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Updated estimates of UK GDP from the income side, 1841–1920

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Abstract

This article brings together some of the improvements to GDP estimates from the income side since the publication of Charles Feinstein's 1972 volume *National income, expenditure and output of the United Kingdom, 1855–1965*. Many of the improvements and refinements were made by Feinstein himself and this paper makes a start in bringing the different elements together, focusing chiefly on reconstructing the income-based estimates for the period 1841–1920. The new data are then used to comment on several features of the late nineteenth-century UK economy, considering both the trend and cyclical path of the economy. The new data, coupled with modern de-trending methods, suggest that there was a long-term slowing of the UK economy from the late nineteenth century, starting from the 1870s. To undertake the trend–cycle decomposition, we employ a wavelets methodology to describe the time–varying features of trends and cycles over this period.

KEYWORDS
economic cycles, economic growth, economic history

Developing reliable historical national account data is essential to research in economics and economic history. The Maddison Project[1] recognizes the importance of such work and has set out to co-ordinate an international dataset to reflect best practices:

[1] Bolt and van Zanden, 'The Maddison Project', p. 627.

> The main goal of the Maddison Project is to continue Maddison's work by creating new generations of estimates of GDP, population, and GDP per capita in the world economy…

Our paper provides a contribution by improving the UK historical national accounts data for the income series of GDP over the period *c*.1841–1920. The improved series complements earlier research for the pre-1870[2] and post-1920[3] periods. Combining these data series will provide researchers with improved long-run national accounts data for the UK in the spirit of the Maddison Project.

To date, most economists and economic historians continue to rely heavily on Feinstein's 1972 edition of his national accounts estimates.[4] Feinstein was able to estimate GDP using income, output, and expenditure approaches over the period 1855–1965 and many have used Feinstein's 'compromise' series for GDP – the average of the output, income, and expenditure estimates – or balanced measure[5] that considers the relative reliability of the component series. Feinstein himself was not satisfied with the reliability of the 1972 estimates and produced major revisions to many national income components in subsequent work. Before he died in 2004, he was working on a major revision of the UK historical national accounts which was not completed. Here we complete the revision of the income series of UK GDP.

Focusing on the income side of the national accounts, Feinstein was aware of a number of key problems with the 1972 estimates. Firstly, Feinstein had largely relied on Bowley's[6] published 'final' index for wage earnings. Feinstein had initially believed this had brought together all the results of Bowley's previous investigations as well as those of others. In fact, Bowley's index did not cover key sectors of the economy such as steel, clothing, and footwear in the manufacturing sector, and the full range of service sector industries. For these reasons, Feinstein undertook a revision of the earnings index for the 1880–1913 period. Similar work was undertaken for the pre-1880 period to construct earnings estimates for 20 sectors covering around 80 per cent of wage earners. Secondly, Greasley[7] noted the need to revise the estimated number of wage earners in the UK. Bowley's estimate of wage earners' income used by Feinstein had been incorrectly based on the number of wage earners in Great Britain (GB) rather than the UK, which was significant given that the number of Irish wage earners had been growing at a slower rate than in Great Britain over this period. Feinstein[8] subsequently developed new estimates of UK wage earners. Thirdly, revisions to depreciation or capital consumption arising from Feinstein's revisions to the investment and capital stock data[9] need to be incorporated into the estimate of profits derived from income tax data because assessments were made on profits after accounting for depreciation. Finally, Feinstein's revision to the number of non-wage earners has effects on intermediate incomes (non-wage earnings that were below the liability for income tax) that need to be incorporated into revised GDP estimates.

[2] Broadberry et al., *British economic growth*; Solomou and Weale, 'Balanced estimates'.

[3] Sefton and Weale, *Reconciliation of national income.*

[4] Feinstein, *National income.*

[5] Solomou and Weale, 'Balanced estimates'.

[6] Bowley, *Wages and income.*

[7] Greasley, 'British economic growth'; idem, 'British wages and income'.

[8] Feinstein, 'Wages and the paradox of the 1880s'.

[9] Idem, 'National statistics'.

We build a revised series for GDP from the income side that incorporates all the revisions from Feinstein.[10] At the same time, we also include research from other scholars in related fields that has implications for UK GDP estimates. Firstly, we incorporate revisions to unemployment from Boyer and Hatton[11] who revise the Board of Trade measure of unemployment used by Feinstein in the period after 1870. We extend this back to 1841 on the basis of an extrapolation of their methods. Second, we incorporate the research on the numbers of wage earners in Britain and Ireland and their earnings to reconstruct total employment and wage incomes for the UK back to 1841.[12] Coupled with the income tax data and the various adjustments made by previous authors, we can then construct total GDP over the same period. We also consider Feinstein's treatment of tax evasion in the profit series and undertake a sensitivity analysis of different assumptions to evaluate the implications of Feinstein's solution to this problem in the 1972 estimates. Finally, all these revisions focus on deriving the best estimate of nominal GDP; we also use several deflators to determine the path of real GDP.

The article proceeds in sections. In the first, we derive a new income-based estimate of nominal GDP and evaluate the use of different price deflators to derive a measure of real GDP. In the second section, we use the new data to describe some of the features of the UK economy over the pre-1914 period. Our third section provides a more detailed econometric analysis of the new data, while the fourth offers some conclusions. The new data allows us to contribute to our understanding of the UK economy in the Victorian and Edwardian periods. The new GDP data, together with new hours of work data, allow us to comment on the debate over the UK productivity slowdown. The old data pointed towards an Edwardian slowdown in productivity, based on a comparison of relevant period averages. This view was confirmed in subsequent work by Feinstein, Matthews, and Odling-Smee.[13] The new data, coupled with modern de-trending methods, suggests there was a long-term slowing of the UK economy from the late nineteenth century starting from the 1870s, a result that is consistent with the more recent discussions of Crafts and Mills.[14] The analysis of productivity growth will be of interest to debates in economic history, such as the effects of general-purpose technology on long-term economic growth, and to studies seeking comparisons to understand recent experiences in a historical perspective. For example, the productivity puzzle of the post-2008 financial crisis has given rise to homologies to Edwardian productivity retardation. Our analysis of productivity trends is consistent with Crafts and Mills, who suggest that the homologies with the Edwardian period are misleading.

We also use modern wavelets methods to analyse the cyclical structure of the UK economy over this period. The new data allows us to evaluate the existence of long swings in the cyclical path of the UK economy. Long swings are medium-term cycles around a 20-year frequency. Recent research on credit/financial cycles has revived an interest in the importance of the medium-term frequency, which economic historians have seen as a key feature of the pre-1914 era.[15] One of the advantages of the wavelets methodology (considered below) is that the method can be used to study multiple cycles affecting the economy. Our new data are consistent with the co-existence

[10] Ibid.; idem, 'New estimates'; and idem, 'Pessimism perpetuated'.

[11] Boyer and Hatton, 'New estimates of British unemployment'.

[12] Feinstein, 'National statistics', Begley et al., 'Convergence in the pre-1914 Atlantic economy'; Geary, 'Regional industrial structure'; idem, 'Deindustrialization in Ireland'; Geary and Stark, 'Examining Ireland's post-famine economic growth'; eisdem, 'Trends in real wages'.

[13] Matthews et al., *British economic growth*; Feinstein et al., 'The timing of the climacteric'.

[14] Crafts and Mills, 'Sooner than you think'. Similar results are reported in Crafts, 'Understanding productivity growth'.

[15] Feinstein et al., 'The timing of the climacteric'; Solomou, *Phases*.

of long swings and the classic business cycle, confirming the usefulness of the new income-based estimate of GDP to analyse UK business cycles.

I | A REVISED INCOME MEASURE OF GDP

Of the three approaches to measuring GDP, the income estimate is thought to provide more accurate information about the cyclical time–profile of the UK economy.[16] It is now recognized that the existing output and expenditure estimates suffer from the extensive use of linear interpolation and artefact cyclicality.[17] That suggests that a focus on income-based measures is probably the more accurate approach for attempting a trend–cycle decomposition of the GDP data over this period.

Following Feinstein's approach, there are five components of the income side to estimate: (i), the compensation of wage earners; (ii), the income of salaried workers; (iii), the income of employers and the self-employed, including farmers' income; (iv) the gross trading profits of companies, non-profit institutions, and general government; and (v), income derived from rental on dwellings and the operating surplus of the household sector.

The first component depends on the construction of wages and employment data. Income tax data cannot be used for wage earnings because, prior to the First World War, most wage earners were exempt from income tax. Components 2–4 depend largely on income tax data but also depend on estimates of 'intermediate incomes' – essentially non-wage incomes that were not subject to income tax. Each of these components is reconsidered in the light of later research by Feinstein and others. The components are also extended back to 1841 using similar methods to those that were used by Feinstein and his predecessors. The next sections discuss the key revisions to these components in turn. The final component is discussed in the supplementary material to the paper.

