TRENDS IN REAL WAGES IN BRITAIN 1750-1913

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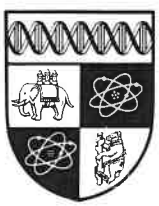

DEPARTMENT OF ECONOMICS

UNIVERSITY OF WARWICK
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I. Introduction

In three recent papers we have combined modern time series analysis with the most recent data for industrial production and GDP to obtain new and improved estimates of trends in economic growth in nineteenth century Britain and Europe.[1] The new methodology used in these papers obviates the need to specify discrete breaks in trend ex-ante, guards against biases in estimation resulting from incorrect assumptions as to the stationarity of residuals, and allows trend and cycle to be jointly modelled as stochastic processes, while the data series investigated embody the revisions to the once predominant work of Hoffmann and Deane and Cole that stem from the work of Crafts, Feinstein, and Harley.[2]

In this paper we extend our earlier work to consider trends in real wages, which we regard as a crucial indicator of the

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[1]N.F.R. Crafts, S.J. Leybourne, and T.C. Mills, "Trends and Cycles in British Industrial Production, 1700-1913", *Journal of the Royal Statistical Society*, Series A, 152 (Jan 1989), pp. 43-60, N.F.R. Crafts, S.J. Leybourne, and T.C. Mills, "The Climacteric in Late Victorian Britain and France: A Review of the Evidence", *Journal of Applied Econometrics*, 4 (May 1989), pp. 103-117 and N.F.R. Crafts, S.J. Leybourne, and T.C. Mills, "Measurement of Trend Growth in European Industrial Output before 1914: Methodological Issues and New Estimates", *Explorations in Economic History*, 27 (Oct 1990), pp. 442-467.

[2]W.G. Hoffmann, *British Industry, 1700-1950* (Oxford, 1955); P. Deane and W.A. Cole, *British Economic Growth, 1688-1959* (Cambridge, 1962); N.F.R. Crafts, *British Economic Growth During the Industrial Revolution* (Oxford, 1985); C.H. Feinstein, *National Income, Expenditure and Output of the United Kingdom, 1855-1965* (Cambridge, 1962); C.K. Harley, "British Industrialization before 1841: Evidence of Slower Growth During the Industrial Revolution", this JOURNAL, 42 (Jun 1982), pp. 267-89.

performance of the economy over time. As in the case of the analysis of trends in output growth, the time series approach adopted here provides substantially better estimating techniques than have hitherto been used in this area, and again there are improved data series available.[3] In section II we review this work in some detail and build upon it to develop an annual series of money wages, deflated by the cost of living, for 1750-1913.[4] For the period 1830-1913 we are also able to analyze a new series for own-product real wages based on Feinstein's latest revisions to his national income estimates.[5] In section III we describe our methodology and present the results so obtained.

Obviously, our work relates to the classic standard of living debate.[6] Indeed, a major dispute in the recent debate has

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[3]On prices, see N.F.R. Crafts, "Real Wages, Inequality and Economic Growth in Britain, 1750-1850: A Review of Recent Research", in P. Scholliers (ed.), *Real Wages in 19th and 20th Century Europe* (Oxford, 1989), pp. 75-95, I. Gazeley, "The Cost of Living for Urban Workers in Late Victorian and Edwardian Britain", *Economic History Review*, 42 (May 1989), pp. 207-21, and P.H. Lindert and J.G. Williamson, "English Workers' Real Wages: Reply to Crafts", this JOURNAL, 45 (Mar 1985), pp. 145-53. On wages, see L. Schwarz, "The Standard of Living in the Long Run: London 1700-1860", *Economic History Review*, 38 (Feb 1985), pp. 24-41. On both wages and prices, see C.H. Feinstein, "What Really Happened to Real Wages", (paper given to the ESRC Quantitative Economic History Study Group, 1987), F.W. Botham and E.H. Hunt, "Wages in Britain during the Industrial Revolution", *Economic History Review*, 40 (Aug 1987), pp. 380-99, and P.H. Lindert and J.G. Williamson, "English Workers' Living Standards during the Industrial Revolution: A New Look", *Economic History Review*, 36 (Feb 1983), pp. 1-25.

[4]This series would unavoidably become too crude before 1750 to mbase much faith in it.

[5]These estimates are reported in B.R. Mitchell, *British Historical Statistics* (Cambridge, 1988), pp. 831-3 and 837-9.

[6]For introductions to and summaries of the debate through the early 1970s, see A.J. Taylor, "Editors Introduction", in A.J.

centered on the issue of the acceleration in real wage growth at the end of the Napoleonic Wars in the context of the suggestion by Flinn that "there are relatively few indications of significant change in levels of real wages either way before 1810/14 ... At best, however, gains in the second quarter of the nineteenth century were of the order of less than 1 per cent per annum ... most of the significant change in levels of real wages during the whole century [1750-1850] was probably concentrated in a single period of scarcely a dozen years...[d]uring the first dozen years of the secular price fall after 1813...".[7] This view contrasts with Lindert and Williamson's finding that post 1820 the economy had ascended to a new and persistently rapid real wage growth and, moreover, it has been criticized for its reliance on unpersuasive and ad hoc procedures for separating secular trends from short run fluctuations in the data.[8] Our approach appears to offer substantial advantages when considering the issues raised by Flinn's controversial claim, besides putting the measurement of

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Taylor (ed.), *The Standard of Living in the Industrial Revolution* (London, 1975), pp, xi-lv, and M.W. Flinn, "Trends in Real Wages, 1750-1850", *Economic History Review*, 27 (Aug 1974), pp. 395-413; for a review of more recent work, see Crafts, "Real Wages, Inequality and Economic Growth".

[7]Flinn, "Trends in Real Wages", pp. 408-9.

[8]Lindert and Williamson, "Living Standards"; see also T.R. Gourvish, "Flinn and Real Wage Trends in Britain, 1750-1850: A Comment", *Economic History Review*, 29 (Feb 1976), pp. 143-5, J. Mokyr and N.E. Savin, "Some Econometric Problems in the Standard of Living Controversy", *Journal of European Economic History*, 7 (Fall 1978), pp. 517-25, G.N. Von Tunzelmann, "Trends in Real Wages, 1750-1850, Revisited", *Economic History Review*, 32 (Feb 1979), pp. 33-49, M.W. Flinn, "English Workers' Living Standards during the Industrial Revolution: A Comment", *Economic History Review*, 37 (Feb 1984), pp. 88-92, Crafts, "Real Wages, Inequality and Economic Growth".

trends in real wage growth during the Industrial Revolution on a sounder footing.

Less widely discussed, but of no less interest, is the relationship late in the nineteenth century between real wage growth and the alleged climacteric in British output and, especially, productivity growth. The conventional wisdom in the literature is that of Matthews, Feinstein and Odling-Smee, whose argument that the climacteric should be located after 1899, and was essentially a result of slower productivity rather than input growth, seems to have been accepted in the textbooks.[9] In our earlier papers we found that, as far as trend output is concerned, any climacteric at this time was very slight, but we did not separately consider productivity growth.[10]

An examination of own-product real wages using Feinstein's new estimates for money wages should be helpful in examining the further question of when and whether there was a climacteric in labour productivity growth, given that the aggregate production function in the economy appears to be Cobb-Douglas.[11] In

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[9]The details of this argument are in R.C.O. Matthews, C.H. Feinstein, and J.C. Odling-Smee, *British Economic Growth 1856-1973*, (Stanford, 1982), but for a succinct summary, see R.C.O. Matthews, C.H. Feinstein, and J.C. Odling-Smee, "The Timing of the Climacteric and its Sectoral Incidence in the UK", in C.P. Kindleberger and G. di Tella (eds.), *Economics in the Long View*, vol. 2 (Oxford, 1982), pp. 168-85. The acceptance by textbook writers is epitomized by the conversion of S.B. Saul, *The Myth of the Great Depression*, 2nd edn. (London, 1985), who also gives a good account of earlier views.

