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Engels' pause: Technical change, capital accumulation, and inequality in the british industrial revolution

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ABSTRACT

The paper reviews the macroeconomic data describing the British economy from 1760 to 1913 and shows that it passed through a two stage evolution of inequality. In the first half of the 19th century, the real wage stagnated while output per worker expanded. The profit rate doubled and the share of profits in national income expanded at the expense of labour and land. After the middle of the 19th century, real wages began to grow in line with productivity, and the profit rate and factor shares stabilized. An integrated model of growth and distribution is developed to explain these trends. The model includes an aggregate production function that explains the distribution of income, while a savings function in which savings depended on property income governs accumulation. Simulations with the model show that technical progress was the prime mover behind the industrial revolution. Capital accumulation was a necessary complement. The surge in inequality was intrinsic to the growth process: technical change increased the demand for capital and raised the profit rate and capital's share. The rise in profits, in turn, sustained the industrial revolution by financing the necessary capital accumulation. After the middle of the 19th century, accumulation had caught up with the requirements of technology and wages rose in line with productivity.

> "Since the Reform Act of 1832 the most important social issue in England has been the condition of the working classes, who form the vast majority of the English people... What is to become of these propertyless millions who own nothing and consume today what they earned yesterday?... The English middle classes prefer to ignore the distress of the workers and this is particularly true of the industrialists, who grow rich on the misery of the mass of wage earners."
>
> –Friedrich Engels, *The Condition of the Working Class in England in 1844*, pp. 25–26.

Engels' *Condition of the Working Class in England in 1844* (1845) was an early and famous account of unequal development. He describes how the industrial revolution led to massive urbanisation and great increases in output. While per capita income was rising, real wages remained constant, however, so the gains from economic development accrued overwhelmingly to capitalists. The period of constant wages in the midst of rising output per worker was 'Engel's pause'. The pause had a progressive side, however, for the bourgeoisie saved from its growing income, and the ensuing investment drove the economy forward. In this paper, I argue that Engel's description of the industrial revolution was, in many respects, an insightful one.

Engels was not alone in his view of British industrialization. Among economists, Ricardo, Malthus, and Marx all believed that real wages would remain constant during capitalist development. They differed, however, in their explanations: Ricardo and Malthus believed that population growth would accelerate in response to any rise in income and ultimately force wages back to subsistence; Marx, on the other hand, believed that technological progress had a labour saving bias that would

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eliminate any upward demand pressure on wages even as output per worker surged. In this paper, I offer a model that explains why Engel's pause happened and why it eventually gave way to a more equitable process of growth in which workers gained as well as capitalists. The model allows us to assess the importance of the demographic and technological factors emphasized by the classical economists in their analyses of industrialization.

The empirical point of departure is the comparison between the growth of output per worker and the real wage shown by the most widely used measures of these variables (Fig. 1). According to the Crafts-Harley estimates of British GDP, output per worker rose by 46% between 1780 and 1840. Over the same period, Feinstein's real wage index rose by only 12%. It was only a slight exaggeration to say that the average real wage was constant, and it certainly rose much less than output per worker. This was the period, and the circumstances, described by Engel's in *The Condition of the Working Class*. In the next 60 years, however, the situation changed. Between 1840 and 1900, output per worker increased by 90% and the real wage by 123%. This was the 'modern' pattern in which labour productivity and wages advance at roughly the same rate, and it emerged in Britain around the time Engel's wrote his famous book.

The key question is: why did the British economy go through this two phase trajectory of development? Table 1 provides some basic macro data in a growth accounting framework that help specify the question. Between 1760 and 1800, the real wage grew slowly (0.39% per annum) but so did output per worker (0.26%), capital per worker, and total factor productivity (0.19%). Between 1800 and 1830, the famous inventions of the industrial revolution came on stream and raised aggregate TFP growth to 0.69% per year. This technology shock pushed up growth in output per worker to 0.63% pa but had little impact on capital accumulation or the real wage, which remained constant. This was the heart of Engel's Pause, and the relationship between technology, capital accumulation, and wages is the problematic of this paper. In the next 30 years 1830–1860, TFP growth increased to almost one percent per annum, capital per worker began to grow, and the growth in output per worker rose to 1.12% pa. The real wage finally began to grow (0.86% pa) but still lagged behind output per worker with most of the shortfall in the beginning of the period. From 1860 to 1900, productivity, capital per worker, and output per worker continued to grow as they had in 1830–1860. In this period, the real wage grew slightly faster than output per worker (1.61% pa versus 1.03%). The 'modern' pattern was established.

Before explaining why the productivity shock of the industrial revolution was accompanied by a lag in real wage growth, we must acknowledge that not everyone shares this characterization of the industrial revolution. There is a long standing, 'optimistic' tradition that maintains that workers did better than Engels and the classical economists thought. The most recent proponent of this view is Clark (2001, 2005, 2007a,b), who believes that the average real wage grew faster than Feinstein contended and who also thinks that GDP grew less rapidly than Crafts and Harley calculated. Putting faster wage growth together with slower output growth implies that 'manual worker's real incomes in the industrial revolution period rose much more than did real output per capita' (Clark, 2001, p. 6). Workers, rather than capitalists, were the winners in the industrial revolution, according to Clark. This is exciting revisionism, but neither Clark's real wage series nor his GDP series are convincing improvements on the existing literature (See Appendix B for more discussion). Consequently, this paper is based largely on the estimates of Feinstein, Crafts, and Harley.

1. The functional distribution of income

A complete description of the functional distribution of income in the industrial revolution requires the histories of the prices of labour, land, and capital as well as the shares of national income accruing to each. Figs. 1–3 graph most of these. All

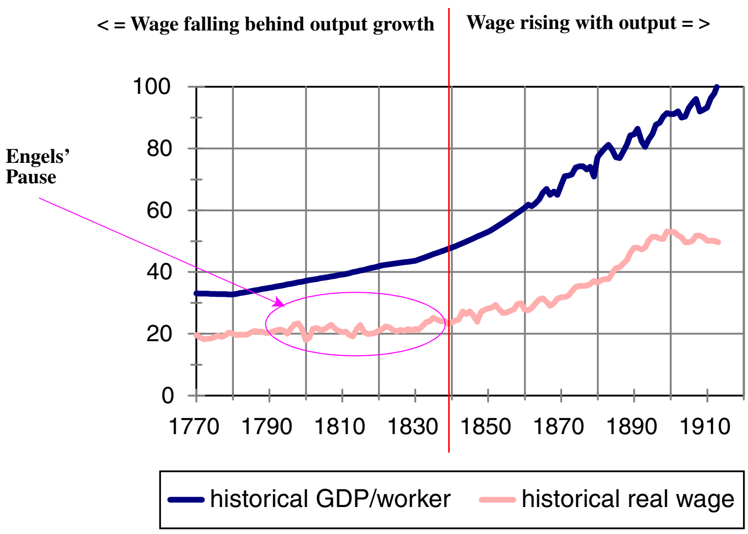

Fig. 1. The two phases of the British industrial revolution.

Table 1
Growth accounting for Great Britain, 1760–1900.

Growth of *Y*/*L*		Due to growth in			Growth of real awage
		K/L	T/L	A	
1760–1800	0.26%	0.11	−0.04	+0.19	0.39%
1800–1830	0.63%	0.13	−0.19	+0.69	0.00%
1830–1860	1.12%	0.37	−0.19	+0.94	0.86%
1860–1900	1.03%	0.30	−0.16	+0.89	1.61%

Note: the table shows growth rates per year for *Y*/*L* and *A* and the real wage. The entries for *K*/*L* and *T*/*L* are the contributions of their growth to the growth in *Y*/*L*, that is the growth rates per year of *K*/*L* and *T*/*L* multiplied by the factor shares of capital (0.35) and land (0.15), respectively.

values are real returns and real shares measured in the prices of the 1850s. I consider them in the order in which they were constructed.

Fig. 1 shows the real wage, which grew very little from 1770 to about 1840 and then rose in line with output per worker. The real wage series in Fig. 1 is my revision of Feinstein's estimate of the average nominal earnings of manual workers divided by the cost of living index. I have increased Feinstein's real earnings index by 14%, so that it equals the average earnings of all labour including the self-employed and those receiving salaries. The 14% mark-up appears to have been constant across the industrial revolution and is explained in Appendix A. With a constant mark-up, the problem of explaining constant earnings of manual workers is the same as explaining the average earnings of labour in general.

The real rent of land rose slowly from1760 to the late 19th century (Clark, 2002, p. 303). *Pace* Ricardo, it does not play a major role in the surges of inequality.