Compensation of wage earners requires estimates of wage earnings, social contributions (after the introduction of national insurance in 1911), and the employment of wage earners in the working population. Two approaches can be followed here. One can first try to create an index of earnings and adjust the earnings series at the component level for losses due to unemployment and short-term working. This earnings series can then be multiplied by the number of wage earners in the working population to get an estimate of the wage bill. Alternatively, an index of 'full employment' weekly earnings can be constructed and this can be multiplied by an estimate of employment where the number of wage earners in the working population is adjusted directly for the number unemployed. We follow the second of these approaches.

The major revisions to full employment earnings and the working population over this period were made by Feinstein himself in a series of papers.[18] The first of these focused on the period since 1880 and were in part prompted by some of the issues raised by Greasley.[19] The second set of estimates focused on the industrial revolution with an aim of looking at the extent to which the living standards of working-class households in Great Britain improved between 1770 and 1880, but also with a longer-term aim of reconstructing GDP from the income side. As part of this second

[16] Feinstein et al., 'The timing of the climacteric'.

[17] For example, in producing the output estimates of industrial production, the early researchers imposed a Juglar cycle of nine years on many component series.

[18] Feinstein, 'New estimates'; idem, 'What really happened'; idem, 'Conjectures'; and idem, 'Pessimism perpetuated'.

[19] Greasley, 'British economic growth'.

stream of work Feinstein also estimated the working population of wage earners for Great Britain and rougher estimates of earnings adjusted for unemployment and for the inclusion of Ireland on the basis of Bowley's original work.[20] Geary and Stark[21] revisited Bowley's work and created a new full employment series of wages for Ireland, which were used to reconstruct earnings for the UK using Feinstein's estimates for Great Britain.

The major revisions to the utilization of labour over this period were made by Boyer and Hatton,[22] who reviewed the Board of Trade measure of unemployment that Feinstein used for his estimates of the wage bill over the 1855–1913 period. They produced new estimates of unemployment for the period after 1870, which can be combined with other proxies for unemployment before 1870 to create a new estimate of the wage bill for the post-1841 period. Together, all these revisions allow for a revised estimate of wage earners' compensation after 1841 and with a split between Great Britain and Ireland. We consider these revisions in more detail below, starting with Feinstein's revisions to earnings in the late Victorian period, 1880–1920.

In his 1972 estimates of GDP, Feinstein had largely relied on the wage and earnings estimates of Bowley[23] and Wood[24], who were the acknowledged authorities on wages over this period. This was understandable given that Feinstein's task for the 1972 volume was essentially to take the core components of the national accounts that had previously been estimated by the key experts in various fields (including his own contributions on capital formation and national accounts), fill in all the remaining gaps, and bring everything together to make a comprehensive set of estimates for GDP from 1855. In this respect Feinstein had relied on Bowley's published index[25] for wage earnings, which the latter had described as his 'final' estimate. Feinstein had initially believed this had brought together all the results of Bowley's previous investigations as well those of others. On a revised examination, however, Feinstein found that these estimates could not have taken into account some key pieces of information, such as the 1906 *Enquiry into earnings and hours*[26] and the *1919* Sankey Commission on earnings in the coal mining industry prior to 1914. Bowley's index also did not cover key sectors of the economy such as steel, clothing, and footwear in the manufacturing sector and the full range of service sector industries. These were very different industries from those covered in Bowley's index, in part because they were not as heavily unionized. For these reasons, Feinstein undertook a wholesale review of the earnings index for the 1880–1913 period. The final new index covered around 85 per cent of the labour force.

The construction of Feinstein's earnings index starts with the definition of the total wage bill which in any year is given by summing across the occupations or industries covered:

$$\sum_{i=1}^{N} Wi_t Ni_t \tag{1}$$

[20] Bowley, 'Statistics of wages in the United Kingdom'.

[21] Geary and Stark, 'Trends in real wages'.

[22] Boyer and Hatton, 'New estimates of British unemployment'.

[23] Wood, 'Real wages'.

[24] Bowley, *Wages and income*; Wood, 'Real wages'.

[25] Bowley, *Wages and income*.

[26] *Report of an Enquiry by the Board of Trade into the Earnings and Hours.*

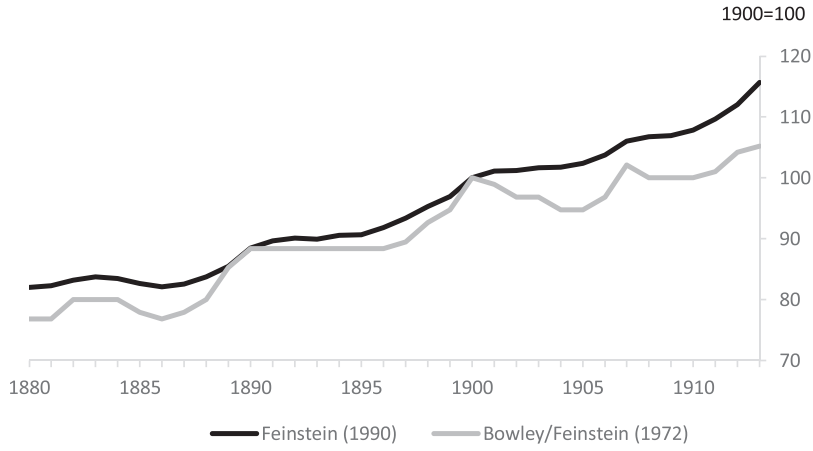

FIGURE 1 Feinstein's revised earnings index for the UK. *Source*: Feinstein 'New estimates', Bowley 'Wages and income', Feinstein 'National income'

where W_i is the average earnings for each sector i (e.g. industry or occupation) and N_i is the number of wage earners in that sector with N as the number of sectors. By definition, an index of average wage earnings based on a reference year r, is given by:

$$\frac{\sum Wi_t Ni_t}{\sum Ni_t} \div \frac{\sum Wi_r Ni_r}{\sum Ni_r} \tag{2}$$

Typically, the available data require the investigator to work with wage relatives, given that W is often not observed for each year and one must rely on indicators of the change in wages. This requires scaling actual wages by wage earnings in the reference year Wi_r and modifying the formula to give:

$$\frac{\sum \left(\frac{Wi_t}{Wi_r} Wi_r\right) Ni_t}{\sum Ni_t} \div \frac{\sum Wi_r Ni_r}{\sum Ni_r} \tag{3}$$

where wage relatives are weighted according to employment shares Ni/ΣNi in each period and, importantly, scaled by the earnings in each sector in the reference year (Wi_r) which allows shifts between occupations with different levels of earnings to affect average wage earnings. Following Bowley, Feinstein used 1911 for his reference year estimates of wage earnings in each industry. Figure 1 shows Feinstein's revised earnings index and compares it with the previous estimates on the basis of Bowley, indexed to 1900 = 100.

The first notable feature is that Feinstein's improved index is much less volatile than Bowley's for most of the period, reflecting the fact that the addition of more sectors lowers the weight on the relatively more volatile earnings of industries which were subject to sliding scales, a prime example being the coal industry.

The second key feature is that the new earnings measure grows more slowly over the 1880s than the old index but faster in the period after 1900. The faster post-1900 growth is largely owing to the data on coal earnings from the Sankey Commission, as well as the fact that the additional sectors added by Feinstein show a marked improvement in performance relative to the sectors covered

TABLE 1 Wage earners in GB and Ireland (mns)

	UK		GB		Ireland	
	Working population	Wage earners	Working population	Wage earners	Working population	Wage earners
1841	12.1	9.9	8.5	7.0	3.6	2.9
1851	12.2	9.9	9.4	7.7	2.8	2.2
1861	13.1	10.7	10.5	8.8	2.6	1.9
1871	14.1	11.5	11.7	9.7	2.4	1.7
1881	15.1	12.2	12.9	10.7	2.2	1.5
1891	16.7	13.4	14.6	12.0	2.0	1.4
1901	18.7	14.9	16.7	13.5	2.0	1.3
1911	20.4	15.9	18.6	14.7	1.8	1.2

Source: See section I.

by Bowley, especially the earnings of domestic servants. This additional growth in wages in the lead up to the First World War has a significant bearing on the scale and timing of the Edwardian productivity slowdown.[27]

The third key factor is that Feinstein's estimate of average wage earnings in the key benchmark year of 1911 was significantly higher than implied by Bowley's. Coupled with revisions to the number of wage earners and unemployment discussed later, it implies roughly a 3 per cent increase in the estimated wage bill in 1911.

Following the work on late-Victorian earnings, Feinstein turned to wages in the Industrial Revolution. As before, the indices of Bowley and Wood were the initial starting point for the estimates but also later work on coal mining earnings.[28] Feinstein generated a wholesale reconstruction of the available earnings indices for the pre-1880 period. For the century or so before 1880, Feinstein was able to construct earnings estimates for 20 sectors covering around 80 per cent of wage earners, largely reflecting wages in Great Britain. He also made an attempt to capture developments in the UK as a whole, using Bowley's index of Irish agricultural wages.[29] Additional work on Irish earnings was carried out by Geary and Stark,[30] who in addition to agricultural earnings collected data on the earnings of construction workers in Ireland and linked the non-contractual earnings of textile workers to prices. They used this information to create a revised UK full employment wage index by replacing the Bowley index used by Feinstein with their new series for Irish wages.[31] We follow their approach; however, we use the estimates of wage earners in Great Britain and Ireland from table 1 as employment shares ($Ni/\Sigma Ni$ in Equation (3)) for the indices instead of population shares. We also adopt Geary and Stark's assumption that in the base year (1861) Irish nominal wages were 47 per cent of those in Great Britain for the reference year wages (Wi_r).