[10]Crafts et al., "The Climacteric", pp. 113-4 and ibid,. "Trends and Cycles", p. 57.

[11]Assuming profit maximisation, under these conditions real wage growth is an indicator of growth in output per person employed. It should be noted that annual estimates on volumes of factor

particular, our approach avoids the need to interpolate employment between censuses, is not dependent on the choice of one of the conflicting estimates for GDP in the period where there is serious divergence between output, income and expenditure measures, and avoids arbitrary periodization. In addition, we hope to throw further light on the nature of the widely remarked check to real wage growth, which Feinstein himself has recently attributed to faltering productivity growth and which forms the background to discussions of rising labor union militancy, in the years prior to World War I.[12]

Our central concerns in this paper are, therefore, to estimate accurately changes in the trend rate of growth of real wages, and to interpret the results in the context of the historiography of British economic performance in the eighteenth and nineteenth centuries. We enlarge on the implications of our empirical estimates in section IV.

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inputs are not available and that trends in own product real wages will, of course, reflect changes in the capital to labour ratio as well as total factor productivity growth.

[12]C.H. Feinstein, "What Really Happened to Real Wages?: Trends in Wages, Prices and Productivity in the United Kingdom, 1880-1913", *Economic History Review*, 43 (Aug 1990), 329-355.

II. The Data

Our purpose in this paper is to find out what can be inferred from the best available series on real wages and, thus, to bring out the implications of the new view of British economic growth which has emerged from the new economic history of the past twenty years. Clearly, there remain substantial data problems, some of the more important of which will be underlined in what follows, and inevitably our findings can only be described as "best guesses", contingent on the data's present quality. For the Industrial Revolution period we concentrate on analysis of an augmented version of Lindert and Williamson's estimates, which are the best avaliable indices for Britain as a whole and which have been claimed by their authors to challenge substantially earlier beliefs on the pace of real wage growth. We have constructed a new Lindert-Williamson type index on an annual basis for 1750-1851.

Our series on money wage rates, reported in Table 1, has been constructed by splicing together the best existing shorter series and interpolating as necessary in the period 1755-1851. It should be regarded, in Lindert and Williamson's terminology, as a series for "all blue-collar workers". For 1855 onwards the data come from Feinstein and incorporate his recent revisions, which substantially extend the occupational coverage for 1880-1913.[13]

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[13]Feinstein, "National Income", Table 65 and ibid, "New Estimates of Average Earnings in the United Kingdom, 1880-1913", *Economic History Review*, 43 (Nov 1990), pp. 595-632. The series is throughout an estimate of wages per worker unadjusted for

For 1755 to 1851 the Lindert and Williamson estimates for benchmark years are employed and other series which match very closely the change between these endpoints are used to interpolate, namely Gilboy for 1755-87, using weights of 0.25 for Lancashire workers and 0.75 for London labourers, a similarly weighted average of Gilboy and Schwarz for 1788-97, Schwarz for 1797-1819 and Bowley's building labourers for 1819-55.[14] Finally, the data from Gilboy are used to extend Lindert and Williamson's series back to 1750.

Our series on the cost of living, again reported in Table 1, is also constructed by splicing together the best available indices for shorter periods. We have used Gazeley's revision of Bowley for 1886-1913, extended back to 1880 by Feinstein's very similar revision of Bowley.[15] Bowley's cost of living index was used faute de mieux for 1851-79 and Lindert-Williamson's revised (1985) index was used for 1781-1850.[16] Prior to 1781 we have relied on a revised version of Phelps Brown and Hopkins well-known index, reweighted on the basis discussed in Crafts's earlier work. The reweghting of the Phelps-Brown and Hopkins index is to bring

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short-time or unemployment.

[14]The well-known Bowley, Gilboy and Lindert-Williamson series can be found in Mitchell, "British Historical Statistics", pp. 152-7, and Schwarz's series is in Schwarz, "Standard of Living", pp. 36-7.

[15]Gazeley, "Urban Workers", Table 3; Feinstein, "What Really Happened", Table 5.

[16]These indices are reported in Mitchell, "British Historical Statistics", pp. 737-8. The Lindert-Williamson index is a major revision of their earlier work, correcting their treatment of clothing prices.

it into line with that of Lindert-Williamson and to include evidence on rent. We have chosen not to seek to extend the series back beyond 1750 as rents data is unavailable.[17]

Deflation of the money wage index by the cost of living index gives the real wage series reported in Table 1. This index, which represents a new synthesis of recent research, is appropriate to measurement of working class living standards. In many periods, movement in this series is very similar to that of own product real wages, where wages are deflated by a measure of home output prices, which are relevant to measuring changes in employers' costs and labour productivity. This is not always the case, however, partly because of changes in the external terms of trade and partly because of changes in relative domestic prices. We have, therefore, investigated separately a series for own product real wages based on a deflation of money wages from Table 1 by Feinstein's GDP deflator for 1830-1913.[18]

The money wage series gives a picture which would mostly be familiar to scholars of the past fifty years, with the possible exception of Feinstein's revisions to the 1880s and 1900s; essentially the work of Gilboy and Bowley still stands in most respects, as does the main weakness, namely limitations in the

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[17]Crafts, "Real Wages, Inequality and Economic Growth", pp. 77-9. The reweighting for 1750-80 utilises data on rents from Botham and Hunt, "Wages in Britain", p. 388. For details of the Phelps Brown and Hopkins index, see E.H. Phelps Brown and S.V. Hopkins, *A Perspective of Wages and Prices*, (London, 1981), pp. 28-44.

[18]The GDP deflator can be derived from the data reported in Mitchell, "British Historical Statistics", pp. 831-9.

coverage of the index.[19] By contrast, recent research has changed considerably our best guess estimates of the cost of living. In particular, this has resulted from major improvements in the weighting of the index and the incorporation of rents into the basket of goods, and there seems to be no doubt that this recent work supercedes earlier studies. On the other hand, there are still important weaknesses in the cost of living estimates, especially because of gaps in information on prices of non-food items, notably prior to 1880, and it must be accepted that the quality of budget studies for the industrial revolution is disappointing.

III. Trend Decompositions of Real Wages

In this section we consider methods of decomposing the logarithm of a real wage series, w_t, into its constituent trend and cycle components, logarithms being used because such a transformation stabilises fluctuations around the level of the series. To be able to do this, we must make some assumptions as to how these unobservable and, therefore, unknown but estimatable, components evolve through time. A traditional approach is to

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[19]The money wage figures are an average of all blue-collar workers and, as such, in some periods do not reflect movements in particular regions. This is particularly the case during the Industrial Revolution and has been the subject of recent concern, see Botham and Hunt, "Wages in Britain" and Schwarz, "Standard of Living". As Crafts, "Real Wages, Inequality and Economic Growth", pp. 83-4, demonstrates, however, the overall Bowley/ Lindert-Williamson wage series are quite consistent with a suitably weighted average of regional wage trends.

begin by assuming that w_t can be decomposed additively into a trend (or level), μ_t, and a cycle, ψ_t,

$$w_t = \mu_t + \psi_t \quad , \tag{1}$$

such that the components are independent of each other. While this assumption of independence is not the only one that could be made (we could, for example, assume that μ_t and ψ_t are perfectly correlated), some assumption has to be made to ensure that the components are identifiable, and this seems to be the most reasonable in the circumstances.[20]

To make the decomposition in (1) operational, specific models for the components have to be assumed. We first consider a set of specifications which together make up what is known as the *basic structural model*.[21] The trend model is given by the pair of equations

$$\begin{aligned} \mu_t &= \mu_{t-1} + \beta_t + \varepsilon_t \\ \beta_t &= \beta_{t-1} + \upsilon_t \quad , \end{aligned} \tag{2}$$

where ε_t and υ_t are serially uncorrelated and independent errors with zero means and variances σ_ε^2 and σ_υ^2 respectively. The trend model (2) thus allows the current level of the series, μ_t, to

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[20]For a detailed discussion of the identification assumptions needed for 'unobserved components' models such as this, see M.W. Watson, "Univariate Detrending Methods with Stochastic Trends", *Journal of Monetary Economics,* 18 (Jan 1986), pp. 49-75.