By multiplying the real wage by the occupied population and the real rent by the cultivated land, one obtains the wage bill and total rent. Subtracting these from GDP gives profits, and dividing total wages, rent, and profits by GDP gives shares.

Before 1860, capital income was primarily the net income of unincorporated enterprises where the owners' labour has been deducted as a cost valued at the earnings of salaried employees. Profits in this context included the return to entrepreneurship as well as the return to capital narrowly defined. Businessmen of the period regarded "profitability as a product of business acumen rather than the return to capital." As a result, business accounts usually distinguished "between interest on capital and the profits of business." (Hudson, 1986, p. 235) While I impute business profits to capital, this interpretation needs to be kept in mind. Capital income also included the return to residential housing and, beginning about 1840, the net income of railways, which were the principal business corporations before the middle of the 19th century. Thereafter, corporate earnings became an increasingly important part of capital income.

The shares are graphed in Fig. 2. The share of rent in national income declined gradually over the century. The shares of wages and profits exhibited conflicting trends. In the late 18th century, labour's share was about 60%. It declined steadily until the middle of the 19th century to around one half. Then it rose steadily to a peak around 1900 when its value was back to its late 18th century level. Finally, labour's share sagged again in the decade before the First World War. Capital's share moved inversely, more than doubling from a late 18th century value of 20% to over 40% in the middle of the 19th century. It fluctuated around the level until the First World War.

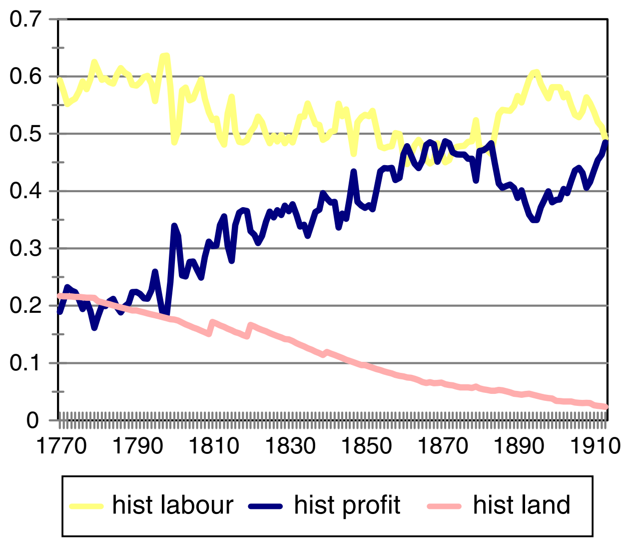

Fig. 2. Historical factor shares, 1770–1913.

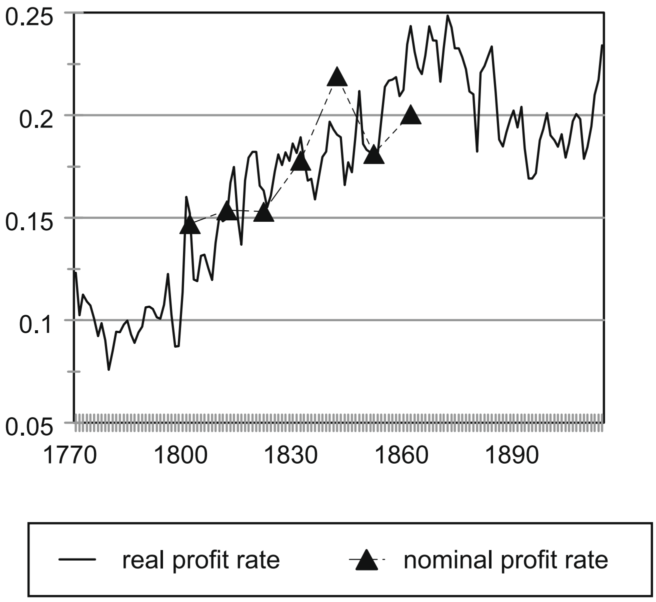

Fig. 3. Historical profit rate, 1770–1860.

These shares are calculated from real values of factor prices and GDP. Nominal values exhibit similar trends. I have revised Deane and Cole's (1969, p. 166) nominal GDP series by replacing their nominal wage series with Feinstein's to value labour. This makes the GDP estimates consistent with the wage estimates. Using these figures, labour's share dropped from 50% in 1801 to 45% in 1841. This was the period of Engel's pause. The distributional shifts we are analysing are not simply due to relative price movements.

Finally, one can calculate the gross profit rate by dividing profits as defined above by the capital stock. Fig. 3 shows two ways of doing the calculation. The 'real profit rate' equals real profits (real GDP less the real wage bill and total real rents) divided by Feinstein's real capital stock. The 'nominal profit rate' is the ratio of Deane and Cole's current value estimate of profits (their estimate of property income less the rent of agricultural land) divided by the capital stock valued in the prices of the year in question. The two series agree closely showing again that the trends analysed in this paper appear in both real and nominal series. In both cases, the series show that the profit rate was comparatively low at the end of the 18th century and rose until the middle of the 19th century when it stabilized until the First World War.

The rate of return to capital rose from near 10% in the late 18th century to 15% in the early 19th and surpassed 20% in the middle of the century. Even deducting a few percentage points for depreciation, the return to capital in the 19th century exceeded interest rates by a wide margin.[1] Some confirmation for these rates c. 1800 comes from Harley's (2006) estimates of the return to capital in the cotton industry calculated from business records: they imply a rate of return (net of depreciation) in the range 9–13% in the late 18th and early 19th centuries. Hudson's (1986, pp. 235–241, 272, 277) study of the records of wool and worsted firms reveals profit rates on business capital of 12–16% in the 1850s. Business capital was roughly half trade credit and half fixed capital, so the return on the latter was over 20%, which is in line with Fig. 3. A 20th century perspective is provided by Matthews et al. (1982, p. 187–188)) calculations of the profit rate realized by unincorporated businesses in the UK since the 1930s. These profit rates were in the range of 15–20% with some industries like construction and commerce occasionally realizing returns as high as 27%. Capital invested elsewhere in the economy realized much lower rates of return. This pattern emerged in the first half of the 19th century.

Figs. 1–3 show the facts that an investigation of growth and distribution in Britain must explain. The figures verify key features of Engels' pause in the first half of the 19th century: the stagnant real wage, the decline in labour's share of the national income, the rise in capital's, and the increase in the gross profit rate. In addition, the improved position of labour after the middle of the 19th century must be explained.

2. Explanations not taken

There are two approaches to explaining these trends. The first attributes them to a series of accidents: bad harvests and the Napoleonic Wars raised agricultural prices in Britain and checked the growth of real wages at the beginning of the 19th century (Mokyr and Savin, 1976). The Corn Laws then kept food prices high until 1846 and prevented wages from rising

[1] Interest rates do not show the same increase either, but they were too heavily regulated to be a reliable indicator of the demand for capital. Temin and Voth (2005). found that Hoare's bank rationed credit instead of raising interest rates.

(Williamson, 1990). These unfavourable events were reversed after 1870 with the American grain invasion, which lowered wheat prices and led to higher real wages (O'Rourke, 1997; O'Rourke and Williamson, 1999).

While these features of the global economy undoubtedly deserve attention, this paper pursues the second approach, which roots the macro trends in a model of the macro economy. In this model, technical change and capital accumulation govern the history of factor prices. It turns out that a simple model of this sort does a good job of explaining wage stagnation followed by wage acceleration. In view of that success, perhaps incidental features like the Corn Laws really were just incidental?

The obvious place to start any discussion of Britain's inequality trends is Lewis' (1954) famous model of 'economic development with unlimited supplies of labour,' for it predicts a two phase development process like that shown in Fig. 1. Conceptually, Lewis divided the economy into two sectors: one was peasant agriculture where the population was in surplus, capital was scarce, the marginal product of labour was zero, and income sharing guaranteed subsistence to all. The other was the modern, industrial sector where capital intensive production meant that labour productivity was high. Growth occurred as the modern sector expanded through capital accumulation. Labour to man the new capacity was available from the agricultural sector in infinitely elastic supply at the subsistence wage. This supply condition kept wages in the modern sector at subsistence–pessimism in action! – with the result that profits increased. The increase in profits provided the savings that allowed the modern sector to enlarge. When it was large enough to absorb all the labour surplus, further accumulation meant that wages rose along with productivity. The result was a two stage growth process with rising inequality in the first stage followed by a more equitable growth trajectory in the second.