The resulting series are shown in figure 2 over the 40 years between 1841 and 1881. The main difference is to smooth out a large rise and fall of earnings in the early 1870s around the time of the

[27] Feinstein, 'What really happened'.

[28] Bowley, *Wages and income*; Wood, 'Real wages'; Mitchell, *Economic development;* and Church, *History*.

[29] Bowley, 'Statistics of wages in the United Kingdom'.

[30] Geary and Stark, 'Trends in real wages'.

[31] We are grateful to Frank Geary and Tom Stark for supplying us with their annual time series for Irish and UK wages and prices.

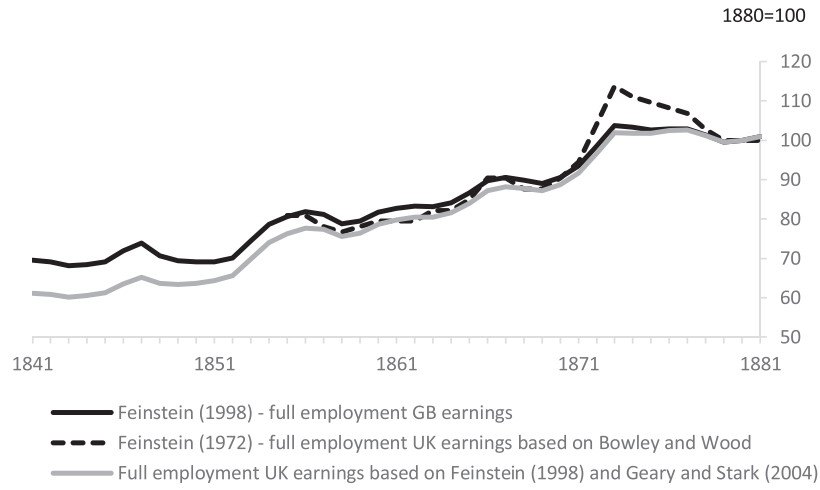

FIGURE 2 A revised full employment earnings index for the UK, 1841–80. *Source*: Feinstein, 'Pessimism Perpetuated', 'Geary and Stark', 'Trends in real wages' and see text Section I

panic of 1873. Feinstein makes no particular comment on this feature because he did not make a comparison with the Bowley and Wood series over this period. However, the new index appears to show a plateau in the level of earnings that carries through to the late 1880s when combined with the estimates in figure 1, rather than a reversal of a large increase in the first half of the 1870s. This is likely to reflect the broadening of the coverage of the index to other sectors and the relatively volatile sectors captured in Bowley's index. The new series for Irish earnings shows a stronger trend increase in Irish nominal earnings largely in the years following the famine, although this does not necessarily translate into real earnings given the divergent movement in prices.[32]

The third set of revisions that need to be considered are those to the estimated number of wage earners in the UK economy and their utilization over the business cycle. As pointed out by Greasley,[33] Bowley's estimate of wage earners' income used by Feinstein had been incorrectly based on the numbers of wage earners in Great Britain rather than the UK. In reply to Greasley, Feinstein developed new estimates of UK wage earners on the basis of reworking the census data from 1861 onwards.[34] Additionally, in his subsequent work on the industrial revolution,[35] he developed new estimates for Great Britain between 1770 and 1851. This can be carried back to 1841 on a UK basis using estimates by Begley, Geary, and Stark in a number of papers for the Irish labour force and wage earners.[36] Table 1 summarizes the decadal estimates for the working population and wage earners in the UK and GB. The full annual time series is available in online appendix A.

[32] Geary and Stark, 'Trends in real wages'.

[33] Greasley, 'British economic growth'.

[34] Feinstein, 'Wages and the paradox of the 1880s'.

[35] Idem, 'Pessimism perpetuated'.

[36] Begley et al., 'Convergence in the pre-1914 Atlantic economy'; Geary 'Regional industrial structure'; idem, 'Deindustrialization in Ireland'; Geary and Stark, 'Examining Ireland's post-famine economic growth'. As noted by Feinstein and these authors, a number of difficulties are encountered when deriving the number of wage earners from census data. The classification of farmers and shop assistants are common problems to both Britain and Ireland in the late nineteenth century. In addition, there are specific problems with the Irish census returns for female domestic servants and agricultural labourers.

These revisions also implied changes to the number of salaried and self-employed workers which affect other components of the income accounts (these are discussed separately below).

For the utilization of the labour force, the two key pieces of research to incorporate are the revisions to the Board of Trade index of unemployment by Boyer and Hatton[37] for the period 1870–1913 and work by MacKinnon and Southall on the use of poor law and union data in the pre-1870 period.[38]

Boyer and Hatton reviewed both the coverage and weighting of the Board of Trade series used by Bowley in his estimates of wage income and which were relied upon by Feinstein in his 1972 estimates. There were a number of improvements they made to the series: first, they used the labour force in each industry rather than union membership to weight the data for unemployment in each of the unionized industries; second, they also estimated unemployment in those sectors where the union data were unrepresentative or no union data existed, specifically mining, textiles, and transport;[39] finally, union-based measures largely reflect unemployed skilled labourers, so poor relief data based on the work of MacKinnon on the number of male, able-bodied paupers were used to estimate the unemployment of general unskilled labour.[40]

Together these improvements led to an industrial unemployment index that covered just over 50 per cent of the total workforce over this period. Generally, the Board of Trade measure understated the average level of unemployment but overstated its volatility and that is true even if the short-time and unskilled estimates are removed from the picture. Boyer and Hatton then make two adjustments to this industrial series to convert it into a broader whole economy series, consistent with national unemployment insurance (UI) and claimant count estimates available from 1920 onwards.[41] First, over the interwar and post-Second World War periods (1923–39 and 1948–71) they use the post-1920 data to look at the relationship between overall unemployment and unemployment in the industries they cover in their pre-1914 index. This gives them a regression relationship they apply to the pre-1914 data. Second, prior to applying the regression, they scale the pre-war series by a further 21 per cent to reflect the fact that the union-based insurance data appears to understate unemployment in the sector as a whole when they compare it with the equivalent industry in the UI data. This is based on the short period in the early 1920s when both trade union and UI estimates are available. Figure 3 shows the effect of these two adjustments on the unemployment rate over the 1870–1913 period, which work to lower the volatility of the series.

Prior to 1870 the information on unemployment is very scarce and scattered. The trade union data published by the Board of Trade and used by Bowley and Feinstein are available back to the early 1860s, and for the engineering, metal, and shipbuilding unions to 1851.[42] The longest time series is the unemployment rate of the Friendly Society of Ironfounders which records unemployment of its members back to 1831.[43] The statistics on indoor pauperism used by Boyer and Hatton for unskilled workers also extend back to the late 1840s. In addition, over the period 1848–60 we have statistics from the *Annual Reports of the Poor Law Board* on the number of outdoor paupers

[37] Boyer and Hatton, 'New estimates of British unemployment'.

[38] MacKinnon, 'Poor law policy'; and Southall, 'Poor law statistics'.

[39] For mining, very few unions offered unemployment benefits, at least before the 1890s. These were also industries in which there was considerable short-time work and this was also built into the estimates for these sectors.

[40] MacKinnon, 'Poor law policy'.

[41] The national unemployment insurance (UI) scheme was introduced in 1911 but was quite narrow to begin with. It was widened extensively in 1920.

[42] Southall, 'Poor law statistics'.

[43] Gayer, Rostow, and Schwartz, *Growth and fluctuation*.

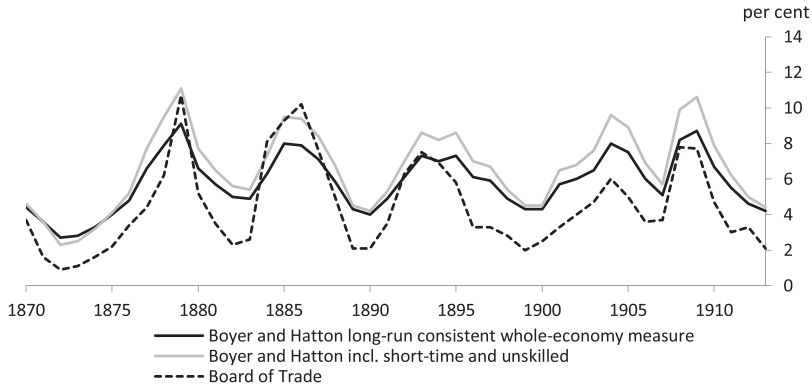

FIGURE 3 British unemployment rates, 1870–1913: two variants and the Board of Trade index. *Source*: Boyer and Hatton, *'New estimates of British unemployment'*