[21]See, for example, Crafts et al, "Trends and Cycles", and A.C. Harvey, "Trends in Cycles in Macroeconomic Time Series", *Journal of Business and Economic Statistics*, 3 (Jun 1985), pp. 216-227.

evolve as a random walk with a drift of β_t, which itself evolves as a (driftless) random walk independent of the level. It has the equivalent interpetation that the trend is a local linear function of time, where both the slope and intercept are continually being updated as new observations become available. Two special cases of this model are worthy of attention. If $\sigma_\upsilon^2=0$ then the drift of μ_t is constant through time, *i.e.* $\beta_t=\beta$, say, in which case (1) can be written as

$$w_t - w_{t-1} = \nabla w_t = \beta + v_t \ , \tag{3}$$

where ∇w_t is the observed growth rate of real wages and where v_t is, in general, a stationary but serially correlated error. This model is known, in the terminology of Nelson and Plosser, as a difference stationary process.[22] If, furthermore, $\sigma_\varepsilon^2=0$, μ_t then reduces to a deterministic linear trend so that w_t is trend stationary[23]:

$$w_t = \alpha + \beta t + u_t \ , \tag{4}$$

where again u_t is a stationary, serially correlated, error.

The cyclical component, ψ_t, is modelled as a sinusoidal process dependent upon three parameters: the variance of the errors driving the process, σ_δ^2, and two parameters, λ and ρ, measuring the frequency and damping factor of the cycle,

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[22]C.R. Nelson and C.I. Plosser, "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications", *Journal of Monetary Economics*, 10 (Feb 1982), pp. 139-62.

[23]Nelson and Plosser, "Trends and Random Walks".

respectively. If $\rho=0$, ψ_t will not contain a cycle, while if $\sigma_\delta^2=0$, any cycle will be deterministic rather than stochastic.

Fitting this basic structural model to our cost of living real wage series over the period 1750-1913 produced the following parameter estimates, standard errors of the nonzero parameters being shown in parentheses:[24]

$$\sigma_\varepsilon^2 = 0, \quad \underset{(0.00\times10^{-5})}{\sigma_\upsilon^2 = 1.58\times10^{-5}}, \quad \underset{(0.40\times10^{-3})}{\sigma_\delta^2 = 2.89\times10^{-3}},$$

$$\underset{(0.05)}{\rho = 0.71}, \quad \underset{(0.09)}{\lambda = 0.76}$$

Since $\sigma_\delta^2>0$ and $0<\rho<1$, the cyclical component ψ_t is both stochastic and stable, the period of the cycle, given by $2\pi/\lambda$, being approximately $8\frac{1}{4}$ years. As $\sigma_\upsilon^2>0$, the growth rate of trend real wages is variable although, given the size of the estimate, it will be fairly stable, and the model does not reduce to a difference stationary process. Interestingly, $\sigma_\varepsilon^2=0$, and this implies that all fluctuations in the level of w_t are the result of changes in drift: there are thus no "once-and-for-all" shifts in the level of real wages. This is identical to the findings of Crafts, Leybourne and Mills for industrial production during this period.[25]

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[24]The model was estimated using the STAMP package, see A.C. Harvey, *Forecasting, Structural Time Series Models, and the Kalman Filter*, (Cambridge, 1990).

[25]Crafts et al, "Trends and Cycles".

Given these parameter estimates, we can then estimate the unobserved trend component μ_t.[26] This is superimposed on the observed cost of living real wage series w_t in Figure 1, and yields a picture of slowly declining trend real wages in the second half of the eighteenth century, an increasing trend beginning early in the nineteenth century and continuing throughout the 1800s, and a flat trend from the turn of the twentieth century to the outbreak of the First World War. It is also apparent that trend real wages appear to go through long cycles during the period.

A close examination of Figure 1 suggests a second possibility for modelling the trend in cost of living real wages. The finding that σ_v^2 is positive, thus implying that the drift in trend is not constant throughout the sample period, is clearly a consequence of the flatness of observed real wages in the eighteenth and twentieth centuries, with the intervening years being a period of relatively constant growth. A simple model capturing these features would be a *segmented trend* of the form

$$\mu_t = \alpha_0 + \alpha_1 \varphi_t \quad , \tag{5}$$

where φ_t is defined as

$$\varphi_t = \begin{cases} 0, & 0 \le t \le T_A \\ t - T_A, & T_A + 1 \le t < T_B \\ T_B - T_A, & T_B \le t \end{cases} ,$$

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[26] See Harvey, "Forecasting", for details.

using the convention that t=0 in 1750. The model thus implies that trend growth was zero up till year T_A, the level of ψ_t being α_0, it then grew at a constant rate of α_1 until year T_B, after which it remained at the level $\alpha_0+\alpha_1(T_B-T_A)$.[27]

In fitting such a model, the 'break points' T_A and T_B need to be chosen. From both a visual examination of Figure 1 and historical considerations, the years 1813 and 1903 suggest themselves, thus yielding the settings T_A=63 and T_B=153. Other combinations of break point years close to 1813 and 1903 were considered, in particular 1817 and 1899, but these provided only minor differences to the estimated parameters of the segmented trend model reported below: indeed, in terms of goodness of fit criteria, the above settings of T_A and T_B were superior to all of the other combinations examined.[28]

While it is possible to employ the cyclical process from the basic structural model, when working with a segmented trend model it is easier to model ψ_t as a second order autoregressive process, for such models can easily capture cyclicality and they allow

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[27]Although segmented trend models, which are a special case of a more general class of models known as grafted polynomials, have a long history in time series analysis (see W.A. Fuller, *Introduction to Statistical Time Series*, (New York, 1976)), there has recently been a resurgence of interest in them with regard to testing whether series are actually generated by difference stationary models such as (3). See P. Rappoport and L. Reichlin, "Segmented Trends and Non-stationary Time Series", *Economic Journal*, 99 (Supplement, 1989), pp. 168-177, and P. Perron, "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", *Econometrica*, 57 (Nov 1989), pp. 1361-1401.

[28]It should also be reported that more general segmented trends were fitted that allowed trend growth before 1813 and after 1903 to be nonzero. The restriction to zero growth in these periods could not be rejected, however.

estimation of the combined model to be carried out by autoregressive least squares, *i.e.*

$$\psi_t = \phi_1\psi_{t-1} + \phi_2\psi_{t-2} + a_t \quad . \tag{6}$$

Combining (5) and (6) with (1) led to the fitted model

$$w_t = \underset{(0.014)}{3.560} + \underset{(.0003)}{.0119}\varphi_t + \psi_t$$

$$\psi_t = \underset{(.076)}{.811}\psi_{t-1} - \underset{(.075)}{.304}\psi_{t-2} + a_t \quad ,$$

where standard errors are shown in parentheses. All coefficients are precisely estimated and the estimate of α_1 implies that trend real wages grew at a constant rate of 1.2% per annum during the period 1813 to 1903. The autoregressive coefficients imply that the period of the cycle is 8.4 years and Figure 2 shows the real wage series with the fitted segmented trend superimposed.