Although Lewis' model was inspired by the classical economists analysing the British industrial revolution, the emphasis he placed on surplus labour is hard to reconcile with British history. As a general matter, surplus labour in the countryside is difficult to reconcile with a positive wage. In addition, there are particular problems to applying it to the British industrial revolution. British agriculture did not function as source of surplus labour that kept wages down. For one thing it was too small. In 1801 only 36% of the work force was in agriculture (Deane and Cole, 1969, p. 142) compared to the 75–80% that characterized the less developed countries Lewis was describing. Moreover, contrary to Marx, the parliament enclosures did not drive workers from the land; indeed, the poor law (through the Speenhamland system) paid men to stay in the countryside and reduced rural–urban migration. Finally, while real wages were stagnant in industrializing Britain, they stagnated at a high level when seen internationally: real wages in 18th century Britain and the Low Countries were higher than anywhere else in Eurasia (Allen, 2001). This does not square with Lewis' scenario. We need another approach.

3. A model of growth and income distribution

We can avoid the implausibilities of the Lewis model with an integrated model of growth and distribution. This model is a Solow (1956) one sector growth model in which savings are a function of property income rather than total income. Profits as a source of savings is one of Lewis's themes, and it is more revealing than his ideas about surplus labour, for the connection between technical progress, savings, and capital accumulation turns out to be fundamental to explaining the advent and cessation of Engel's pause. Suitably calibrated, this modification of the Solow model closely tracks the growth and inequality history of the industrial revolution. Simulations from 1760 to 1913 reproduce the two phases of rising and then constant inequality that Lewis delineated. Finally, the model allows us to probe the causes of inequality more deeply. While the classical economists all expected the real wage to remain constant, they disagreed about the reason: Malthus and Ricardo emphasized the growth of population, while Marx emphasized the labour saving bias of technical change. We can establish the importance of these explanations by simulating the integrated model.

Unlike the standard Solow model, the model proposed here does integrate growth and income distribution.[2] Output and factor prices are determined by neoclassical production function and its marginal products. Savings depends on property income and, thus, on the distribution of income, which, therefore, also feeds back on the growth rate. I begin with the three equations that comprise the heart of the Solow (1956) growth model:

$$Y = f(AL, K, T) \tag{1}$$

$$K_t = K_{t-1} + I_t - \delta K_{t-1} \tag{2}$$

$$I = sY \tag{3}$$

The first is a neoclassical production function in which GDP (Y) depends on the aggregate workforce (L), capital stock (K), and land area (T). The measurement of these variables was defined previously and is discussed in detail in Appendix A. Land is not normally included in a Solow model but is added here due to its importance in the British economy during the industrial revolution. A is an index of labour augmenting technical change. Technical change of this sort is necessary for a continuous rise in per capita income and the real wage, but it also paradoxically represents Marx's view of labour displacing technical change. In the simulations A plays both roles.

[2] David (1978) analysed American growth with a model like this and called it a "Cantabridgian Synthesis" since it incorporated elements of both the Cambridge, Massachusetts, and Cambridge, England, styles of growth models. See also Abramovitz and David (2001). Samuelson and Modigliani (1966) analysed the model theoretically and called it "a Neoclassical Kaldorian Case" (p. 295). They anticipated the Cantabrigian terminology with their quip that their analysis "can encompass valid theories in Cambridge, Massachusetts, Cambridge, Wisconsin, or any other Cambridge." (P. 297).

One input that Eq. (1) does not include is human capital. It is not explicitly represented because human capital accumulation was not an important feature of the industrial revolution. There was little increase in literacy or schooling rates. In this context, the constancy of relative earnings across occupations indicates a lack of rising demand for human capital. Britain before 1860 looks like a good example of Galor and Moav's (2006) picture of an early industrializer where the demand for physical capital was increasing more vigorously than the demand for human capital. Expenditures on education were also much less than those on physical capital. For these reasons, the accumulation of human capital is not explicitly modelled and labour is treated as having an unchanging amount of human capital (Mitch, 2004).[3]

Physical capital accumulation, however, is modelled, and the second equation defines the evolution of the stock. The stock in one year equals the stock in the previous year plus gross investment (I) and minus depreciation (at the rate δ) of the previous year's capital stock.

The third equation is the savings or investment function according to which investment is a constant fraction (s) of national income. Eq. (3) is the very simple Keynesian specification that Solow used. In some simulations, I will use it to set the economy-wide savings rate. However, Eq. (3) is not descriptive of industrializing Britain where all saving was done by landlords and capitalists. This idea is incorporated into the model with a savings function along the lines of Kalecki (1942) and Kaldor (1956):

$$I = (s_K\phi_K + s_T\phi_T)Y \tag{4}$$

In this specification, capitalists and landowners do all the savings since s_K is the propensity to saving out of profits and ϕ_K is the share of profits in national income. Likewise, s_T is the propensity to saving out of rents and ϕ_T is the share of rents. The economy-wide savings rate $s = (s_K\phi_K + s_T\phi_T)$ depends on the distribution of income. With Eq. (4), accumulation and income distribution are interdependent and cannot be analysed separately. In other words, one cannot first ask why income grew and then ask how the benefits of growth were distributed. Each process influenced the other.

Usually, a growth model also includes an equation specifying the growth in the work force or population (assumed to be proportional) at some exogenous rate. Since the model is being applied here to past events, the work force is simply taken to be its historical time series. There was some variation in the fraction of the population that was employed. I will ignore that, however, in this paper and use the terms output per worker and per capita income interchangeably.

Three more equations model the distribution of income explicitly. The derivatives of Eq. (1) with respect to L, K, and T are the marginal products of labour, capital, and land, and imply the trajectories of the real wage, return to capital, and rent of land. These factor prices can also be expressed as proportions of the average products of the inputs:

$$w = \phi_L \frac{Y}{L} \tag{5}$$

$$i = \phi_K \frac{Y}{K} \tag{6}$$

$$r = \phi_T \frac{Y}{T} \tag{7}$$

Here w, i, and r are the real wage, profit rate, and rent of land. ϕ_L, ϕ_K, ϕ_T are the shares of labour, capital, and land in national income, as previously noted.

A production function must be specified to apply the model to historical data. The Cobb–Douglas is commonly used, and, indeed, I used a Cobb–Douglas for trial simulations and to determine a provisional trajectory for productivity growth. The function is:

$$Y = A_0(AL)^{\alpha}K^{\beta}T^{\gamma} \tag{8}$$

where α, β, γ are positive fractions that sum to one when there is constant returns to scale, as will be assumed. A_0 is a scaling parameter. With a Cobb–Douglas technology, A can be factored out as A^{α} which is the conventional, Hicks neutral, total factory productivity index. In addition, in competitive equilibrium, the exponents α, β, and γ equal the shares of national income accruing to the factors (ϕ_L, ϕ_K, and ϕ_T). These shares are constants. They can be calculated from the national accounts of one year; in other words, the model can be calibrated from a single data point.[4]

Ultimately, however, the Cobb–Douglas is not satisfactory for understanding inequality since the essence of the matter is that the shares were not constant. Economists have proposed more general functions that relax that restriction. The simplest is the CES (constant elasticity of substitution). It is not general enough, however, for it requires that the elasticities of substitution between all pairs of inputs be equal (although not necessarily equal to one). Instead, I have used the translog production function.[5] It is the natural generalization of the Cobb–Douglas. With the translog, all shares can vary as can all of the pair-wise elasticities of substitution. The translog is usually written in logarithmic form:

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[3] The issue warrants attention in future research, however, given the importance of skilled biased technical change in the twentieth century and the wide spread impression that technical change was skill saving during the 19th century. See on these points, Goldin and Katz (1998), Sokoloff (1984), Williamson (1985).

[4] Van Zanden (2005) uses a Solow model with a Cobb–Douglas function to analyze early modern economic growth.

[5] Introduced by Christensen et al. (1971) and Layard et al. (1971).