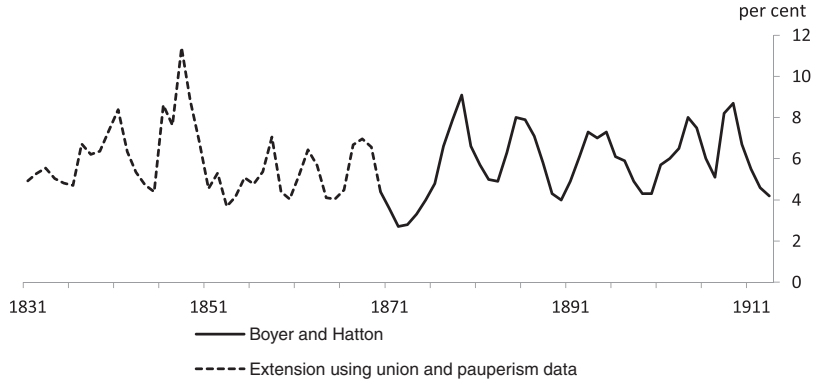

FIGURE 4 Estimates of the aggregate unemployment rate, 1831–1913. *Source*: See section I

who were relieved owing 'to want of work'.[44] Although collectively these statistics only cover a small section of the potential working population, there seems to be agreement from experts in the field[45] that variation in these series should give some guide to cyclical movements in unemployment and can be used as an indicator series. Figure 4 shows an extension of unemployment back to 1831 using these indicator variables based on a simple econometric relationship with the relevant components of Boyer and Hatton's unemployment series. The resulting series over the pre-1870 period exhibits peaks in unemployment in 1848, 1858, 1862, and 1868, which look plausible given that they followed major commercial and financial crises.

Bringing the different elements together, these series allow for an estimate for wage income to be constructed back to 1841. Following Feinstein, we begin with the estimated wage bill in 1911. As noted earlier, Feinstein's revised estimates of wage earnings and the number of wage earners suggest that Bowley's benchmark of £802 mn needs to be revised. Table 2 shows that the revised estimate suggests a wage bill some 3 per cent higher, once unemployment (applied to civilian wage

[44] Poor Law Board, *Annual report*.

[45] MacKinnon, 'Poor law policy'; and Southall, 'Poor law statistics'.

TABLE 2 The UK wage bill in 1911

Full employment earnings per head	**£58.6**
Number of wage earners	15.9 mn
Armed forces	0.4 mn
Civilian wage earners	15.5 mn
Number of weeks lost to strikes and sickness	1.77
Allowance for old/retired workers	3%
Unemployment rate (including short-time)	5.5%
Total UK wage bill including armed forces	**£826 mn**
Memo: Bowley-Feinstein estimate	£802 mn

Source: See section I.

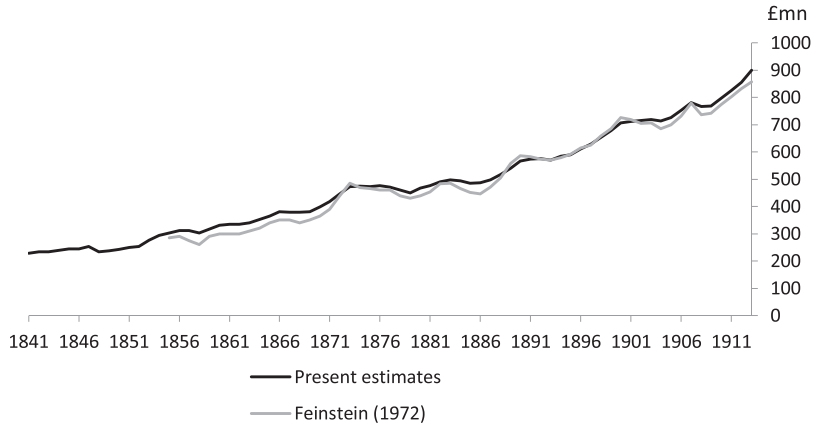

FIGURE 5 Total wage incomes. *Source*: See section I and Feinstein, *'National Income'*

earners), the number of strikes and sickness, and the number of old/retired workers are considered. This upwards revision was anticipated by Feinstein, but it is still true that the benchmark level may be understated because of supplementary earnings from second jobs or possible contributions from retired workers, which would negate the 3 per cent adjustment allowance for older workers somewhat.

From the 1911 reference point a complete series of the wage bill can be constructed using the average earnings indices, number of wage earners, the unemployment series, and a series for days lost through sickness and strikes (for as far back as the data exist). Figure 5 shows the series for wage income compared with Feinstein's 1972 estimates. Wage incomes are generally higher throughout but less variable owing to the stability of Feinstein's revised earnings estimates. Online appendix A contains the new series and a split between British and Irish wage incomes.

Intermediate incomes are essentially non-wage earnings that were below the liability for income tax. This means they are not captured by either the wage and employment data or the income tax data that are typically used to construct GDP from the income side. They therefore need to be estimated from the number of non-wage earners not subject to income tax and how much income they earned. This income also needs to be attributed appropriately to salaries, farm incomes, and non-farm self-employment income and profits, so that these components can be estimated appropriately once combined with the evidence from the income tax data.

TABLE 3 Intermediate incomes in key benchmark years (mns of £, unless otherwise stated)

	1860	1870	1880	1891	1901	1911
No. of non-wage earners (mn)	2.36	2.58	2.83	3.25	3.82	4.5
No. of taxpayers with incomes over £160 (£100 for 1860*) (mn)	0.47	0.34	0.62	0.7	0.8	0.9
Non-wage earners exempt from tax (mn)	1.89	2.24	2.21	2.55	3.02	3.59
Average income (£)	54	62	70	76	82	88
Unadjusted intermediate income	102	139	155	194	248	314
1860 Adjustment for those in £100–£160 range*	25					
1911 deduction for wage earners not exempt from tax*						8
Total intermediate income	**127**	**139**	**155**	**194**	**248**	**306**
Memo: Estimates of Feinstein (1972)	*90*		*120*			*306*

Source: See Feinstein, *National Income*, appendix 7.3, for a discussion of the 1860 and 1911 adjustments.

The main revisions to Feinstein's data here are due to the revision in the number of non-wage earners arising from his re-estimation of earnings and the number of wage earners. This is noted in Feinstein's 1989 article.[46] The number of non-wage earners estimated in 1860 (2.67 mn) is considerably higher than the numbers Feinstein used from Bowley in his 1972 estimates (1.65–1.85 mn). Table 3 reworks Feinstein's original numbers,[47] which were based on estimates of the number of non-wage taxpayers and their earnings in benchmark years (1860, 1880, and 1911), using information from the work of Bowley and Stamp. Essentially intermediate incomes are higher by around 40 per cent in 1860 and 30 per cent in 1880.[48] No revisions, however, are necessary for the 1911 estimates. In addition, intermediate benchmarks are calculated for 1870, 1880, 1891, and 1901 on the basis of Bowley and Stamp's estimates.

Table 4 then allocates these to salaries and other forms of income in proportion to Feinstein's original estimates.[49] The revisions are made only to salaries and self-employment income. Rows 2, 4, 5, and 6 of this table can now be used to augment the estimates of salaries, profits, and self-employment data from income tax assessments. Rows 1, 3, and 7 are redundant in that they refer either to transfer payments or are covered in other estimated components (for example total farm incomes are estimated separately and implicitly already capture row 3). The implications for total salaries are discussed in online appendix A.[50]

Feinstein's 1972 estimates of gross trading profits and non-farm income from self-employment are based on income tax returns under Schedule C and D, while separate estimates are made for farmers' incomes and non-wage intermediate incomes that were exempt from tax (discussed earlier). The split between profits and non-farm self-employment income can only be made after 1889. There are four sets of revisions and refinements to Feinstein's estimates that need to be considered, two of which are relatively straightforward.

[46] See Feinstein, 'Wages and the paradox of the 1880s', p. 244, n5.

[47] Idem, *National income*, appendix 7.3.

[48] Bowley and Stamp, *Three Studies on the National Income*.

[49] See ibid., appendix 7.3, table 7.19.

[50] Online appendix A, table A3.

TABLE 4 Allocation of intermediate incomes, £mn

	1860	1870	1880	1891	1901	1911
Salaries						
1. £160 but not exempt						10
2. Below £160 and exempt	40	48	57	70	88	102
Self-employment income						
3. Farmers' income	17	17	17	23	30	37
4. Other income from self-employment	57	58	61	74	93	107
5. Rent	10	12	15	21	28	35
Interest and dividends						
6. Assessed but exempt	3	4	5	6	8	10
7. Not assessed						5
Total intermediate income	**127**	**139**	**155**	**194**	**248**	**306**

Source: See section I.

First, there are some changes to the estimates of profits and self-employment that appeared in Mitchell's 1988 statistics on national income,[51] which were supplied by Feinstein. These changes just needed to be sourced and verified. We were able to retrieve the underlying numbers from Feinstein's working notes for his capital formation volume of 1988[52], currently held in the library of Nuffield College, Oxford.[53] These were the result of revisions to capital consumption (for total assets excluding building and works), based on updated lifetime assumptions that were made for each asset. Second, as discussed earlier, Feinstein's revision to the number of wage earners has implications for self-employment income not captured in Schedule D of the income tax assessments (Rows 4 and 6 of table 4).[54] As a result, we revised Feinstein's series for incomes not subject to tax at several benchmark years. To interpolate between benchmarks and to extrapolate back to 1841 we follow Feinstein's method[55] of using schedule D assessments relative to trend. The revised series for both capital consumption and small incomes not subject to tax are shown in online appendix A.[56] The remaining two adjustments that need to be considered are more involved.