A more complicated segmented trend model was also entertained. Based on the work of Flinn quoted above, a segmented trend containing further break points at 1825 and 1850, the intervening years having zero trend growth, was fitted to w_t. The fit was found to be rather worse than that of the model reported above, its' residual variance being some 17% larger.

What comparisons can be made between the basic structural model and the segmented trend for providing decompositions of the cost of living real wage series? In terms of goodness of fit, there is very little to choose between the two, the R^2 statistics being .968 and .974 respectively, with both models passing standard diagnostic checks for residual autocorrelation. The

periods of the cycle computed from the two models are also almost identical.

A possible way of discriminating between the two models is to utilise various unit root tests. The basic structural model implies that w_t contains *two* unit roots, i.e. that it requires differencing twice to achieve stationarity. A test of whether the series actually does contain two unit roots is able to reject this hypothesis convincingly in favour of w_t having just a single unit root. In turn, the hypothesis that w_t contains a unit root (i.e. is difference stationary) is itself rejected in favour of the segmented trend model estimated above.[29]

The segmented trend may thus be favoured on statistical grounds and, we would argue, because it provides also a clearer and simpler representation of movements in trend, but both models nevertheless do present a consistent picture of the behaviour of cost of living real wage trends in the period from 1750 to 1913. This is perhaps best seen from Figure 3, which plots annual growth rates of the observed series and the two trend components.

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[29]A test of the null hypothesis of two unit roots against the alternative of only one utilises the t-ratio on the slope coefficient estimated from the regression of $\nabla^2 w_t$ on ∇w_{t-1}, comparing it with the τ_μ statistic tabulated in Fuller, "Introduction to Statistical Time Series", Table 8.5.2. The computed value is -11.74, which strongly rejects the null in favour of the alternative. Extending the testing procedures suggested by Reichlin and Rappoport, "Segmented Trends", and Perron, "The Great Crash", allows us almost certainly to reject the difference stationary model for real wages in favour of the segmented trend model. For example, computing the test statistic proposed by Perron yields a value of -7.66. While critical values for the case of two breaks of trend considered herehave not been established, such a value would surely be enough to reject the null of a difference stationary model.

The basic structural model was also fitted to the own product real wage series available from 1830. The resulting parameter estimates were

$$\underset{(1.60\times10^{-4})}{\sigma_\varepsilon^2 = 2.51\times10^{-4}}, \quad \underset{(0.00\times10^{-5})}{\sigma_\upsilon^2 = 0.24\times10^{-5}}, \quad \underset{(3.08\times10^{-5})}{\sigma_\delta^2 = 1.56\times10^{-5}},$$

$$\underset{(0.08)}{\rho = 0.97}, \quad \underset{(0.07)}{\lambda = 0.65}$$

All variances are positive, although σ_ε^2 and σ_δ^2 are rather imprecisely estimated, and the small estimate for the latter variance, combined with the large estimate of ρ, implies a cycle that is both pronounced, in terms of amplitude, and stable, the period of which is estimated to be 9.7 years, somewhat larger than that obtained for cost of living real wages. The model passes standard diagnostic checks for residual autocorrelation and has an R^2 of .982.

Figure 4 shows the own product real wage series with its estimated trend component superimposed, while Figure 5 plots the corresponding growth rates. The large movements in the observed series during the years 1830-1850 are seen to be primarily cyclical fluctuations, the trend component being relatively smooth during this period. Indeed, trend growth rates are fairly stable throughout the entire period, averaging 0.76% per annum with a standard deviation of 1.09 as compared to the observed average of 0.81 but standard deviation of 2.65. The mean for the period between the business cycle peaks of 1882-1899 is 1.09%, falling to 0.50% in the period 1900-1913. In particular then, there appears to be less of a slowdown in trend growth around the turn of the

century and thus, presumably, less of a climacteric in productivity growth during these years than Feinstein has recently found using endpoint measures of his revised series for the income measure of GDP/worker.[30]

These findings suggest that a trend stationary process of either the type (4) or (5) would not be acceptable for modelling this series and, indeed, unit root tests cannot reject the difference stationary hypothesis in favour of either a trend stationary model or a segmented trend with a break point around the turn of the century. In fact, the growth rate series is adequately modelled by a first order moving average process:

$$\nabla w_t = \underset{(.0028)}{.0073} + a_t - \underset{(.112)}{.222}a_{t-1} ,$$

whose fit compares favourably with that of the basic structural model (its residual standard error is 2.57% compared with 2.61% for the latter model). The implied trend component from this model is of the form (2) but with β_t=.0073 being constant (since σ_υ^2=0) and σ_ε^2=.0200. It can be estimated as a two sided (exponentially weighted) moving average taking the form

$$\mu_t = .636 \sum_{j=-\infty}^{\infty} .222^{|j|} w_{t-j}$$
$$= \left(\ldots + .03w_{t-2} + .14w_{t-1} + .64w_t + .14w_{t-1} + .03w_{t-2} + \ldots \right)$$

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[30]Feinstein, "What Really Happened", p. 344 reports 1.43% per year for 1882-99 and 0.31% for 1899-1913.

Since the moving average is dominated by the weight placed on the current observation, the trend will be smooth and follow quite closely the path of w_t. Furthermore, as the implied estimates of the structural variances σ_ε^2 and σ_υ^2 are close to those obtained from estimating the basic structural model, the above trend will be very similar to that shown in Figure 4.

IV. Some Implications of the Results

In this section we consider first the evidence of our results in terms of the standard of living debate and then, secondly, review the question of a productivity climacteric in Edwardian Britain. Our discussion is placed firmly in the context of the recent historiography of real wages.

Our preferred model of cost of living real wages is one of a segmented trend with zero growth before 1813, trend growth at 1.2% per year between 1813 and 1903, and zero thereafter. This is based on an index of real wages along the lines proposed by Lindert and Williamson and comes to an interpretation of the data for the industrial revolution period which is broadly similar to theirs. We agree that trend growth of real wages before 1810 was negligible; however, we find that their stress on an estimate of real wage growth at 1.5% per year for 1810-51 exaggerates the change in trend.[31]

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[31]Lindert and Williamson, "Reply to Crafts", p. 153.

The estimate of trend real wage growth at 1.2% per year for 1813 onwards is very similar to Crafts's crude endpoints estimate for 1820-50 based on the outcome of his debate with Lindert-Williamson.[32] The improved procedures of this paper suggest, however, that Crafts's use of a periodization based on a division at 1820, which derived essentially from his challenge to Lindert and Williamson's earlier paper, probably was somewhat misleading and tended to understate the change around the end of the French Wars.[33] Nevertheless, the results strongly confirm Crafts's claim that Lindert and Williamson's original estimate of real wage growth in 1820-50 at 1.9% per year was much too high.[34]

On this evidence only a part of Flinn's claims can be accepted. His emphasis on 1813 as a turning point is vindicated but his suggestion that trend growth of real wages in the second quarter was slight is not valid for this dataset. Our rejection of Flinn's view of 1825-50 is not an artefact of reliance on data for isolated and atypical years, as he claimed Lindert and Williamson's original rejection of his argument was, and holds despite the changes made to Lindert and Williamson's cost of

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[32]Crafts, "Real Wages, Inequality and Economic Growth", p.80.

