution: a Restatement of the Crafts-Harley View", *Economic History Review*, 45, 703-30.

Crafts, N. and Mills, T.C. (2009) From Malthus to Solow: how did the Malthusian economy really evolve?, *Journal of Macroeconomics*, 31, 68-93.

Deane, P. (1968) New estimates of gross national product for the United Kingdom, 1830-1914, *Review of Income and Wealth*, 14, 95-112.

Deane, P. and Cole W. A. (1962) *British Economic Growth, 1688-1959*. Cambridge University Press, Cambridge.

Engels, F. (1887) *The Condition of the Working Class in England in 1844.* John W. Lovell Company, New York.

Feinstein, C.H. (1978) Capital formation in Great Britain, in P. Mathias and M.M. Postan (eds), *The Cambridge Economic History of Europe*, vol. 7, Cambridge University Press, Cambridge, 28-96.

Feinstein, C.H. (1988a) The rise and fall of the Williamson curve, *Journal of Economic History*, 48, 679-729.

Feinstein, C. H. (1988b) National statistics, 1760-1920, in C. H. Feinstein and S. Pollard (eds), *Studies in Capital Formation in the United Kingdom, 1750-1920*, Clarendon Press, Oxford, 259-471.

Feinstein, C.H. (1998) Pessimism perpetuated: real wages and the standard of living in Britain during the industrial revolution, *Journal of Economic History*, 58, 625-58.

Frey, C.B. (2019) *The Technology Trap: Capital, Labor and Power in the Age of Automation.* Princeton University Press, Princeton.

Humphries, J. and Weisdorf, J. (2019) Unreal wages? Real Income and economic growth in England, 1260-1850, *Economic Journal*, 129, 2867-87.

International Monetary Fund (2017) Understanding the downward trend in labor income shares", *World Economic Outlook* (April), 121-72.

Kanefsky, J. (1979) The diffusion of power technology in British Industry. Unpublished Ph. D. Dissertation, University of Exeter, Exeter.

Karabarbounis, L. and Neiman, B. (2014) The global decline of the labor share. *Quarterly Journal of Economics,* 129, 61-103.

Lee, R. and Anderson, M. (2002) Malthus in state space: macro economic-demographic relations in English history, *Journal of Population Economics*, 15, 195-220.

Matthews, R. C.O., Feinstein, C. H. and Odling-Smee, J. C. (1982) *British Economic Growth 1856-1973*. Stanford University Press, Stanford.

Mokyr, J. (2002) *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Princeton University Press, Princeton.

Nuvolari, A. and Tartari, V. (2011) Bennet Woodcroft and the value of English patents, 1617-1841, *Explorations in Economic History*, 48, 97-115.

Nuvolari, A. and Verspagen, B. (2009) Technical choice, innovation and British steam engineering, 1800-1850, *Economic History Review*, 62, 685-710.

Shaw-Taylor, L. (2009) The occupational structure of England and Wales, 1750-1871: a preliminary report. Cambridge Group for the History of Population and Social Structure Occupations Project Paper No. 19.

Tepper, A. and Borowiecki, K.J. (2015) Accounting for breakout in Britain: the industrial revolution through a Malthusian lens, *Journal of Macroeconomics*, 44, 219-33.

Thomas, R. and Dimsdale, N. (2017) A Millennium of UK Data, Bank of England OBRA Dataset. http://www.bankofengland.co.uk/research/Pages/onebank/threecenturies.aspx (Last accessed August 10, 2020).

Von Tunzelmann, G. N. (1978) *Steam Power and British Industrialization to 1860*. Clarendon Press, Oxford.

Wood, G.H. (1910) The statistics of wages in the United Kingdom during the nineteenth century (part XVIII): the cotton industry, *Journal of the Royal Statistical Society*, 73, 411-34.

Table 1. Rates of Growth of Real GDP/Worker and Real Earnings (% per year)

	Real GDP/ Worker	*Real Consumption Earnings*	*Real Product Wages*
1770-1800	0.43	0.30	0.14
1800-1830	0.31	0.15	0.59
1830-1860	0.92	1.01	0.99

Note: real consumption earnings are money wage earnings deflated by a cost of living index whereas real product wages are money wage earnings deflated by the GDP deflator.