Feinstein's measurement of profits and non-farm self-employment income were derived from Schedules C and D of the income tax returns. Schedule C represents interest on British and Foreign Government securities but is a necessary part of the calculation because Schedule D also contained various interest and profit income earned from abroad. Feinstein adds Schedules C and D together, then deducts both interest payments on British securities and an estimate of total net property income from abroad to leave an estimate of profits on domestic production and non-farm self-employment income.

The most important issue is with the timing of profits contained in Schedule D. Income tax assessments were largely made on a moving average of past profits. Unscrambling the annual

[51] Mitchell, *British Historical Statistics*.

[52] Feinstein, National statistics,

[53] See Nuffield College, 'A handlist', for the complete set of papers available.

[54] Note that Row 6, the dividend component, represents a transfer payment but is necessary to include here given that total interest and dividends will be removed in the calculation of self-employment income and gross trading profits.

[55] See Feinstein, *National income*, p. 175.

[56] Online appendix A, table A4 (columns 10 and 6, respectively).

profile of profits from the averaged tax assessments provided a major challenge. A 'least squares' solution to recovering the annual estimates from the moving averages was suggested by Champernowne and implemented by Prest and Feinstein in their estimates.[57] Prest, and later Greasley, argued that the profits derived via this method appear to be a year 'too early' given other cyclical indicators of profitability especially in the 1880s.[58] They therefore shifted their data one year into the future. Feinstein, in his 1972 estimates, preferred to leave the data unadjusted on the basis that there was no single reason to justify this shift over the whole period. Here we follow Feinstein and use the unscrambled profits based on the Champernowne/Prest method and make no additional timing adjustments.

The only additional task we attempt is to apply the unscrambling method back to 1841 using the Schedule D assessments. This requires splitting the Schedule D assessments into those which were based on current and previous year's profits and those based on moving averages of previous years (five years for coal mining and three years for other industries). Following this approach, we apply the unscrambling method for the period 1841–67.[59] However, there is a complication applying this to the UK as a whole because Ireland was not subject to income tax in the 1842–52 period. We use Stamp's estimates of UK Schedule D assessments,[60] which included his estimates for Ireland over the 1842–52 period and adjusted to be consistent with the later £160 tax exemption threshold.[61] The resulting estimates over the 1840s suggest that a similar timing issue arises as that identified in the post-1855 data – namely that the peak in profits appears to be a year too early compared with other indicators. For example, a peak in profits occurs in 1844 when the peak of the cycle is generally associated with 1845 given the indicators suggested by Gayer, Rostow, and Schwartz (figure 6).[62]

A key uncertainty about the reliability of the tax data is the amount of tax evasion. Feinstein used the information in the *12th Inland Revenue Report*[63] where a comparison was made between profits returned for taxation in 1864/5 and those submitted by the same parties as the basis for compensation claimed in connection with a redevelopment programme. The estimate made by the Commissioner was that the gross Schedule D assessment should be increased by 52 per cent. Bowley estimated tax evasion amounted to £60 mn in 1880,[64] about 22 per cent of Schedule D profits for that year. Stamp provided a 5.5 per cent estimate for 1913.[65] Feinstein's basis for calculating

[57] Prest, 'National income'; Feinstein, *National income*.

[58] For more details, see Prest, 'National income'; Greasley, 'British economic growth'; and Solomou and Thomas, 'Feinstein fulfilled'.

[59] The assessments based on previous years' profits only require lagging the data by one period. For coal mining it is possible to work backwards from Stamp's estimates of annual coal-mining profits and use the five-year moving average assessments to back out the underlying annual estimates. The unscrambling method for the other industries on a three-year assessment basis uses the Champernowne/Prest method, which involves solving for a set of initial values that minimize the squared deviations of the annual series from the moving average. This imposes the condition that there is no three-year cycle in profits and is also sensitive to potential breaks in the tax assessment so must be applied to appropriate subperiods to get sensible results.

[60] Stamp, *British incomes and property*.

[61] As Stamp pointed out, this method is adequate for adjusting Great Britain estimates of Schedule D to a total UK basis, but would not be appropriate to use in calculating an estimate for Irish national incomes.

[62] Gayer, Rostow, and Schwartz, *Growth and fluctuation.*

[63] Twelfth Report of the Commissioners of Her Majesty's Inland Revenue.

[64] Bowley, *Division of the product,* p. 9.

[65] Stamp, *British incomes and property*, pp. 315, 320–4.

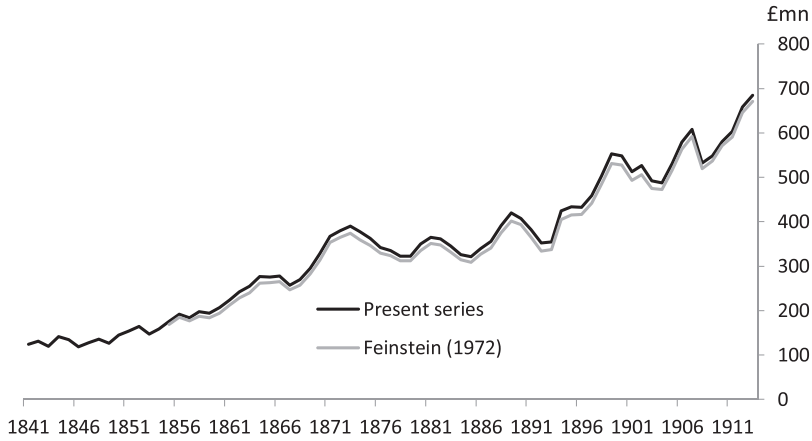

FIGURE 6 Non-farm profit and self-employment income from Schedule D assessments. *Source*: See text and Feinstein, *National Income*

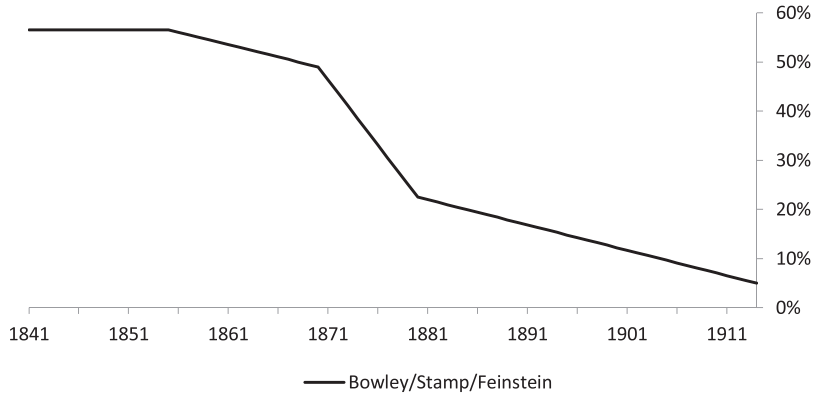

FIGURE 7 Tax evasion rate adjustment in Feinstein, *National income*. *Source*: Feinstein, *National Income*

tax evasion in this period is simply to extrapolate and interpolate the data on the basis of these three data points, with the additional information that there were major reforms in the administration and collection of tax introduced in the budget of 1869 that reduced evasion after 1870. Thus, Feinstein assumed that tax evasion fell by 0.5 per cent per annum between 1855 and 1870, starting from a level of 57 per cent (and hitting the 52 per cent benchmark in 1864/5). After 1870 the evasion adjustment is then assumed to fall rapidly to the 22 per cent estimated by Bowley for 1880. The level of the 1880s is then assumed to fall on a linear path to conform to Stamp's estimate for 1913. To carry the data back to 1841 we just use Feinstein's 1855 rate of 57 per cent. The only other benchmark we have prior to 1855 is that of Deane and Cole and their analysis of income taxes during the Napoleonic wars.[66] They estimated that evasion amounted to about one-third in 1801 and around 50 per cent in 1811. Assuming a flat 57 per cent benchmark for 1842–55 seems more reasonable than retropolating with an increasing level of evasion which would imply a rate of evasion of 64 per cent in 1841 (Figure 7).

[66] See Deane and Cole, *British economic growth*, p. 328.

In attempting to make these three guestimates of tax evasion conform with each other, Feinstein imposed a potentially significant effect on the growth path of the income estimate for the 1870s cycle. The effect is to reduce the growth rate of nominal income by approximately 0.5 per cent per annum over the business cycle of 1873–82, as we show later. Such an administrative view of tax evasion is likely to be incomplete and potentially misleading. To understand tax evasion, we also need to focus on the social psychology of tax evasion which recognizes that the problem reduces to a game theoretic framework with individuals responding to tax rates and other pressures to evade taxes, such as profitability.[67] The period witnessed large shifts in tax rates and movements in profitability and investment which implies that a purely administrative picture of tax evasion is likely to be incomplete. Given that it is unlikely that we will uncover the true time–profile of tax evasion in this period we undertake a sensitivity analysis of this assumption in section II.