[33]Lindert and Williamson, "Living Standards", stressed 1820 as a divide and Crafts, "English Workers' Real Wages during the Industrial Revolution: Some Remaining Problems", this JOURNAL, 45 (Mar 1985), pp. 139-44 and "Real Wages, Inequality and Economic Growth" assessed the evidence on the extent of this claimed difference between pre- and post-1820. It should be noted that it remains true that, if 1820 is chosen as a divide, real personal consumption and real wages grew at fairly similar rates both before and after.

[34]Lindert and Williamson, "Living Standards", p. 13; Crafts, "Some Remaining Problems", p. 143-4.

living index in their 1985 revision.[35]

The change in trend real wage growth surely has its long term basis in an increased rate of growth of both the capital to labor ratio and of total factor productivity. The sources of growth calculation presented by Crafts suggests that TFP growth rose from 0.2% per year before 1800, to 0.7% per year in 1801-31, and to 1.0% in the period 1831-60, while the most recent revisions made by Feinstein to his capital stock estimates indicate that capital per worker grew at an average of 0.4% per year for the 50 years up to 1810, before rising to 0.54% in 1810-20, 0.80% in 1820-30 and 1.10% in 1830-40.[36] These seem to have been more substantial influences on real wages than Flinn, whose discussion hinged on falls in agricultural prices relative to sticky money wages, acknowledged. Our estimate of trend growth of own product real wages, shown in Figure 3, averages 0.90% for 1830-50. Our estimates for cost of living real wages confirm the long-recognized check to real wage growth in Edwardian Britain, although our best estimate of the segmented trend slightly prefers a break in 1903 to the more traditional choice of 1899. The size of the change in trend is similar in magnitude to that suggested by Feinstein using crude endpoint calculations based on 1882-99

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[35]Flinn, "A Comment", p.89.

[36]Crafts, "British Economic Growth", Table 4.2. Figures for net capital stock are from C. H. Feinstein, "National Statistics, 1760-1920", in C. H. Feinstein and S. Pollard (eds.), *Studies in Capital Formation in the United Kingdom, 1750-1920* (Oxford, 1988), p. 441, and for the labor force from E. A. Wrigley and R. Schofield, *The Population History of England, 1541-1871* (London, 1981).

and 1899-1913.[37]

It is instructive to compare these results with our estimates for own-product real wages, as shown in Figure 3. The decline in trend for this series is smaller and, of course, less abrupt. As noted in section III above, the average for trend growth of own product real wages falls by 0.59% per year between 1882-99 and 1900-13. It should also be noted that the standard deviations are 0.41 and 0.54 respectively, so that there is no statistically significant decline in estimated trend growth. In conjunction with our earlier findings that the national income series show evidence of only a small decline in estimated trend growth, we would take this as further evidence that Matthews et al. have exaggerated the extent of an Edwardian climacteric.[38]

Combining the evidence of the point estimates from the two trend growth rates, we would regard the wage check after 1903 as probably coming roughly equally from a decline in labour productivity growth and from a change in relative prices. Table 1 shows that the Edwardian period saw rises in the cost of living relative to the GDP deflator, a reversal of the experience of the 1880s and 1890s.[39] This would lead us to doubt Feinstein's recent

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[37]Feinstein, "What Really Happened", p. 344 estimates a decline from 1.58% per year in 1882-99 to 0.29% in 1899-1913.

[38]Matthews et al., "British Economic Growth" show real GDP (compromise) per worker falling from a growth rate of 1.3% in 1873-82 to 1.1% in 1882-99 and 0.5% in 1899-1913; Crafts et al., "The Climacteric", p. 113 suggested the decline in trend growth of GDP was less than 0.2% per year.

[39]For 1882-99 our estimate of the cost of living falls by 0.71% per year compared with 0.29% for the GDP deflator, while between 1899 and 1913 the cost of living rises by 1.11% per year while the GDP deflator goes up by 0.83%, a turnaround in relative price growth

assessment that the underlying source of the check to real wages came almost entirely from productivity growth, despite our use of his new estimates for money wages. We would not, of course, wish to go as far as Lewis in regarding relative prices as the major explanation.[40]

Obviously, our differences with Feinstein stem mainly from the methodology with which we have looked at trend measurement and our use of real wage data rather than his new measure of GDP (income) per worker. Nevertheless, another look at Feinstein's own data leads us to suggest that his emphasis on the productivity explanation is overstated. Thus, his endpoint calculations show that while he finds a decline in the rate of growth of real employment income per worker between 1882-99 and 1899-1913 of 1.12% per year, there was also a 0.53% decline from relative price trends.[41]

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of 0.7% per year.

[40]Feinstein, What Really Happened", pp. 351-3; W. A. Lewis, *Growth and Fluctuations, 1870-1913* (London, 1978).

[41]Based on Feinstein, "What Really Happened", Table 4, taking productivity growth from row 6 and using row 9 as the relative price adjustment.

V. Conclusions

This exploration in the use of time series analysis to investigate trends in real wages points, we believe, to a number of conclusions, which are as follows:

1) Our most important point is that there are substantial advantages in applying modern econometric techniques to problems of trend estimation. Traditional methodology requires the use of unnecessarily restrictive assumptions and runs the risk of obtaining biased estimates.

2) We find that on the best presently available evidence trend real wage growth was zero for the period 1750-1813 but then rose to 1.2% per year. This finding offers some support for Lindert and Williamson's basic interpretation of real wage trends, while adjusting downward the magnitude of the post Napoleonic Wars growth. It remains the case, however, that the underlying data on which this calculation is based are relatively fragile and may well be subject to revisions by future researchers.

3) We confirm a sharp check to real wages of workers at the beginning of the twentieth century. Our approach leads us still to be sceptical, however, of the suggestion that this resulted from a large climacteric in productivity growth. We would place roughly equal weight on slower labor productivity growth and on changes in relative prices, in contrast to Feinstein's recent analysis.

Table 1.

Money Wages, the Cost of Living and Real Wages, 1700-1913. (1900 = 100)

	Money Wages	Cost of Living	Cost of Living Real Wages	Own Product Real Wages
1750	32	76	42	
1751	32	78	41	
1752	32	83	39	
1753	32	82	39	
1754	32	81	40	
1755	32	77	42	
1756	32	83	39	
1757	30	106	28	
1758	30	100	30	
1759	32	87	37	
1760	31	80	39	
1761	31	79	39	
1762	31	82	38	
1763	35	84	42	
1764	34	92	37	
1765	34	97	35	
1766	34	97	35	
1767	34	112	30	
1768	37	109	34	
1769	37	94	39	
1770	37	98	38	
1771	35	108	32	
1772	37	115	32	
1773	37	117	32	
1774	37	116	32	
1775	36	113	32	
1776	36	103	35	
1777	36	108	33	
1778	36	108	33	
1779	37	97	38	

	Money Wages	Cost of Living	Cost of Living Real Wages	Own Product Real Wages
1780	37	99	37	
1781	37	109	34	
1782	38	109	35	
1783	37	111	33	
1784	36	108	33	
1785	38	102	37	
1786	39	100	39	
1787	38	103	37	
1788	38	105	36	
1789	38	112	34	
1790	39	115	34	
1791	39	112	35	
1792	39	109	36	
1793	40	117	34	
1794	41	121	34	
1795	43	143	30	
1796	44	150	29	
1797	45	130	35	
1798	47	128	37	
1799	47	146	32	
1800	49	196	25	
1801	49	205	24	
1802	49	151	32	
1803	49	147	33	
1804	49	151	32	
1805	59	174	34	
1806	65	165	39	
1807	66	158	42	
1808	66	169	39	
1809	66	192	34	
1810	66	203	33	
1811	68	192	35	
1812	68	223	30	
1813	69	217	32	