Sources: derived from Thomas and Dimsdale (2017): GDP/Worker based on Table A8 Column B and A49 Column AI, real consumption earnings based on Table A48 Column X, and real product wages based on Table A47 Columns B and R. The real earnings and real product wages are 5-year averages centred on the end-point dates. The compilation by Thomas and Dimsdale is the most convenient way to access these data which are taken unchanged from the original sources listed in the text.

Table 2. Levels of Real GDP/Worker and Real Earnings (1770 = 100)

	Real GDP/ Worker	*Real Consumption Earnings*	*Real Product Wages*
1770	100.0	100.0	100.0
1780	104.0	105.2	97.0
1790	104.2	109.3	97.6
1800	113.8	109.3	104.2
1810	118.7	109.6	109.8
1820	115.9	111.6	112.2
1830	124.7	114.3	124.3
1840	143.9	127.1	139.8
1850	154.3	148.9	165.3
1860	164.1	154.7	167.1

Note: columns 2 and 3 are 5-year averages centred on year stated.

Sources: as for Table 1.

Table 3. Factor Shares (%GDP) and Implied Profit Rate (%)

	Labour	*Land*	*Capital*	*Profit Rate*
1770	61.0	21.8	17.2	9.8
1780	56.8	21.4	21.8	12.6
1790	57.1	19.8	23.1	13.1
1800	55.8	18.3	25.9	15.3
1810	56.4	16.3	27.3	16.0
1820	59.0	15.8	25.2	14.3
1830	60.7	15.1	24.2	14.1
1840	59.2	12.5	28.3	15.9
1850	65.3	10.5	24.2	12.9
1860	62.0	8.5	29.5	17.2

Note: profit rate obtained by dividing capital's share by the capital-output ratio using capital stock estimates in Feinstein (1988b).

Sources: land from Allen (2009) and own calculations, see text.

Table 4. Factor Shares: Previous Estimates (%GDP)

	Labour	*Land*	*Capital*
Allen (2019)			
1759	59.1	26.6	14.3
1798	56.6	18.0	25.4
1846	56.6	10.2	33.2
1867	55.1	6.3	38.6
Clark (2010)			
1760	58.4	19.5	22.1
1770	58.4	20.2	21.5
1780	60.3	18.6	21.1
1790	59.0	18.4	22.6
1800	57.7	17.7	24.6
1810	58.6	16.5	25.0
1820	60.9	14.0	25.1
1830	62.4	11.6	26.0
1840	64.5	10.8	24.7
1850	65.1	9.2	25.7
1860	65.1	7.7	27.2
Matthews et al. (1982)			
1856	57.8	10.1	32.1
Allen (2009)			
1770	56.5	21.7	21.8
1780	55.3	21.4	23.3
1790	56.2	19.8	24.0
1800	55.8	18.3	25.9
1810	54.1	16.3	29.6
1820	48.3	15.8	35.9
1830	49.9	15.1	35.0
1840	49.0	12.5	38.5
1850	47.4	10.5	42.1
1860	44.4	8.5	47.1

Note: Allen (2009) estimates are decadal averages.

Table 5. Primal Growth Accounting Estimates (% per year)

	Labour Contribution	*Capital Contribution*	*Land Contribution*	*TFP Growth*	*Real GDP Growth*
1770-1800	0.6*1.0	0.2*1.2	0.2*0.5	0.26	1.2
1800-1830	0.6*1.3	0.25*1.7	0.15*0.1	0.38	1.6
1830-1860	0.6*1.1	0.3*2.9	0.1*0.1	0.76	2.3

Note: weights approximate factor shares as in Table 3. Land input growth from (Allen, 2009); capital input growth from Feinstein (1988, p. 454); labour input growth measured in hours worked using headcount of workers as in Table 1 adjusted to an hours-worked basis using Thomas and Dimsdale Table A54 column F for 1770 to 1830 and A54 Column AW for 1830 to 1860; GDP growth from Thomas and Dimsdale (2017), as in Table 1.