Bringing the evasion estimates together with the three other revisions allows for a complete re-calculation of non-farm self-employment and profits. Feinstein does not provide an annual time series of all the components used to calculate the aggregate, but having retraced his steps through our search to provide updated estimates, we have been able to produce the components underlying the annual time series shown in figure 6 above.[68]

II | GDP ESTIMATES

Given the set of components constructed in earlier sections, we are now able to construct a revised estimate of nominal GDP extended back to 1841. In online appendix A we discuss some remaining extensions required to take three other components – salaries, farmers' profits, and rent – back to 1841.[69] Table A1 summarizes the complete nominal GDP(I) series and its key components.[70] In the table we make an attempt to split out self-employment income by assuming for non-farm incomes they are a constant share of total profits and self-employment income and then adding this to farmers' incomes.

To construct real GDP(I) over the 1841–1920 period we deflate the nominal estimates by the GDP expenditure deflator from Mitchell's 1988 statistics, which extends back to 1830.[71] The estimates for real GDP(I) are compared with Feinstein's original 1972 estimates of real GDP(I) in figure 8 between 1855 and 1913.[72] Table 5 compares growth rates in various subperiods. Overall, the estimates suggest slightly lower growth on average over the whole period. Generally, growth before the 1890s is estimated to be weaker than the previous income estimates and growth after 1907 is slightly stronger, with similar growth rates in between.

To examine the underlying performance of the UK economy implied by the new estimates, we construct a measure of labour productivity on the basis of GDP per hour worked, using total

[67] Tanzi, *The underground economy.*

[68] Online appendix A, table A4.

[69] Online appendix A, tables A3, A5, and A6.

[70] The present estimate of nominal GDP(I) for 1841 (£508 mn) is only 3 per cent below the input–output table benchmark of Horrell et al., 'An input-output table for 1841', suggesting a close correspondence between the two estimates. See Solomou and Thomas, 'Feinstein fulfilled', for more discussion.

[71] Mitchell, *British historical statistics*. These are based on extensions Feinstein made to his post-1870 estimates based on Deane, 'New estimates'.

[72] See the working paper version Solomou and Thomas, 'Feinstein fulfilled', for a comparison with other estimates and a revised compromise measure.

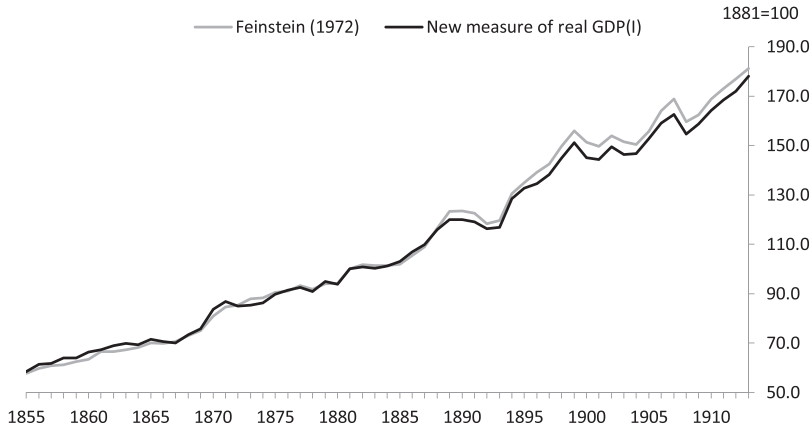

FIGURE 8 GDP(I) estimates, old and new in Feinstein, *National income*. *Source*: See text, section II

TABLE 5 GDP(I) estimates old and new, average annual growth rates (%)

	New GDP(I)	GDP(I) Feinstein, *National income*
1856–73	2.0	2.3
1873–82	1.9	1.7
1882–9	2.5	2.8
1889–99	2.3	2.4
1899–1907	0.9	1.0
1907–13	1.5	1.2
1856–1913	**1.9**	**2.0**

Source: See text and Feinstein, *National income*.

hours data from Thomas and Dimsdale.[73] Total hours worked grew slowly in the 20 years leading up to 1880, in part owing to a reduction in average hours worked in the early 1870s. Between 1880 and 1913, however, growth in the workforce was not offset by a fall in hours worked. This pick up in total hours worked was not matched by a similar rise in GDP growth. Figure 9 shows labour productivity, as measured by GDP per hour worked, for the old and new GDP(I) measures. The new GDP(I) labour productivity measure displays significant differences in the period after the 1880s.

Table 6 summarizes the growth rate of labour productivity over key benchmark periods. The new data suggest a more gradual slowdown in productivity growth starting in the 1870s following a peak in the productivity growth rate over the 1856–73 period – the high-water mark of the Victorian period. There is less of a slowdown in the 1890s than in the older data and more of a pickup in the period prior to the First World War. So, the new data, superficially at least, push us away from the idea of a sudden slowdown in the late Victorian or Edwardian era and more towards a gradual slowdown starting from around 1870 onwards, although clearly there are strong cyclical movements around the turn of the century (we investigate this further in section III).

[73] Thomas and Dimsdale, 'A millennium of macroeconomic data', sheet A56.

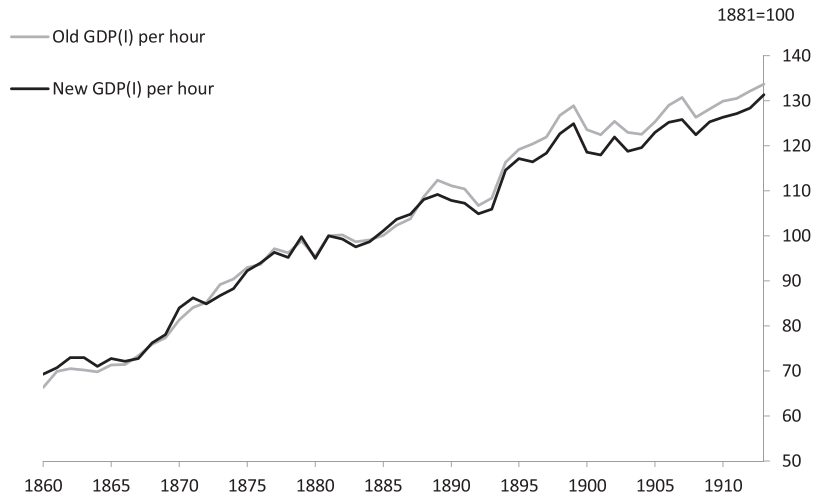

FIGURE 9 Productivity comparison between old and new income measures. *Source*: See text, section III

TABLE 6 Productivity estimates old and new, average annual growth rates (%)

	New GDP(I)	GDP(I) Feinstein, *National income*
1841–56	1.5	
1856–73	1.6	2.0
1873–82	1.5	1.3
1882–9	1.4	1.6
1889–99	1.4	1.4
1899–1907	0.1	0.2
1907–13	0.7	0.4
1856–1913	1.2	1.3

Source: See section II and Feinstein, *National income*.

We now apply some sensitivity analysis to our central case estimates. First, we consider the impact of tax evasion on our new estimates by looking at a simple alternative which adds a constant adjustment of 33 per cent throughout the period (approximately the average of Feinstein's adjustment) to highlight the impact of the assumed path of tax evasion made by Feinstein. Table 7 summarizes the impact on GDP per hour over each benchmark cycle.

The table shows that Feinstein's declining adjustment for evasion detracts around 0.5 percentage points (pps) per annum from average labour productivity growth over the 1873–82 period and around 0.1–0.3 pps in the subsequent benchmark periods. The assumption about tax evasion is material for the debate surrounding the timing of the slowdown in UK productivity in the late nineteenth century. Without Feinstein's declining adjustment for evasion the new data would suggest the decline in productivity growth starts in the 1880s rather than the 1870s but then shows more of a recovery in the period leading up to the First World War. We analyse the implications of this for trend productivity further in section III.

As further sensitivity analysis, we look at the impact of potential measurement error in the GDP deflator which is likely to be significant given this is a period involving considerable shifts in

TABLE 7 Productivity growth estimates (%) – sensitivity to evasion and alternative deflator assumptions

	New GDP(I)	Constant evasion adjustment	Compromise/balanced deflator	Bottom-up PPI-based deflator
1841–56	1.5		1.9	2.3
1856–73	1.6	1.7	1.7	1.3
1873–82	1.5	2.0	1.6	1.8
1882–9	1.4	1.5	1.0	1.6
1889–99	1.4	1.5	1.3	1.5
1899–1907	0.1	0.2	0.6	−0.6
1907–13	0.7	1.0	1.0	0.5
1856–1913	**1.2**	**1.4**	**1.3**	**1.1**

Source: See section II.

relative prices. For our central case estimates we used the deflator from the expenditure estimate of GDP.[74] However, given that the expenditure accounts also need to be revised significantly, the series used is likely to be revised in future. As a robustness exercise, we also consider two further deflators: first, the GDP deflator that drops out of the compromise or balanced estimates we have for this period;[75] and second, a bottom-up deflator we constructed using output prices for each industry, in line with the approach adopted by Broadberry et al.[76] when constructing their estimates of British GDP.[77] Table 7 shows that different deflator assumptions also suggest significant changes in the timing of the Victorian productivity slowdown, which we investigate further in the next section.[78]

III | ECONOMETRIC ANALYSIS OF THE NEW DATA SET

The long-term performance and phasing of economic growth in the UK economy since the mid-nineteenth century has attracted the attention of British and American economists with an interest in the historical process of economic growth.[79] Over the years, new ideas have gone hand-in-hand with new and improved datasets. For example, revisions to Hoffman's industrial production data by Lewis[80] resulted in the view that the 'Great depression' over the period 1873–96 was a myth. Revisions to UK national income data by Prest, Jefferys and Walters, and Feinstein have resulted in the view of a 'climacteric' in UK economic growth in the Edwardian period.[81]

[74] Mitchell, *British historical statistics*.