	Money Wages	Cost of Living	Cost of Living Real Wages	Own Product Real Wages
1814	69	188	37	
1815	65	161	40	
1816	65	177	37	
1817	65	183	36	
1818	65	176	37	
1819	62	163	38	
1820	62	148	42	
1821	62	124	50	
1822	62	131	47	
1823	62	131	47	
1824	62	140	44	
1825	62	148	42	
1826	62	133	47	
1827	59	129	46	
1828	59	133	44	
1829	59	136	43	
1830	59	133	44	58
1831	59	134	44	60
1832	59	127	46	63
1833	58	120	48	64
1834	58	114	51	62
1835	57	107	53	60
1836	58	123	47	58
1837	59	127	46	61
1838	59	137	43	60
1839	60	140	43	61
1840	60	137	44	63
1841	60	132	45	64
1842	60	124	48	67
1843	60	111	54	69
1844	60	115	52	66
1845	60	113	53	66
1846	60	118	51	65
1847	60	139	43	61

	Money Wages	Cost of Living	Cost of Living Real Wages	Own Product Real Wages
1848	61	113	54	67
1849	61	103	59	67
1850	61	101	60	72
1851	61	98	62	71
1852	61	100	61	72
1853	67	112	60	72
1854	70	119	59	72
1855	71	118	60	72
1856	71	118	60	72
1857	68	121	56	69
1858	67	110	61	70
1859	67	112	60	69
1860	68	117	58	70
1861	68	116	59	68
1862	69	117	59	69
1863	70	119	59	68
1864	73	119	61	68
1865	75	117	64	71
1866	77	118	65	70
1867	76	118	64	70
1868	75	117	64	71
1869	75	115	65	72
1870	77	115	67	76
1871	80	117	68	77
1872	85	125	68	76
1873	89	127	70	77
1874	90	119	76	79
1875	88	115	77	82
1876	87	115	76	83
1877	86	115	75	84
1878	84	108	78	82
1879	82	104	79	86
1880	82	109	75	81
1881	82	106	77	84

	Money Wages	Cost of Living	Cost of Living Real Wages	Own Product Real Wages
1882	83	108	77	84
1883	84	108	78	85
1884	83	105	79	86
1885	83	101	82	89
1886	82	100	82	89
1887	83	99	84	90
1888	84	99	85	92
1889	86	100	86	93
1890	88	99	89	93
1891	90	99	91	95
1892	90	99	91	95
1893	90	97	93	96
1894	91	94	97	99
1895	91	93	98	100
1896	92	94	98	100
1897	93	95	98	100
1898	95	97	98	102
1899	97	96	101	103
1900	100	100	100	100
1901	101	101	100	101
1902	101	100	101	103
1903	102	100	102	104
1904	102	101	101	104
1905	102	101	101	104
1906	104	101	103	105
1907	106	103	103	105
1908	107	105	102	105
1909	107	105	102	107
1910	108	106	102	108
1911	110	106	104	108
1912	112	110	102	107
1913	116	112	104	110

Sources: see text.

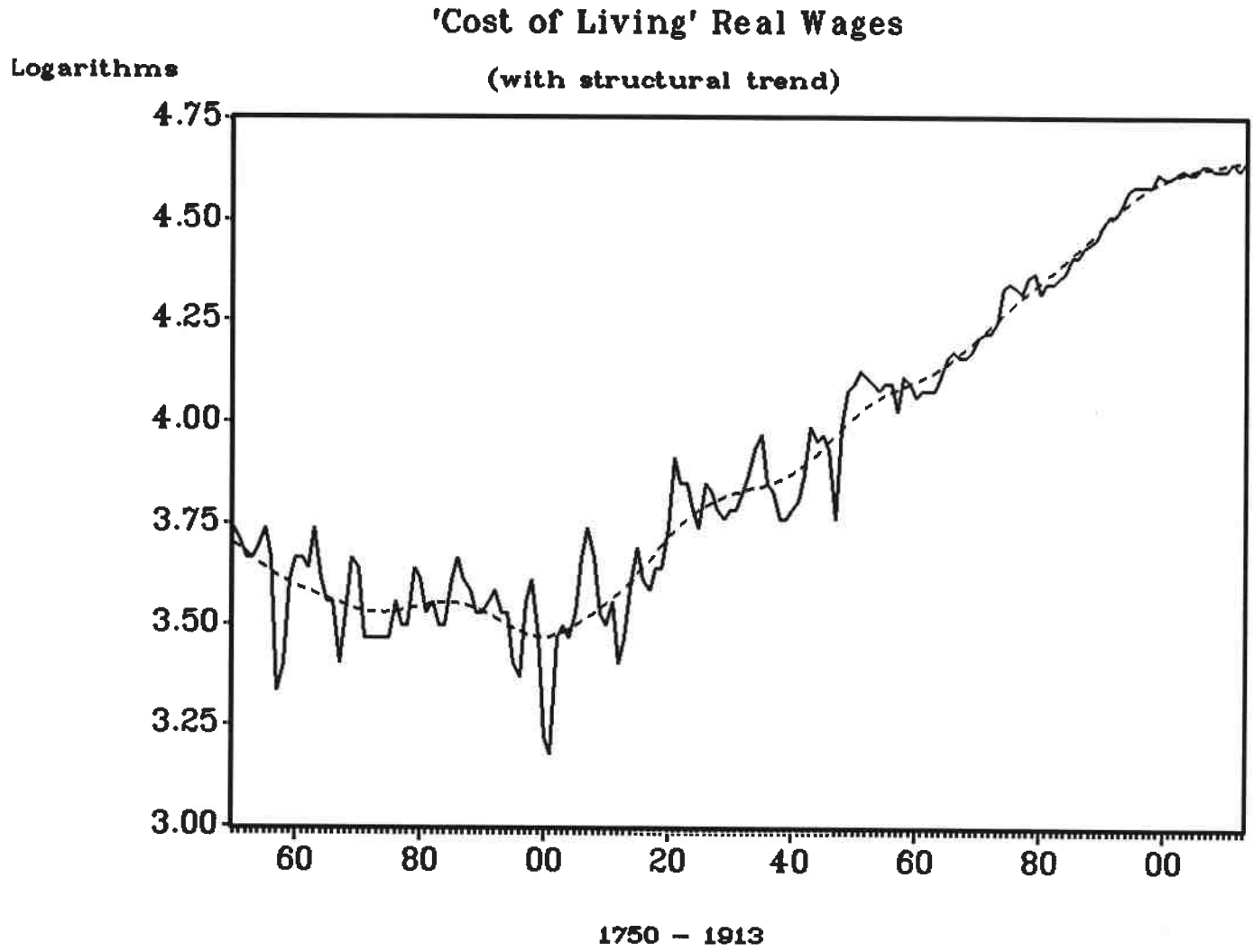

'Cost of Living' Real Wages
(with structural trend)
Logarithms
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
60
80
00
20
40
60
80
00
1750 – 1913

Figure 1

'Cost of Living' Real Wages

(with segmented trend)