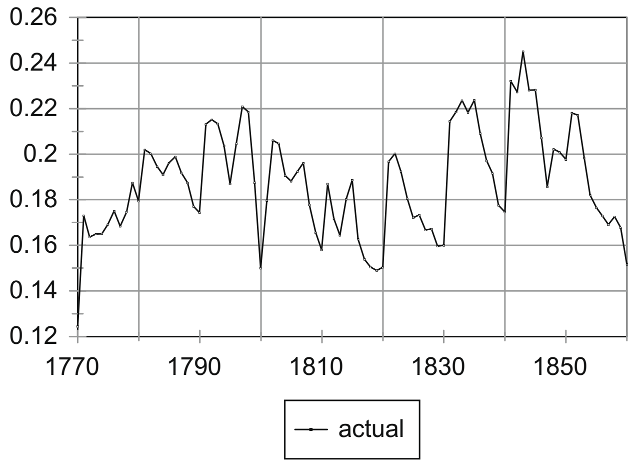

Fig. 4. Savings propensity out of property income.

$$\ln Y = \alpha_0 + \alpha_K \ln K + \alpha_L \ln(AL) + \alpha_T \ln T + (1/2)\beta_{KK}(\ln K)^2 + \beta_{KL} \ln K \ln(AL) + \beta_{KT} \ln K \ln T + (1/2)\beta_{LL}(\ln(AL))^2 + \beta_{LT} \ln(AL) \ln T + (1/2)\beta_{TT}(\ln T)^2 \quad (9)$$

subject to the adding up conditions $\alpha_K + \alpha_L + \alpha_T = 1$, $\beta_{KK} + \beta_{LK} + \beta_{TK} = 0$, $\beta_{KL} + \beta_{LL} + \beta_{TL} = 0$, and $\beta_{KT} + \beta_{LT} + \beta_{TT} = 0$. When all of the $\beta_{ij} = 0$, the translog function reduces to the Cobb–Douglas.

Logarithmic differentiation of the translog function gives share equations that imply trajectories of factor prices in accord with Eqs. (5)–(7):

$$\phi_K = \alpha_K + \beta_{KK} \ln K + \beta_{KL} \ln(AL) + \beta_{KT} \ln T \quad (10)$$
$$\phi_L = \alpha_L + \beta_{LK} \ln K + \beta_{LL} \ln(AL) + \beta_{LT} \ln T \quad (11)$$
$$\phi_T = \alpha_T + \beta_{TK} \ln K + \beta_{TL} \ln(AL) + \beta_{TT} \ln T \quad (12)$$

These equations are the basis for calibrating the model, as we will see.

4. Savings and production function calibration

The savings and production functions are central to the growth model, and each must be estimated. Were there sufficient data, this could be done econometrically, but data are too limited for that. Instead they are calibrated.

There are two variants of the savings function. In the case of $I = sY$ (Eq. (2)), s is determined by dividing real gross investment by real GDP. The ratio rises gradually from about 6% in 1760 to 11% in the 1830s and 1840s. It sags to about 10% in the 1850s.

The alternative savings function is the Kalecki function $I = (s_K\phi_K + s_T\phi_T)Y$ (Eq. (4)). This function is preferred since household budgets from the industrial revolution indicate that, on average, workers did not save (Horrell and Humphries, 1992; Horrell, 1996). All of the savings, therefore, came from landlords and capitalists.

Fig. 4 shows the ratio of savings to their income. Use is made of the identity that savings equals investment, and of Feinstein's estimates of the latter.[6] There is some suggestion that the savings rate out of property income rose in the 1760s and 1770s, but thereafter there was no trend. Regression of the savings rate on the shares of profits and rents in national income for the period 1770–1913 showed a small difference between landlords and capitalists:

$$I/Y = 0.138\phi_T + 0.196\phi_K \quad (13)$$

The coefficients had estimated standards errors of 0.013 and 0.004, respectively. In this model, capitalists saved a higher proportion of income than landlords. I used this equation for most simulations except that I lowered the coefficient of savings by capitalists to 0.14 in the 1760s and 0.16 in the 1770s. This improved the simulations in those years and creates a small exogenous component to the rise in savings in 1780. The increase in savings in later years remains dependent on changes in the distribution of income.

[6] Feinstein (1988, p. 441) presents decennial estimates of gross investment for 1761–1860 for Great Britain in 1851–1860 prices. The investment or savings rate was computing by dividing these by real British GDP expressed in prices of the same year. The investment rate was extended to 1913 using an estimate of the UK savings rate for the same period. This rate was calculated by first deflating Feinstein's (1988, pp. 427–428, 470–471)) annual estimates of investment for the United Kingdom in current prices by his capital goods price index to get real investment in prices for 1851–1860. Deflated UK investment was then divided by real UK GDP (Feinstein, 1978, p. 84) to get a UK investment rate. The investment rate for the 1850s is generated by both procedures, and they agree closely. Factor shares are computed in accord with the text and Appendix A.

Table 2
Translog coefficients.

$\alpha_O = -5.5749055$
$\alpha_K = -6.1135524$
$\alpha_L = 5.9731428$
$\alpha_T = 1.1404097$
$\beta_{KK} = -2.0670448$
$\beta_{KL} = 1.7289444$
$\beta_{KT} = 0.3381003$
$\beta_{LL} = -1.3908441$
$\beta_{LT} = -0.3381003$
$\beta_{TT} = -1.99 \times 10^{-15}$

The parameters of the translog function must also be determined. While the parameters of the Cobb–Douglas function can be calculated from the factor shares at one point in time, the translog requires two sets of factor shares.[7] If the adding up conditions $\alpha_K + \alpha_L + \alpha_T = 1$, $\beta_{KL} + \beta_{LL} + \beta_{TL} = 0$ and $\beta_{KT} + \beta_{LT} + \beta_{TT} = 0$ are imposed[8] on Eqs. (10)–(12), one gets:

$$\begin{vmatrix} \phi_K \\ \phi_L \\ \phi_T - 1 \end{vmatrix} = \begin{vmatrix} 1 & 0 & \ln K & \ln L & \ln T & 0 \\ 0 & 1 & 0 & \ln K - \ln AL & \ln AL - \ln T & -\ln AL - \ln T \\ -1 & -1 & 0 & 0 & \ln K - \ln AL & \ln T - \ln AL \end{vmatrix} \begin{vmatrix} \alpha_K \\ \alpha_L \\ \beta_{KK} \\ \beta_{KL} \\ \beta_{KT} \\ \beta_{TT} \end{vmatrix}$$

If the values for the three shares and the corresponding K, T, L, and A are substituted into these three equations for two years, then one obtains six equations in the six unknown parameters α_K, α_L, β_{KK}, β_{KL}, β_{KT}, and β_{TT}. These can be solved by inverting the matrix and premultiplying the share vector with it. The remaining parameters can be calculated from the imposed conditions.

A complication is that the parameters depend on A, and A depends on the parameters, so values must be obtained by iterating from one to the other. In reality, the dependence of the parameters on A is not very great and vice versa, so that finding a consistent solution is not difficult. The parameters and A were estimated in the following stages. First, I set the factor share values at $\phi_L = 0.68$, $\phi_K = 0.10$, and $\phi_T = 0.22$ in 1770 and 0.58, 0.32, and 0.10 in 1860. These values were typical of those years. Second, a trial set of values of the labour augmenting technological change parameter A was computed by assuming a Cobb–Douglas technology (Eq. (8)). A was set equal to one in 1770 and subsequent values were computed for the later years during the industrial revolution for which GDP has been estimated (1801, 1830, and 1860) as well as 1875, 1896, and 1913, which divide the late 19th century in a conventional manner. Third, the 1770 and 1860 values of A were substituted into the six share equations for those two years, and a set of values of the translog parameters was then computed. Fourth, the now calibrated translog production function was used to compute GDP in 1801, 1831, and so forth up to 1913. These computed values were not equal to the actual values since the values of A had been computed with a different production function. The values of A were changed, so that computed GDP equalled actual GDP. The adjustments were made period by period, i.e., the growth in A between 1770 and 1801 was altered, so that the computed and actual GDP were equal in 1801. This was repeated for 1830, 1860, and so forth to 1913. Fifth, with the new values of A in 1770 and 1860, the six share equations were again solve for a new set of translog parameters as in stage three just described. The cycle of computing values of A and the translog parameters was repeated until estimation errors of GDP were eliminated. This only took a few iterations. The estimated rate of labour augmenting technical change increased from 0.4% per year in 1770–1801 to 1.3% in 1801–1830 and, finally, to 1.4% from 1831 to 1896 when it slumped to 1.0% until 1913. No distributional information between 1770 and 1860 was used to calibrate the model, so its ability to replicate Engel's pause (as we will see) is independent verification of the model rather than an artefact of its construction.

The estimated translog parameter values are shown in Table 2. Their economic significance lies in their implications for elasticities of substitution – in particular, for the elasticity of substitution between labour and capital. In this case, it was close to zero and that plays an important role in explaining both economic growth and the two phase history of inequality.

Fig. 5 shows the labour–capital isoquant for the translog function in 1810 and, for comparison, a Cobb–Douglas isoquant through the same input combination.[9] The Cobb–Douglas has an elasticity of substitution equal to one for all input pairs. In the

[7] This is suggested by Diewert's (1976) quadratic approximation lemma, which he used to prove that the Törnqvist-Divisia input index is exact for a translog production function.