[75] Feinstein, *National income*; Solomou and Weale, 'Balanced estimates'.

[76] Broadberry et al., *British economic growth*.

[77] See online appendix A for details.

[78] The working version of this article, Solomou and Thomas, 'Feinstein fulfilled', also discusses issues with the deflator and their impact on calendar year growth rates in the 1840s.

[79] Rostow, *British economy*; Cairncross, *Home and foreign investment*; Feinstein et al., 'The timing of the climacteric'; Matthews et al., *British economic growth*; Crafts and Mills, 'Sooner than you think'; Solomou and Weale, 'Balanced estimates'.

[80] Lewis, 'Deceleration of British growth'.

[81] Prest, 'National income'; Jefferys and Walters, 'National income'; Feinstein et al., 'The timing of the climacteric'.

The construction of balanced national accounts data for the period 1870–1914 and the focus on trend productivity growth rather than GDP has challenged the idea of an Edwardian climacteric.[82] Crafts and Mills provide the most recent analysis of productivity on the basis of the balanced data and conclude that the slowdown in productivity growth was a gradual one beginning in the 1870s.[83]

Another feature of UK economic growth in the pre-1914 period is the existence of long swings.[84] Long swings are medium-term growth cycles with an approximately 20-year frequency. The historical discussions of long swings have emphasized the role of international migration and capital flows as a key feature of these fluctuations. Increasingly, the modern perspective on economic fluctuations also recognizes the importance of medium-term business cycle frequencies, assigning a role to technology shocks[85] and financial shocks[86] that have persistence profiles that are much longer than the conventional business cycle frequency.

Our new dataset allows us to evaluate the evidence for the existence of medium-term cycles in GDP and productivity over this period, together with any variations in the trend growth path of the economy. Clearly, this must be seen as a first step that may need further refinement once we have a full set of national accounts from revised output and expenditure estimates of GDP to complement our revised income estimate of GDP. Whilst the peak-to-peak growth calculations discussed above are suggestive about the growth-cycle path of the UK economy, it is important to use all the data and apply formal statistical techniques to form a more robust description of the trends and cycles over this period.

Many standard methods of trend–cycle decomposition, such as the Hodrick–Prescott filter, only seek to distinguish a single cyclical component from the trend. This was the approach adopted recently by Crafts and Mills.[87] Until recently, the Fourier transform and the windowed Fourier transform (WFT) were the most often used techniques to detect multiple cyclical components in a time series in the frequency domain. As an example, the WFT has been applied successfully to analyse economic data in the work of Harvey.[88] A standard application of this approach allows a time series to be decomposed into a trend component, irregular (and seasonal) components, and multiple cyclical components. Both the Fourier and WFT methods have significant limitations when applied to economic data. The basic idea of the WFT is to break a time series into segments with a selected window function. The Fourier transform is applied to each segment separately, producing a sequence of 'local' spectrums of the time series $x(t)$ along the time dimension. A major drawback of the WFT is that it uses a fixed window width to analyse economic time series that often display economic cycles with low and high frequencies and time-varying features. Optimally, a long time window should be applied when considering low-frequency fluctuations, while the short time window is required for analysing high-frequency fluctuations.

The wavelets methodology significantly improves these methods (see online appendix B for further details). The wavelet transform uses a two-parameter family of function: a time location

[82] Solomou and Weale, 'Balanced estimates'.

[83] Crafts and Mills, 'Sooner than you think'.

[84] Cairncross, *Home and foreign investment*; Thomas, *Migration and economic growth*; Feinstein et al., 'The timing of the climacteric'; and Solomou, *Phases*.

[85] Comin and Gertler, 'Medium-term business cycles'.

[86] Hall, 'Financial crisis'.

[87] Crafts and Mills 'Sooner than you think'.

[88] Harvey, *Forecasting, structural time series models*.

parameter τ and scale parameter λ,

$$WT_x(\tau,\lambda) = \frac{1}{\sqrt{\lambda}} \sum_{t=1}^{N} x(t)\psi^* \left(\frac{t-\tau}{\lambda}\right)$$

where $\psi^*(.)$ is the complex conjugation of the wavelet function $\psi[(t-\tau)/\lambda]$, the basis function in the wavelet transform. Wavelet algorithms process data at different scales or resolutions. The wavelet is dilated or compressed to extract frequency information from a time series $x(t)$. The extent of dilation or compression is determined by the scale parameter λ, which is inversely related to the frequency of the wavelet. Hence, the wavelet algorithm uses short windows at high frequencies and long windows at low frequencies, resulting in an optimum window width to determine the fluctuations of an economy. Another advantage of wavelets analysis over the Fourier transform is the flexibility of basis functions used for cyclical analysis. Whilst the Fourier transform has a single set of basis functions, sines and cosines, the wavelet transform has an infinite set of possible basis functions. Such a flexibility means that wavelets can capture the irregular and changing features of economic fluctuations.

The discrete wavelet transform (DWT) is derived as a critical sample of the continuous wavelet transform, which takes on values at every point on the time–frequency plane, containing a high amount of redundant information. The DWT allows us to focus on a small number of scales that can be related to specific economic cycles. In calculating wavelet coefficients, an approach that is often used is the dyadic scales and time locations (translations): $\lambda = 2^j$ and $\tau = 2^j k$, where j and k are integers. Working with this DWT gives efficient estimates without loss of accuracy. In this study, we use four levels of details $D_1 \sim D_4$ and (smoothed) approximation $S_{4:}$ S_4 reflects the trend of the data; D_1 captures irregular shocks and dynamics around 2–4 years; D_2 describes a cycle of 4–8 years; D_3 describes a cycle of 8–16 years; and D_4 describes a cycle of 16–32 years:

$$x_t = S_4 + \sum_{j=0}^{4} D_{jt} \tag{4}$$

However, the classic DWT has several limitations, namely (i) it requires the sample size to be exactly a power of 2 for the full transform, and (ii) the DWT-based analysis of a time series depends critically on the starting sample of a time series, which means that the analysis is sensitive to the starting sample. Maximal overlap discrete wavelet transform (MODWT) is a development in wavelets that modifies the DWT to address these problems, resulting in more robustness to boundary effects. Two of the main advantages of the MODWT for our study are that it can handle any sample size in the data regardless of whether it is dyadic or not, and since the MODWT is shift invariant, the decompositions will not change with a shift in the time series. Because of these desirable properties, the MODWT estimate is used for trend–cycle analysis in this study.

Figure 10 displays the MODWT decomposition of UK real GDP for the period 1841–1913.[89] It is based on estimating four cycles as described above: D1 can be thought of as very high frequency fluctuations between 2 and 4 years; D2 displays frequency business cycles of 4–8 years; D3 displays

[89] Using more conventional time series decomposition methods such as the Baxter–King band pass filter and focusing on cycles between 2 and 32 years yields decompositions that are similar to those derived using the MODWT. Given that the wavelets methods have improved conventional cyclical decomposition methods, we focus on the results using these methods as the more robust methodology.

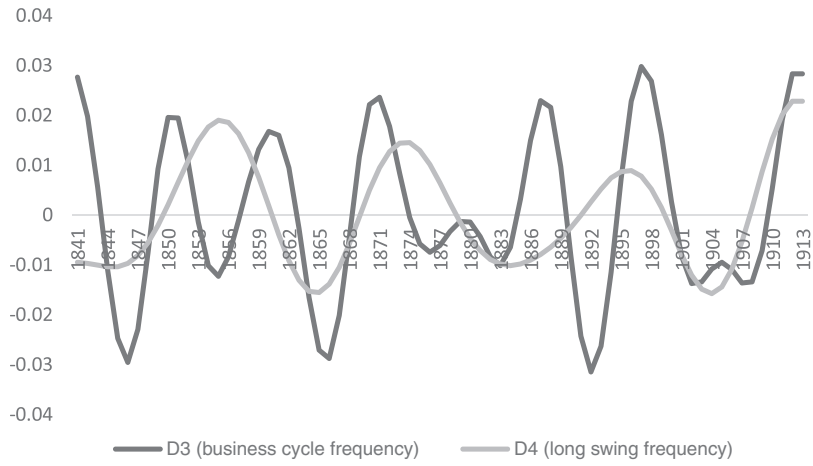

FIGURE 10 The business cycle and long swing cycles in the UK economy. *Source*: See text, section III

8–16 year cycles (capturing the range of the Juglar business cycle frequency noted for the pre-1914 period); and D4 allows for the possible existence of long swings of 16–32 years. For clarity we only display the D3 and the D4 cycles for the GDP series.[90] The decompositions suggest that the classic Juglar cycle is identified and is the dominant fluctuation in terms of amplitude. The methodology also identifies a 20-year medium-term frequency which provides evidence for the long swings discussed in the historical literature. The phases of the observed swings are in line with existing historiography with a boom period from the mid-1860s until 1873, a slowing of the economy in 1870s and early 1880s, a pickup of growth in the 1890s, and further slowing in the early twentieth century. A key feature of the new data is that the recovery in the post 1907/8 period is strong, suggesting that the episode of slow cyclical growth in the early twentieth century is observed over a shorter period than previously discussed in the long swing literature.[91] In the supplementary material to this paper, we provide further sensitivity tests on this description, using different data series and assumptions to evaluate the robustness of this description.