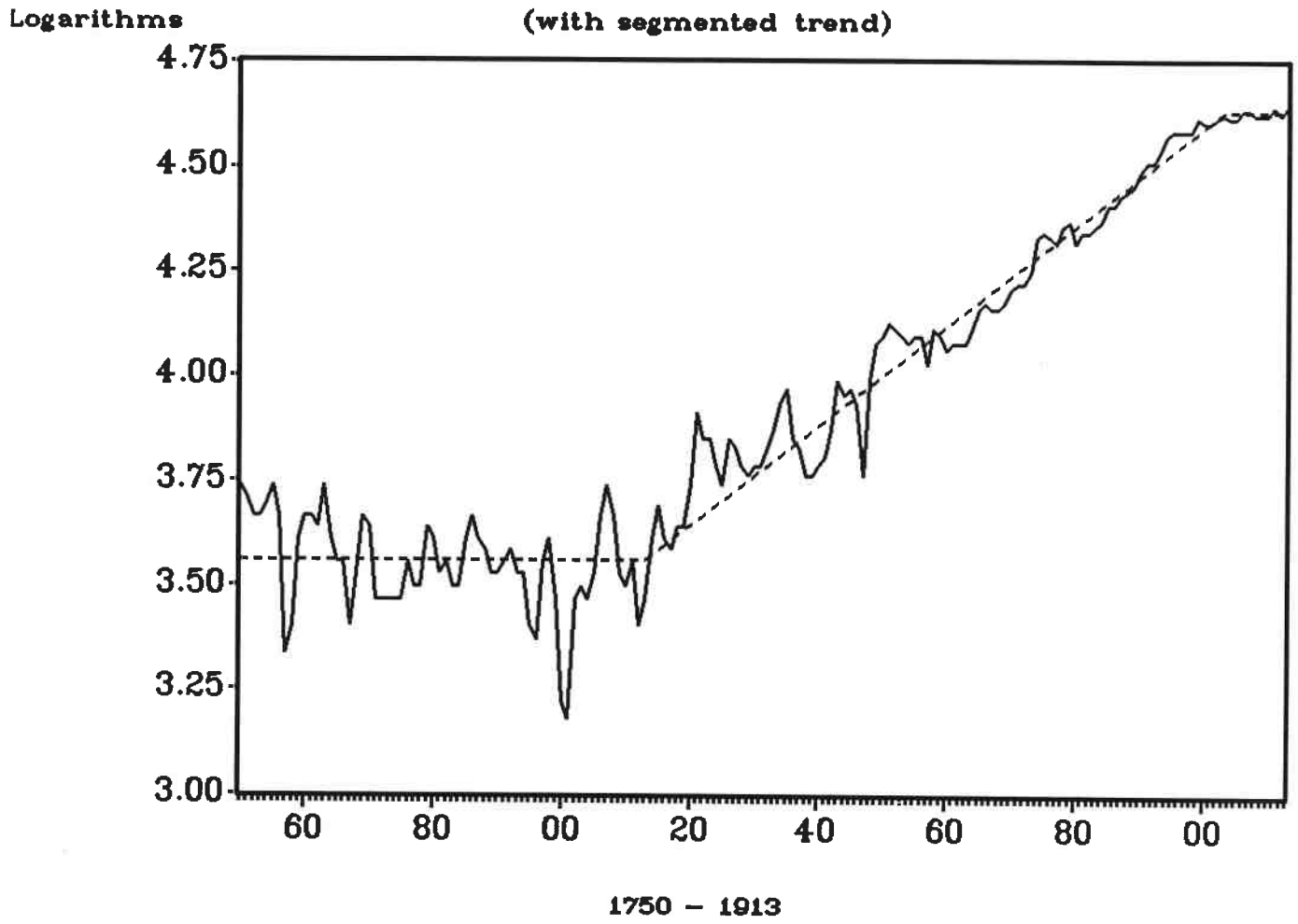
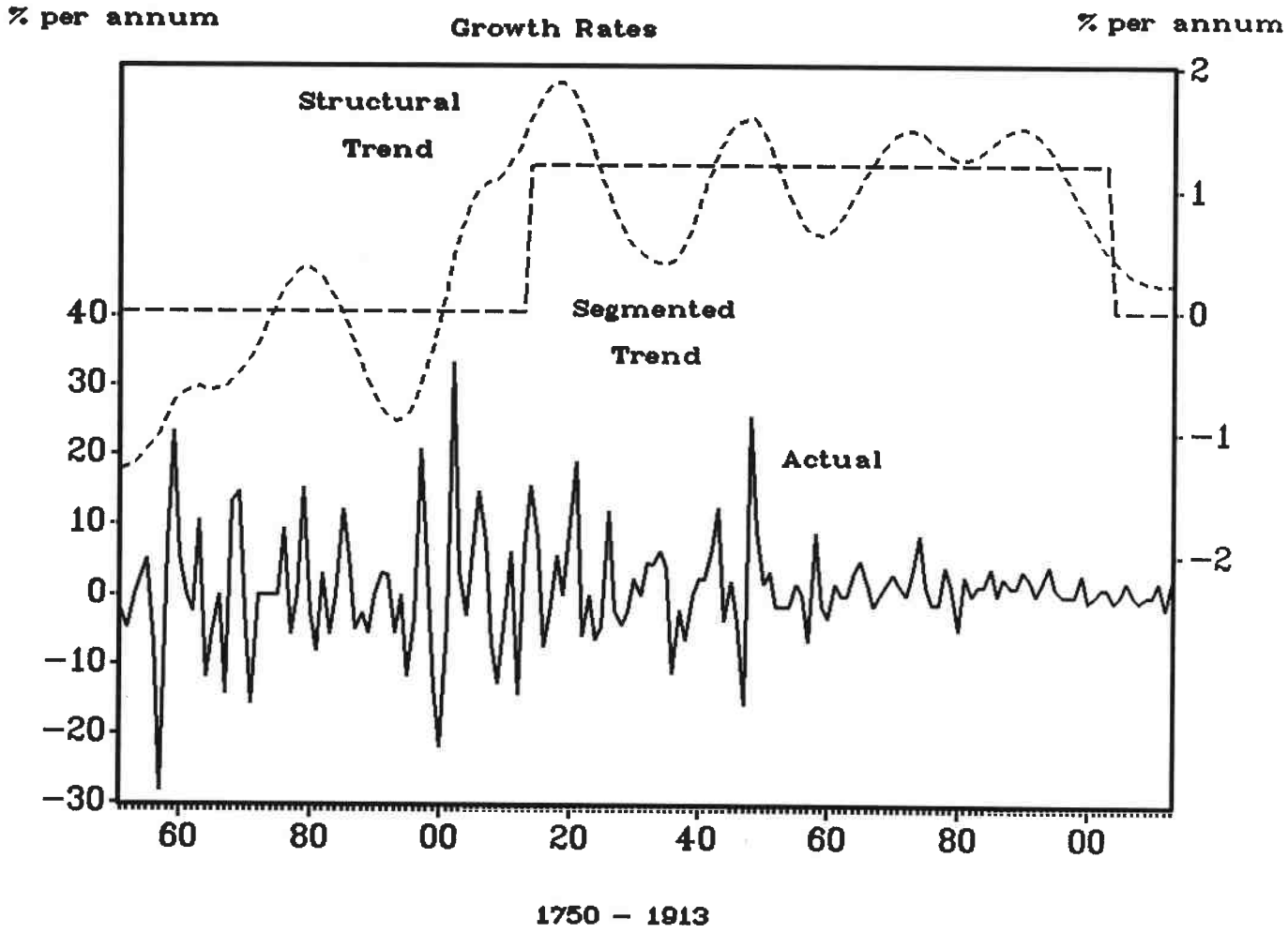