[8] It is not necessary to explicitly impose the adding up condition $\beta_{KK} + \beta_{KL} + \beta_{KT} = 0$ since it is implied by the others.

[9] The translog function is not necessarily concave for all parameter values and input levels. The discerning reader may be able to see that the translog isoquant in Fig. 5 turns up when capital increases from 450 to 500 – in violation of the standard assumptions. This defect is an issue for only the last few years of one simulation discussed in this paper.

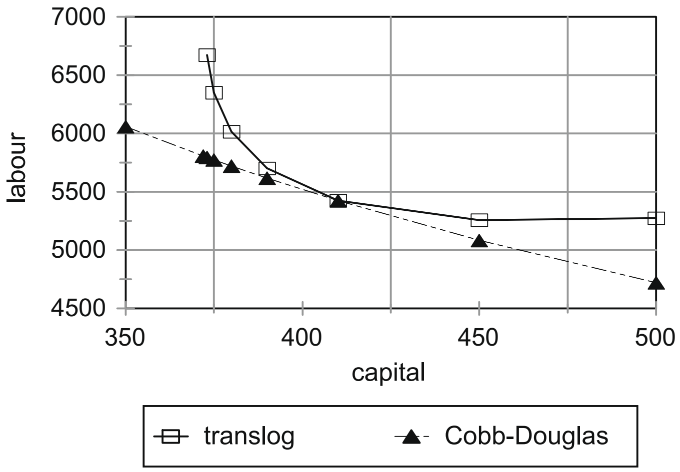

Fig. 5. Translog and Cobb–Douglas isoquants, 1810.

figure, the Cobb–Douglas isoquant is quite flat, while the translog is closer to the right angle of a Leontief fixed proportions technology. The elasticity of substitution between capital and labour was estimated by trial and improvement to be approximately 0.2 in 1810.[10] Berndt (1976) claimed a value of one for twentieth century America, but some older and many recent investigators have concluded that the elasticity of substitution was considerably lower – in some cases as low as 0.2–0.3 (Acemoglu, 2003; Antràs, 2004; David and van de Klundert, 1965; Lucas, 1969; McAdam and Willman, 2006). The production function of industrializing Britain used here is consistent with this line of research.

The low elasticity of substitution between capital and labour reflected two important features of industrializing Britain. First, much of the investment was in social overhead capital (Feinstein, 1988, p. 431), and that did not admit much substitutability between capital and labour. The population was expanding, and industrialization meant urbanization. Each new job, in other words, required a large dollop of housing and infrastructure. The British industrial revolution was done on the cheap, so far as this kind of investment was concerned (Williamson, 1990), so these dollops were as small as possible and did not admit much substitutability with labour. As Britain was industrializing, capital was required in fixed proportion to labour, and that is what the low elasticity of substitution picks up. Later, when the urban structure was stabilized, the substitution of capital for labour at the plant level influenced the aggregate statistics more, and estimated elasticities of substitution were greater.

Second, for many industries during the industrial revolution, there was little scope to substitute capital for labour even at the plant level. The implements of production in many industries were the same around the world irrespective of relative factor prices. In the 1760s, cloth was woven on similar looms in England where wages were high and in India where they were low (Broadberry and Gupta, 2006a,b). The creation of mechanized technology during the industrial revolution meant that the scope for factor substitution broadened. By the late 19th century, weaving was done by power looms in Britain and America and by handlooms in the third world, while everyone had used hand looms a century before. However, the implication of the slow rate of aggregate TFP growth shown in Table 1 is that this modernization (and with it the increase in the elasticity of substitution) was confined to only a few 'revolutionized' industries (Crafts, 1985a; Crafts and Harley, 1992). Throughout the industrial revolution, the opportunities to substitute capital for labour in most branches of the economy were limited, and that is reflected in the low elasticity of substitution between capital and labour.

The low elasticity of substitution has an important implication for growth: Under this circumstance, both capital and productivity (i.e., effective labour) must increase in tandem for growth to occur. More capital without more productivity scarcely raises output. Likewise, productivity growth without capital accumulation fails to increase production. Without both technical progress and the capital accumulation to match it, there was no economic growth.

5. How well does the model perform?

To see how well the model performs, we need to simulate it with historical values for the exogenous variables to check that the simulated values of the endogenous variables track their historical counterparts. GDP, of course, is tracked very closely since the rates of technical progress and the production function parameters were chosen to ensure that. The history of

[10] The actual 1810 capital–labour ratio and the ratio of the marginal products of labour and capital were first obtained. Labour was next increased by a small amount, which increased output in turn. Then capital was reduced until the original output was produced. The new capital–labour ratio and corresponding ratio of marginal products were computed. The elasticity of substitution was computed as the ratio of the percentage change in the capital–labour ratio divided by the percentage change in the marginal product ratio. The procedure was repeated with different changes in labour with little variation in the elasticity.

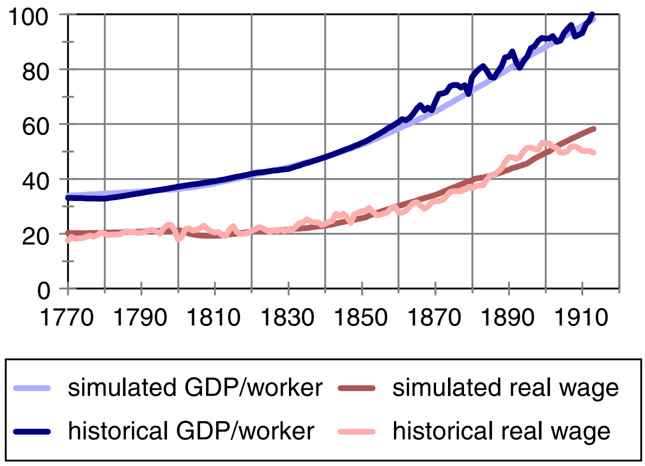

Fig. 6. Simulating Britain's two stage development trajectory.

the other endogenous variables provide a better test of the model. The most fundamental question is whether the model replicates the two phase pattern of British history.

Fig. 6 compares the actual and simulated values of output per worker and the real wage from 1770 to 1913. The trajectories of both are accurately mapped. The simulated wage rate shows the two phases of British history clearly, and the timing of shift from the first to the second – which was not imposed in the estimation – is accurately replicated. The model passes this fundamental test.

The model also replicates the history of the other factor prices. The simulated profit rate reproduces the step pattern of the historical series (whether measured with real or nominal variables) – the comparatively low returns of the 18th century, the doubling between 1800 and 1840, and then stability to the First World War (Fig. 7). Real land rents rose slowly from 1770 to the 'great depression' (1873–1896) when they stabilised and then slumped (Fig. 8). This pattern is also captured.

Finally, the model captures the history of the factor shares (Fig. 9). The decline of labour's share during the first half of the 19th century is reproduced as is the increase later. The declining share of income accruing to land is very accurately reproduced, as is the history of capital's share. Like the profit rate, it went through three phases – a low level in the 18th century, a doubling in the first half of the 19th century, and then stability until World War I. The model was calibrated with shares for 1770 and 1860, so it is no surprise that they are reproduced. However, the timing of the movements between 1770 and 1860 were not imposed, and so the correspondence between actual and predicted values is evidence in favour of the model. The

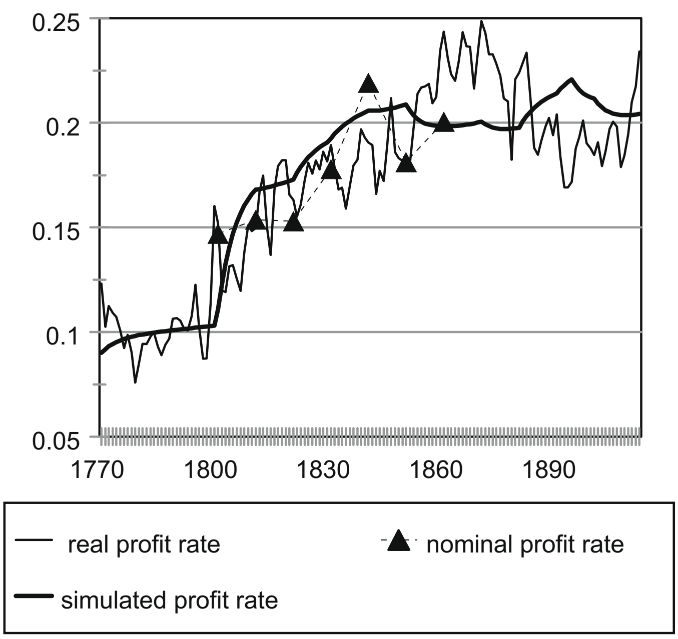

Fig. 7. Actual and simulated profit rates, 1770–1913.