To comment on the trend growth path of the UK economy, we focus on labour productivity. Here the evidence suggests a clear trend deceleration in labour productivity from the 1870s onwards, as displayed in figures 11 and 12. Before this point labour productivity displays a path of trend acceleration from the 1840s until the early 1870s. The picture that emerges from an analysis of the new labour productivity data is similar to that presented in Crafts and Mills[92] – the retardation of productivity in the UK economy is not Edwardian but is part of a longer-term process with the turning point around the 1870s. As a sensitivity test, we also estimated the trend in labour productivity for the longer period 1830–1920: for the overlap period 1841–1913 the estimated trends are very close to each other. As expected, the estimation over a longer period implies a smoother adjustment in trend growth (see online appendix C).

To evaluate the robustness of this desciption we consider how the deflator affects the description of the trend by deflating with the Producer Price Index (PPI) deflator. Relative to the baseline – where the turning point was found to be in the early 1870s – using the PPI deflator

[90] We show the full decomposition in online appendix C.

[91] Feinstein et al., 'The timing of the climacteric'; Solomou, *Phases*.

[92] Crafts and Mills, 'Sooner than you think'.

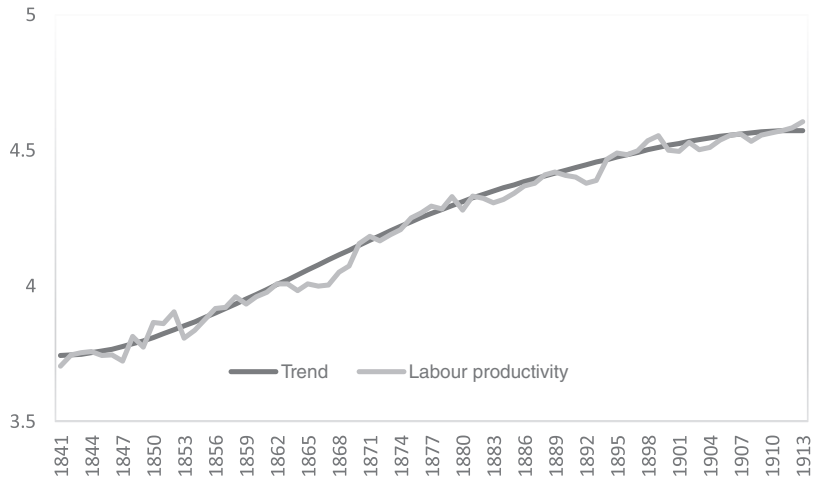

FIGURE 11 Trend of log labour productivity in the UK economy. *Source*: See text, section III

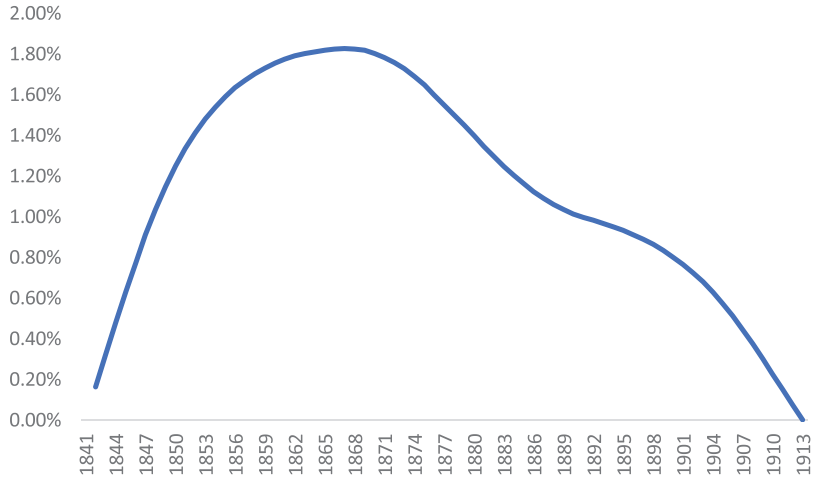

FIGURE 12 Movements in the trend growth path of labour productivity. *Source*: See text, section III
[Colour figure can be viewed at wileyonlinelibrary.com]

suggests a trend retardation starting in the early 1880s (see figure 13). Clearly this does not allow us to be certain as to which deflator is optimal. Instead, the results highlight an importance of future research in improving the GDP deflator with a revision of the expenditure accounts of UK GDP. Finally, we consider the results of changing the tax evasion assumption from Feinstein's methodology to one that assumes a constant proportion of tax evasion. The effect of this change would be to slow down the rate of deceleration in the 1870s. So, viewed from the income side, the evasion assumption matters for the conclusion about the nature of the trend slowdown in productivity. However, despite these differences the key result remains robust – productivity retardation has its origins in the late nineteenth century, not the Edwardian period.

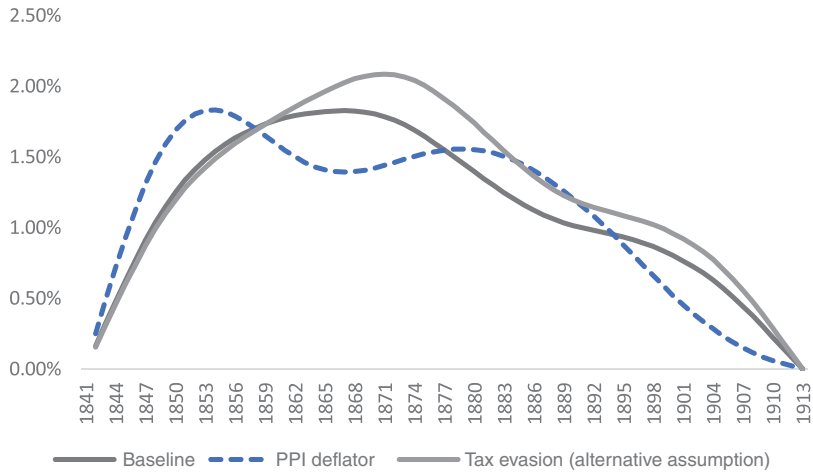

FIGURE 13 Sensitivity of trend growth in labour productivity to the PPI deflator and evasion assumption. *Source*: See text, section III [Colour figure can be viewed at wileyonlinelibrary.com]

IV | CONCLUSIONS

This paper has attempted to bring together some of the improvements to the national income estimates since the publication of Charles Feinstein's 1972 volume *National income, expenditure and output of the United Kingdom, 1855–1965*. These new income-based estimates of GDP provide the most up-to-date information we have on UK GDP over this period. Our analysis of the new data series allows us to draw four key conclusions:

First, Feinstein et al. argued that the income estimate of GDP provides a good measure of the fluctuations in the economy.[93] The robustness tests we have undertaken on the new data suggest that this remains the case. However, more work on unscrambling the cyclical properties of profits from the tax data and appropriate deflation of the income estimates will result in further improvements.

Second, the new GDP measure suggests that there is evidence of a long-term retardation in the UK productivity growth path beginning in the 1870s/1880s, supporting the conclusions of Crafts and Mills.[94] The new data challenge the idea of an Edwardian productivity climacteric and raise doubts about the U-shaped interpretation of UK economic growth over the period 1856–1973, discussed in Matthews et al.[95]

Third, there is evidence of medium-term fluctuations in GDP and productivity in the UK economy over the period 1841–1913. Although the specific features of these fluctuations are affected by the deflator used to derive real GDP, the substantive result suggests that medium-term fluctuations are a feature of the UK economy. An analysis of this historical period suggests that medium-term fluctuations are an important feature of economic cycles.

Fourth, although we are unlikely to quantify the true path of tax evasion, the results reported in this paper suggest that the main effect of the tax evasion assumption affects the trend component of the economy and is not central to the description of business cycles or the medium-term

[93] Feinstein et al., 'Timing of the climacteric'.

[94] Crafts and Mills, 'Sooner than you think'.

[95] Matthews et al., *British economic growth*.

fluctuations. Moreover, although this affects the time path of trend decline, the broad conclusion of a late Victorian retardation remains robust.

We hope this stock-taking, and the discussion of the various measurement issues, encourages future work on revising the output and expenditure side of UK GDP over this period. Once improvements and extensions are made, there would then be scope for constructing new balanced estimates of GDP for the nineteenth- and early twentieth centuries.

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