Source: own calculations.

Table 6. Dual Growth Accounting Estimates (% per Year)

	Wage Rate Component	*Profit Rate Component*	*Land Rental Rate Component*	*TFP Growth*
1770-1800	0.6*0.14	0.2*1.50	0.2*-0.19	0.35
1800-1830	0.6*0.59	0.25*-0.21	0.15*1.60	0.54
1830-1860	0.6*0.99	0.3*0.62	0.1*0.50	0.83

Note: factor shares as in Table 5. Real product wage rate from Table 1; profit rate from Table 3; land rental rate is nominal rental rate from Clark (2002) deflated by GDP deflator.

Source: own calculations.

Table 7. Steam Contributions to Labour Productivity Growth (% per year)

	Steam Capital Deepening	***Steam TFP Growth***	***Total***
1760-1800	0.004	0.005	0.01
1800-1830	0.02	0.001	0.02
1830-1850	0.16	0.04	0.20
1850-1870	0.20	0.21	0.41
1870-1910	0.15	0.16	0.31

Note: these estimates are derived using a standard growth accounting formula:

$$\Delta\ln(Y/L) = \alpha_{KO}\Delta\ln\left(\frac{K_O}{L}\right) + \alpha_{KICT}\Delta\ln\left(\frac{K_{Steam}}{L}\right) + \mu\Delta lnA_O + \phi\Delta lnA_{Steam}$$

where K_{Steam} is steam-capital inputs, A_{Steam} is TFP in production of steam power, K_O is other capital input and A_O is other TFP, α_{KO} and α_{ICT} are the factor shares of profits of other capital and ICT capital, respectively; Φ and μ are Domar weights, i.e., shares in gross output, for the steam and other sectors, respectively.

Source: Crafts (2004).

Appendix

The divergence between the GDP deflator and the cost of living index is mainly apparent between 1770 and 1830 with inflation in the former lower than in the latter, as is reflected in the difference between the growth of real product wages and real consumption earnings reported in Table 1. With 1770 = 100 in each case, in 1830 the GDP deflator is 134.9 and the cost of living index is 146.1.

Not surprisingly, as is reported in Table A1, the weights used in the two indices are substantially different representing as they do the consumption expenditure of a manual worker and the production structure of the aggregate economy. Inter alia, the former has a very high weight for food and the latter has a high weight for industry, the relative prices of which diverged between 1770 and 1830, as is reflected in Table A2, where the price of agricultural goods in 1830 was 159.1 and industry was 95.6 (1770 = 100).[12]

These differences basically explain why the GDP deflator and the cost of living index differed as the following calculation reveals. If we take the prices from Table A2 and apply weights suggested by the cost of living index in Table A1, we get (0.625*159.1) + (0.11*222.5) + (0.025*158.6) + (0.24*95.6) = 150.82. In other words, the re-weighted GDP deflator would show a greater increase in prices and would, in fact, increase slightly more than the cost-of living index.

This calculation is merely illustrative but its message is robust. The reason that the cost of living index shows more inflation between 1770 and 1830 than the GDP deflator is that it gives more (less) weight to items for which relative prices were increasing (decreasing).

Table A1. Weighting Schemes

Cost of Living		*GDP Deflator*	
Food	62.5	Services	41.5
Rent	11.0	Rent	8.5
Beer	11.0	Industry	36.4
Clothing	8.0	Textiles	14.3
Fuel	4.0	Metals	5.7
Services	2.5	Agriculture	22.1
Lighting/Soap	1.0		

Sources: Allen (2007); Broadberry et al. (2015).

Table A2. Prices in 1830 (1770 = 100)

Services	**158.6**
Rent	222.5
Industry	95.6
Textiles	66.8
Metals	76.2
Agriculture	159.1

Source: prices database for Broadberry et al. (2015)

[12] The price index for the 'food, drink and tobacco' sub-set of industry was 163.3.