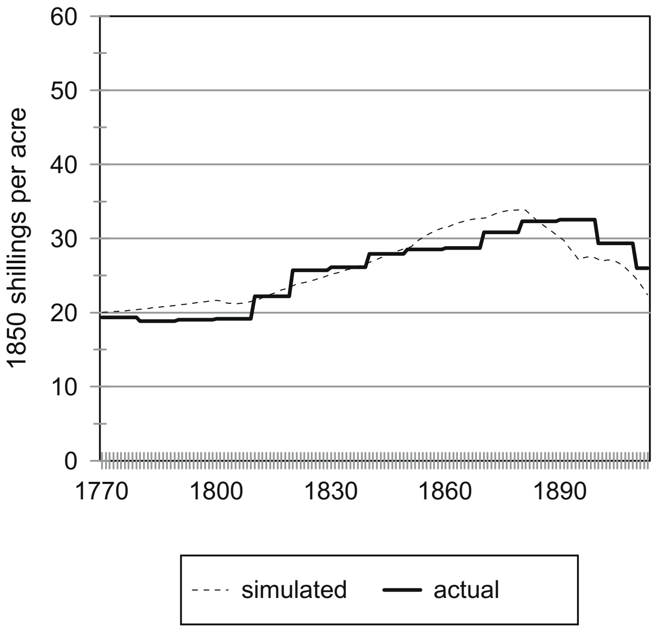

Fig. 8. Actual and simulated land rent, 1770–1913.

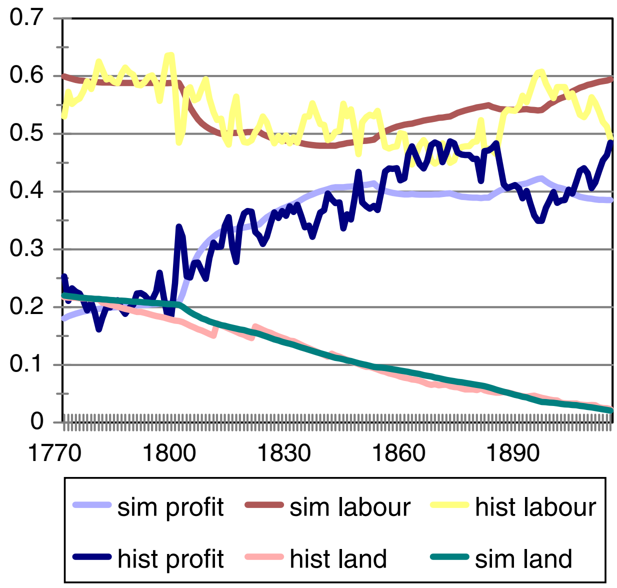

Fig. 9. Actual and simulated shares, 1770–1913.

broad correspondence between predictions and historical trends between 1860 and the First World I is further confirmation of the model. This period provides a distinctly 'out of sample' test.

While the model replicates the broad distribution patterns after 1860, the forecast errors were certainly larger than previously. This is not surprising since the model was calibrated over the period 1770–1860 when the British economy was comparatively closed. It became much more open after the middle of the 19th century with the repeal of the Corn Laws and Navigation Acts and the construction of a global system of railways and steamships. The 'grain invasion' of the late 19th century depressed British agriculture and rents (O'Rourke, 1997). In addition, the opportunities for foreign investment increased dramatically, and millions of Brits moved to North America and Australasia. Growing openness meant that international factors played a much more dramatic role in growth and income distribution in Britain (O'Rourke and Williamson, 2005). Since none of this is included in the model, it is not surprising that it does not track distributional shares as well as it did pre-1860. What is even more surprising, however, is that it works as well as it does. The implication is that technical progress and capital accumulation continued to play important roles in determining output and wages in Britain: cheap American food, in other words, was not the decisive reason that the real wage rose after 1870.

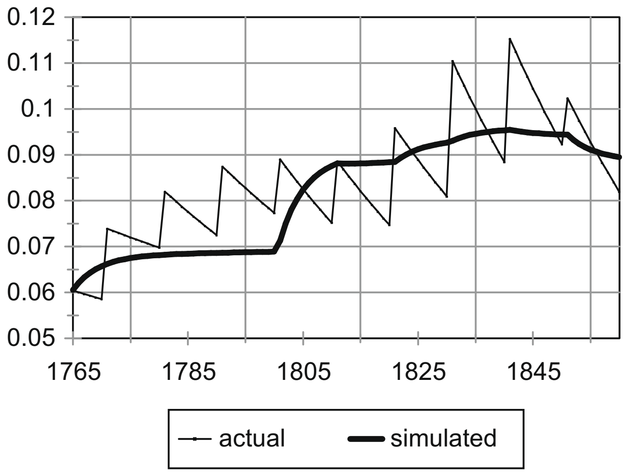

Fig. 10. Actual and simulated investment rates, 1770–1860.

6. Capital accumulation and the two phase history of inequality

Why did Britain exhibit the two stage inequality history that Lewis highlighted? It was not for the reason he advanced, namely, the disappearance of surplus labour. Rather, balance was restored between the accumulation of capital and the growth of productivity.

The first stage of rising inequality was precipitated by the acceleration of technical progress after 1800 in conjunction with the low elasticity of substitution between capital and labour in the aggregate production function. With technical progress specified as labour augmenting, a higher rate of technical progress was like more rapid population growth: it reduced the ratio of capital to augmented labour. A lower capital–labour ratio implied a higher marginal product of capital. With an elasticity of substitution less than one, the higher marginal product of capital translated into a higher share of capital in national income – as Fig. 9 shows. Inequality increased and the real wage stagnated.

The first stage contained the seeds of its own undoing, however. As the share of profits increased, the economy-wide savings rate rose since capitalists saved a constant share of their income. As a result, capital accumulation accelerated. This is shown in Fig. 10, which compares actual and simulated investment rates for 1770–1860. The general rise in investment that took place is replicated by the model.[11] Eventually, enough capital was accumulated to correspond to the requirements of higher productivity. Once steady state growth was achieved, so capital grew as rapidly as augmented labour, productivity growth boosted the real wage as well as GDP per worker. This change occurred in the middle of the 19th century. Britain shifted from Lewis' first stage to his second.

The transition from the first stage to the second, which occurred around the time of the publication of the *Communist Manifesto* (1848), provides a wry commentary on Marx's expectations. The acceleration of productivity growth did, indeed, shift income from workers to capitalists, as he expected. The result, however, was not continually increasing immiseration, for the capitalists invested a portion of their extra income and the increase in the capital stock eventually allowed rising productivity to be manifest as rising real wages. History did, indeed, exhibit a stage pattern of evolution, but the stage of flat real wages was followed by the most sustained rise in real wages ever seen – not by socialist revolution. The integrated growth model captures the logic of history.

7. Malthus versus Marx

The classical economists shared a common expectation that capital accumulation and technical progress would *not* trickle down to the working class as rising wages, but they disagreed about the reason for wage stagnation. Marx thought that a high rate of labour augmenting technical progress would reduce labour demand and keep wages from rising. Malthus, on the other hand, accepted that technical progress would increase the demand for labour but believed this would be offset by an increase in the population. We can explore these conjectures by simulating the model with different rates of productivity growth and population growth.

To explore Marx's view, we can simulate the economy holding the rate of productivity growth at at pre-industrial level. In that case, there was no economic growth and no change in inequality. Rising productivity was a necessary condition for rising inequality–indeed, for anything at all to happen.

[11] It looks as though there were some exogenous boosts to investment in the 1790s and 1840s that were not captured by the model. The was probably associated with 'canal mania' and the second with railway building.

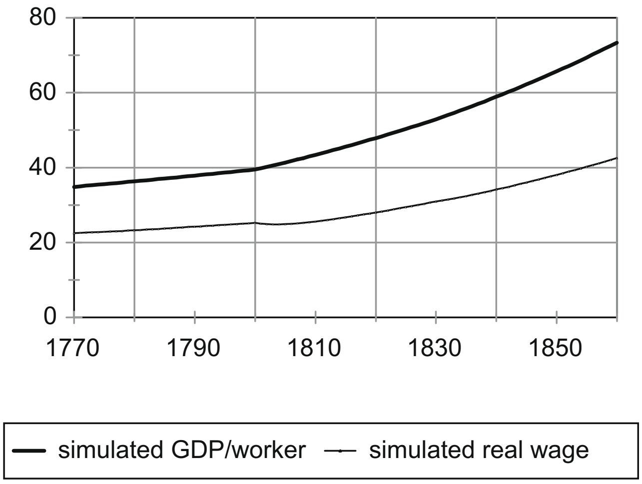

Fig. 11. Simulated GDP/head and the real wage with no population growth.