Figure 2

'Cost of Living' Real Wages



1750 – 1913

Figure 3

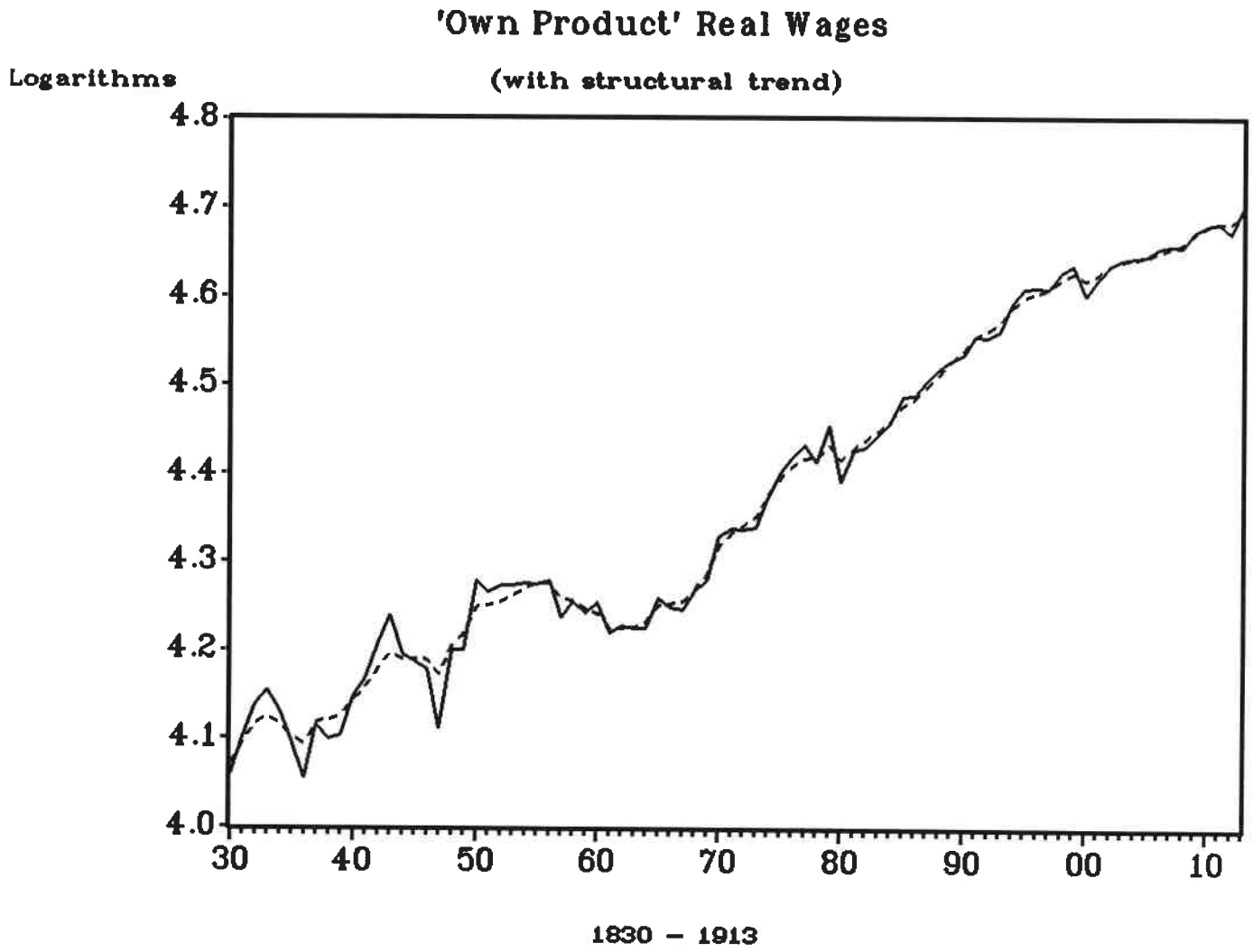

'Own Product' Real Wages
(with structural trend)
Logarithms
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
30
40
50
60
70
80
90
00
10
1830 – 1913

Figure 4

'Own Product' Real Wages

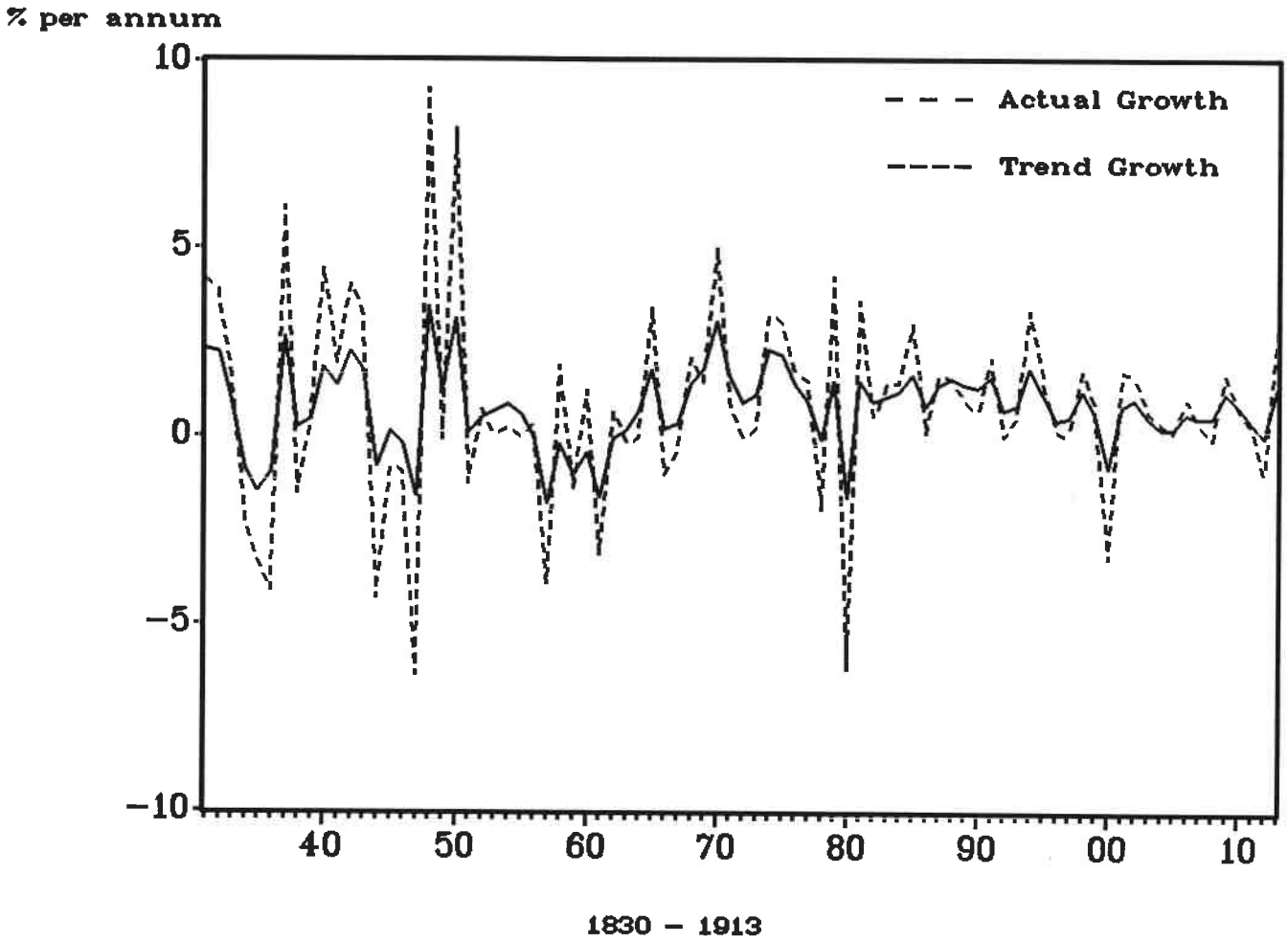


Figure 5