The result is more interesting if we simulate the industrial revolution and eliminate the population explosion that accompanied it. Fig. 11 shows the trajectories of output per worker and the real wage from 1770 to 1860. Both trend upward, and there is little lag of wages behind output after the increase in productivity growth in 1801. Engel's pause in real wage growth is eliminated. The simulated shares change very little. Without the burden of equipping an expanding population, the increased demand for capital induced by rising productivity could be met without a marked shift of income to property owners. Consequently, population growth was a necessary condition for stationary real wages: Engels' pause looks like Malthus' dismal science come true.

History was more complicated, however. While population growth was a necessary condition for rising inequality, it was not sufficient. This is shown by the experience of Britain after 1860 when real wages rose in line with population even though population was growing as rapidly as in the first half of the 19th century. Population growth and technical progress were both necessary for an increase in inequality, but their impact was mediate by the adjustments to the capital stock that are at the core of the integrated growth model. Only by considering the feedbacks in the model can the evolution of output and wages be understood. Malthus and Marx are not enough.

8. Conclusion

The analysis of this paper changes the emphasis in our understanding of the industrial revolution. Three general revisions stand out. First, inequality rose substantially in the first four decades of the 19th century. The share of capital income expanded at the expense of both land and labour income. The average real wage stagnated, while the rate of profit doubled. Second, these trends can be explained without reference to contingent events like the Napoleonic Wars or the settlement of the American West. The main trends can be explained with a simple macroeconomic model. Third, that macro model implies that the explanation of growth cannot be separated from the discussion of inequality since each influenced the other. In the first instance, it was the acceleration of productivity growth that led to the rise in inequality. Reciprocally, it was the rising share of profits that induced the savings that met the demand for capital and allowed output to expand. Moreover, these two general points are interconnected: the production function parameters that make capital accumulation and technical progress complements in the growth analysis are implied by the change in the factor shares between 1770 and 1860.

With these general considerations in mind, we can outline the story of the industrial revolution as follows: the prime mover was technical progress beginning with the famous inventions of the 18th century including mechanical spinning, coke smelting, iron puddling, and the steam engine. It was only after 1800 that the revolutionized industries were large enough to affect the national economy. Their impact was reinforced by a supporting boost from rising agricultural productivity and further inventions like the power loom, the railroad, and the application of steam power more generally (Crafts, 2004). The adoption of these inventions led to a rise in demand for capital – for cities, housing, and infrastructure as well as for plant and equipment. Consequently, the rate of return rose and pushed up the share of profits in national income. With more income, capitalists saved more, but the response was limited, the capital–labour ratio rose only modestly, the urban environment suffered as cities were built on the cheap, and the purchasing power of wages stagnated (Williamson, 1990). Real wages rising in line with the growth of labour productivity was not a viable option since income had to shift in favour of property owners in order for their savings to rise enough to allow the economy to take advantage of the new productivity raising methods. Hence, the upward leap in inequality.

The rise in inequality, however, had ramifications that made it self-extinguishing. The increase in profits induced enough capital formation by the middle of the 19th century for the economy to realize a balanced growth path with capital and augmented labour growing at the same rate. Under this condition, the real wage grew in line with productivity. The European grain invasion and the chance to move to Australia, Canada, or the USA also boosted the real wage. They were not of fundamental importance, however: The burden of the integrated growth model is that productivity growth and capital accumulation were principally responsible for the rise in working class living standards after 1850, just as they had been responsible for their stagnation in the first half of the 19th century. Even sustained, rapid population growth was not enough to prevent labour incomes from rising once the accumulation conditions were right.

Acknowledgements

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Appendix A. Data description

We know much more about economic growth during the industrial revolution than was known 50 years ago thanks to the efforts of several generations of economic historians. Key variables, however, have only been established for benchmark years; in particular, Crafts has estimated real GDP only for 1760, 1780, 1801, 1831, and 1860. The small number of observations precludes the econometric estimation of important relationships and requires calibrating the model instead. Also different series use different benchmark years. To bring them into conformity and to simplify simulations, all series were annualized by interpolating missing values. As a result, the series are artificially smoothed but capture the main trends. Real values are measured in the prices of 1850–1860 or particular years in the decade as available. The price level did not change greatly in this period. All values apply to Great Britain unless otherwise noted.

A.1. Real GDP

Based on Deane and Cole's work, Feinstein (1978, p. 84) reckoned GDP in 1830 at £310 million and in 1860 at £650 million (both in 1851–1860 prices). Crafts and Harley have been continuously improving the measurement of British GDP for earlier years (Crafts, 1985; Crafts and Harley, 1992; Harley, 1993), and I have extrapolated Feinstein's 1830 estimate backwards using the Crafts and Harley (1992, p. 715) real output index. This gives real GDP estimates for the benchmark years just noted. GDP was extrapolated to 1913 using Feinstein's (1972, pp. T118–T119) index of real British GDP.

The inputs were measured as follows:

Land – acreage of arable, meadow, and improved pasture (commons are excluded). Allen (1994, p. 104, 2005) presents benchmark estimates for England and Wales. Following McCulloch (1847, vol. I, pp. 554–555, 566–567)), these have been increased by 12% to include Scotland.

Labour – for 1801, 1811, and continuing at ten year intervals, Deane and Cole's (1969, p. 143) estimates of the occupied population were used. The occupied population for 1760 was estimated by applying the 1801 ratio to the population. Voth (2001) has argued that the working year lengthened in this period. I have not tried to adjust the data for this change, so some of the rise in productivity that I report may be due to greater work intensity.

Capital (and real gross investment) – Feinstein (1988, p. 441) presents average annual gross investment by decade from 1760 to 1860 for Great Britain. The magnitudes are expressed in the prices of the 1850s. He also estimated the capital stock in the same prices at decade intervals by Eq. (3). To annualize the data, I assumed that real gross investment in each year equalled the average for its decade. I reconstructed the capital stock year by year with Eq. (3). With the annualized data, a depreciation rate of $\delta = 2.4\%$ per year gives a capital stock series that matches Feinstein's almost exactly at decennial intervals. Therefore, 2.4% was used in subsequent simulations.

The British capital stock from 1861 to 1913 was calculated as the capital stock in the previous year less depreciation at 2.4% plus real gross investment. The latter was worked out by multiplying real GDP by the UK investment rate. This investment was the ratio of real gross investment for the UK to real GDP for the UK. These were calculated from Feinstein's (1988, pp. 427–428, 470–471) current value investment series, his investment deflator, and his real GDP series given in Feinstein, 1978, p. 84). See also 6.

A.2. Factor returns

Real rent of land – the history of rent has been the subject of considerable controversy, but the Norton and Gilbert (1889), Allen (1992), and Clark (2002) series agree reasonably well for this period, as does the Turner et al. (1997) series after 1800. Clark's (2002, p. 303) series inclusive of taxes and rents is used here.

Real profit rate – calculated as profits divided by the capital stock where profits are computed residually as real GDP minus real wages and salaries minus real land rents.

A.3. Real earnings of manual labourers

1770–1882: Nominal earnings and retail price index from Feinstein (1998, pp. 652–653). For 1770–1860, the revision of the consumer price index in Allen (2007) was used instead of Feinstein's orginal deflator. The difference is not great.

1882–1913: Average weekly earnings and retail prices from Feinstein (1972, p. T140).

A.4. Return to salaried employees and the self-employed

The available data, which are far from perfect, indicate that the average return to all labour in the industrial revolution was a constant mark-up over the earnings of manual workers. Deane and Cole (1969, p. 167) thought that the self-employed earned 50% more than the average manual labourer, while Matthews et al. (1982, pp. 167, 170) assumed that the salaried and self-employed earned 2.0–2.6 times the earnings of manual labourers just before the First World War.

To investigate the mark-up, begin with 1856 for which Matthews et al. (1982, p. 164) found that wages were 43.5% of GNP, salaries were 6.9%, and the labour income of the self-employed was 7.4%. Assuming that the salaried and self-employed made 1.75 times the earnings of manual workers implies that 16% of the workforce were salaried or self-employed and that total labour income was 12% more than the return to labour when it was valued at the manual labourer's earnings. This premium reflects both the earnings premium of the salaried and self-employed and the share of the labour force they comprised.

How did these ratios vary during the industrial revolution? At one time, Williamson (1985) had argued that the earnings of high income earners rose with respect to manual labourers during the industrial revolution, but this position was criticized by Jackson (1987), who established the current orthodoxy that relative earnings were constant. What about the structure of the labour force? Accepting Jackson's findings and assuming that the proportions of salaried and self-employed individuals in the work force remained constant, we can calculate the average return to labour by increasing the earnings of manual labourers by 12%. We can check these assumptions for 1801, for instance, by calculating the number of salaried employees and self-employed as 16% of the occupied population, i.e. 759 thousand people. This figure can be compared to the numbers of people in these categories in Colquhoun's (1806) social table for England and Wales in 1801 (Lindert and Williamson, 1982). The comparison must make allowance for Scotland. Interpreted this way, Colquhoun's figures imply that there were 786 thousand salaried and self-employed people working in Britain in 1801. They were engaged as professionals, civil servants, teachers, merchants, shopkeepers, publicans, manufacturers, farmers, military officers, engineers, and so forth. This is far from an exact science, but there is sufficient correspondence to accept a stable division of the work force between manual workers, on the one hand, and the salaried and self-employed, on the other.

Factor shares – computed by dividing real factor earnings by real GDP.

Appendix B. Clark's wage and output estimates

While Clark's work has raised some important issues, this paper is based on the more established view. So far as wages are concerned, Clark's novel conclusions derive from a new consumer price index. Some of the component series are improvements over those used by Feinstein, but some of Clark's changes degrade the index. A new index based on the best of both is much closer to Feinstein's than to Clark's (Allen, 2007). Moreover, even if Clark's index were used in this paper, the conclusions would be attenuated but not overturned since Clark's index, too, shows a pause in the growth in real wages in the industrial revolution (Fig. 1-Clark). The implied shares and profit rates move similarly to those reported in the text, although the shift against labour is attenuated during the industrial revolution. Indeed, the model can be recalibrated with those data, and it works almost as well as the version reported in this paper. Fig. 1-Clark also shows simulated GDP per worker and the real wage using Clark's real wage and recalibrating the production function accordingly.[12] Clark's work on wages is not enough, therefore, to establish his conclusion that workers were the principal gainers in the industrial revolution nor to suggest a different analysis of its causes.

[12] The translog parameters are $\alpha_K = -4.87027$, $\alpha_L = 4.799868$, $\alpha_T = 1.070403$, $\beta_{KK} = -1.16484$, $\beta_{KL} = 1.352003$, $\beta_{KT} = 0.31284$, $\beta_{LL} = -1.03916$, $\beta_{LT} = -0.31284$, $\beta_{TT} = -5 \times 10^{-16}$

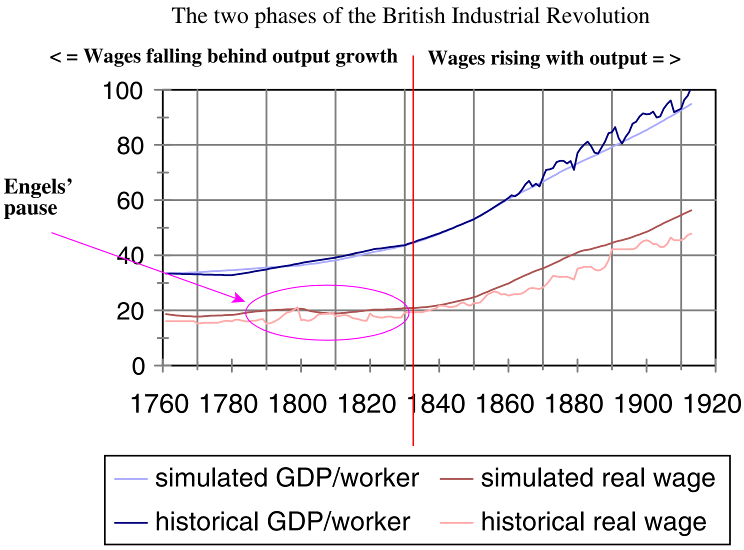

Fig. 1-Clark. The two phases of the British industrial revolution.

To reach that conclusion one must reduce the growth in national income so wages grow faster than profits. Thus, the second pillar of Clark's reinterpretation is his calculation of nominal GDP, which increases less rapidly than Deane and Cole's estimates. Clark's nominal GDP is the sum of factor earnings. He estimates employment and the average wage, the area of cultivated land and the average rent, and various series of capital magnitudes and corresponding rates of rate. Deane and Cole had also estimated labour income from employment and wages, but had estimated property income from the income tax returns. Clark accepts Deane and Cole's GDP for the middle of the 19th century. Their property income and GDP for mid-century was larger than Clark's total, so he scaled up his series for earlier years by the same proportion to account for the income he had not been able to measure. This was primarily entrepreneurial income. Clark's procedure produces a much larger figure for nominal GDP in 1801 than Deane and Cole had calculated from employment, wages, and the tax on property income. Clark decides that Deane and Cole had underestimate property income and GDP in 1801 since he contends that tax evasion was higher than they thought. His reason for this conclusion is that his estimates of land and house rents (derived from the Charity Commission returns) implied a higher tax base than the income tax assessments reported.

I prefer old estimates to Clark's for several reasons. First, so far as 1801 income was concerned, Deane and Cole were very conscious of the problem of tax evasion and considered the matter closely for the various schedules of the income tax. Their work builds on a long tradition of research in this issue, which cannot be lightly set aside. Clark's only reason for doing so is his calculation of the taxable value of land and property, which he found to be greater than that in the tax returns. The problem with Clark's argument, however, is that his data are derived from the returns to the Charity Commission and relate to new lettings, as he himself has indicated (Clark, 2002, pp. 381–383). In a time of inflation like the Napoleonic period, rents were rising, so the return on new lettings exceeded the average rent on all property (Clark, 2001, p. 22). Indeed, this is clear in comparing Clark's index of the rent of houses 1770–1860 and Feinstein's. While Clark's was based on new lettings, Feinstein's was based on the total assessed value of property. The two series agree in showing virtually the same inflation between 1770 and 1860. Clark's, however, inflates first, and leads Feinstein's by a large margin c. 1800. Clark's calculations of the tax base from Charity Commission data are, thus, too high at the critical period, and so his arguments about under assessment are not sustained.

Second, again with respect to 1801, the introduction of the income tax led several contemporaries to estimate the national income at the turn of the century (Deane, 1956), pp. 339–341), and their figures imply totals of £204 million (Beeke's) and £243 million (Bell's). Colquhoun (1806) estimated English national income based on the results of the 1801 census as £241 million if it is scaled up to include Scotland. These estimates corroborate Deane and Cole's (£232 million) while calling Clark's into question. These contemporaries estimate the rental value of housing at the lower values used by Deane and Cole and Feinstein rather than at the higher values implied by the new leases of Charity lands. The lower values are consistent with the assessments in the income tax. There is no reason to prefer Clark's estimate over these.

Third, since Clark's nominal GDP series grows slowly, it implies very slowly growing real GDP when he deflates it. "Output per person increased by only 29% from 1760 to 1860... compared to Craft's estimate of a 73% gain" (Clark, 2001, p. 33). Clark's conclusion can only be accepted if we accept his view on the income tax in the Napoleonic Wars – a view we believe is unsustainable. Craft's conclusion, on the other hand, is based on aggregating all of the available output data for the British economy estimates.[13] This appears a sounder basis of proceeding.

[13] Broadberry et al. (2006) have presented preliminary estimates of real GDP annually. These are 'work in progress' but show the same trends as the series used here.

Fourth, we can assess the reliability of the rival national income series by working out their implications for productivity growth and comparing them to alternative measures. The Crafts series, which we use here, of course imply more rapid TFP growth than Clark's. Both are done by comparing real output growth to the growth of land, labour, and capital, and there is no great disagreement about the measurement of the inputs. In contrast, Antràs and Voth (2003) have measured TFP growth in a dual framework comparing product prices to input prices. Their procedure corroborates Crafts' estimates rather than Clark's.

Fifth, another implication of Clark's estimates is that all of the productivity growth in the industrial revolution was confined to textiles. Studies of iron, canals, shipping, and agriculture, however, have shown that there was productivity growth outside the textile sector, and this is compatible with the Crafts-Harley view of advance (Crafts, 1985, p. 86; Harley, 1993). Indeed, the principal challenge to this view is Temin's (1997) argument from trade data that productivity growth occurred in other industries was well. These results raise the possibility that real output grew more rapidly than Crafts believed rather than less rapidly as Clark maintains.

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