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ABSTRACT

An Analysis of the Changes in British Workers' Real Wages since the 19th Century

The increase in the real wages of British workers over the last one hundred years is often attributed to the growth in labour productivity, but this has rarely been confirmed. In the research reported here, this ascription is confronted with annual observations on wages and productivity spanning more than a century. A positive wage-productivity link is, indeed, found. However, productivity growth alone removes little of the variation over time in real wage changes. When trade union membership was rising, unions were able to direct increases in incomes to the earnings of rank-and-file workers.

JEL Classification: J31, J42, N14, N34

Keywords: real wages , labour productivity, trade unions, monopsony

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AN ANALYSIS OF THE CHANGES IN BRITISH WORKERS' REAL WAGES SINCE THE 19TH CENTURY

John H. Pencavel *

This is an inquiry into the growth of real wages of British workers from the end of the 19th century to the first decades of the 21st century. The real wages of the typical British worker in 2016 were approximately six times their value in 1893. To what may this considerable growth be attributed?

This question was taken up in a remarkable volume over fifty years ago by Henry Phelps Brown and Margaret Browne (1968) who drew upon observations from 1860 to 1960 not only for the U.K. but also, for purposes of comparison, for France, Germany, Sweden, and the U.S.A.[1] They concluded "the rise in real wages has depended mainly on that of productivity" (p.319) which, in turn, "....can be attributed to improvements in the capacity, bodily and mental, of the worker himself, and to his working with a capital embodying an ever greater amount of current resources in equipment of progressively improved design" (p.31).

Phelps Brown and Browne's proposed explanation for the rise in real wages, the growth in labour productivity, will be reconsidered here. This reconsideration will take the form of applying least squares regression analysis to annual observations on real wages and labour productivity and other variables. In this, the analysis here does not follow Phelps Brown and Browne who explicitly

* Many thanks to Ryland Thomas for his help in answering questions about the observations used here.

[1] Writing of the years from 1860 to 1960, Phelps Brown and Browne (1968, p. 31) noted that real wages in Britain in 1960 were 4 to 4.5 times that in 1860 "at a time when the number of hands rose persistently....It has been a major task of our inquiry to find out how this came about".

rejected the use of least-squares regression analysis and who drew inferences from the close examination of various graphs and tables.[2]

I. CHANGES IN REAL WAGES AND CHANGES IN LABOUR PRODUCTIVITY

A micro-economic formulation that might be adaptable to empirical application at an aggregate level starts with the familiar first-order condition of the price-taking and wage-taking net revenue maximizing firm which sets its use of labour such that the marginal product of labour (MP_L) equals W^P, the ratio of the given money wage to the firm's product price or in logarithms $ln\, W^P = ln((MP_L)$. Because changes in natural logarithms are proportional differences and assuming changes in the marginal product of labour (something not directly observed) are proportional to changes in the average product of labour (denoted here by X) as with a Cobb-Douglas production function, this first-order condition may be expressed as an equation amenable to estimation with observations over time, namely,

(1) $$\Delta W^P_t = \kappa_1 + \alpha_1 \Delta X_t + \varepsilon_{1t}$$

where W^P_t is the real product wage in year t and ΔW^P_t is the per cent difference in real product wages between year t and the previous year. ΔX_t is the percent change from one year to the next in the average product of labour, output per worker-hour. ε_{1t} is a stochastic component in year t that incorporates errors in measuring real wages and the effects on ΔW^P_t of variables omitted from the equation. Equation (1) implies that, in the absence of random shocks, changes in labour productivity are sufficient to track changes in real product wages. In equation (1), both ΔW^P and ΔX_t are

[2] One reason they offer for not using regression analysis is that some variables are difficult to quantify (examples they give of such variables are "a change of government, a big strike and a war" (p.33)). A second reason offered is that, in time series, many variables move together and it becomes difficult to select the key associations.

variables measured as proportional rates of change so that α_1 may be interpreted as the elasticity of real product wages with respect to productivity. α_1 is expected to be positive; some go beyond this and expect α_1 to be unity in which case a given increase in labour productivity is associated with the same increase in real product wages.

However, Phelps Brown and Browne did not link labour productivity to real product wages but to real consumption wages W^C_t , that is, nominal wages deflated by the price of the products that consumer-workers buy. The values of index numbers of W^P_t and W^C_t from 1893 to 2016 are shown in Figure 1 where the base for both index numbers is the year 1900 in which both W^P_t and W^C_t take the value of 100. It is apparent from this figure that the two real wages share similar movements (the correlation coefficient over these years between these two real wage series is 0.99). As they have the same numerator in these macroeconomic observations and differ only in their price deflator, this high correlation is unsurprising.

This paper is concerned with real wage changes and the correlation between ΔW^P_t and ΔW^C_t , the annual per cent changes in real product wages and the annual per cent changes in real consumption wages is much lower (at 0.762) though this may not be evident from Figure 2. Therefore, equation (2) is added to equation (1) to determine whether a link exists between changes in labor productivity and changes in real consumption wages :

$$(2) \qquad \Delta W^C_t = \kappa_2 + \alpha_2 \Delta X_t + \varepsilon_{2t}$$

with α_2 interpreted as the elasticity of real consumption wages with respect to labor productivity. The estimate of α_2 in equation (2) will be compared with α_1 in equation (1) to determine whether inferences from changes in one real wage hold also for the other. Observations on real product wages, real consumption wages, and labor productivity from 1893 to 2016 are drawn from the Bank of England's"A Millennium of Macroeconomic Data" [3] maintained by Ryland Thomas.

Annual values of output per worker-hour from 1893 to 2016 are graphed in Figure 3 and its similarity with the graph of real wages in Figure 1 is evident: productivity and real wages rise gradually from the late 19th century, their growth accelerates after 1940, and then decelerates around the end of the 20th century. Annual per cent changes in labour productivity are shown in Figure 4 and these tend to be more volatile before the Second World War as are real wage changes in Figure 2.

Descriptive statistics of the observations on real wages and labour productivity between 1893 and 2916 are contained in Table 1 and least-squares estimates of equations (1) and (2) are shown in Table 2 labelled as equations (1a) and (2a) . These estimates are consistent with the hypothesis that increases in labor productivity are positively associated with increases in real wages - both real product wages and real consumption wages. Thus, according to equations (1a) and (2a) in Table 2, the elasticity of real product wages with respect to labor productivity is 0.45 while the elasticity of real consumption wages with respect to productivity is 0.34, both less than unity.

Because least-squares estimates tend to be sensitive to outlying values of variables, equations (1) and (2) were estimated with a slightly smaller number of years: years in which ΔW^P, ΔW^C_t and ΔX_t registered their maximum and minimum values (these years are 1920, 1922, 1940,and 1971)

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[3] Available at https://bankofengland.co.uk/statistics/research-datasets The numerator of both W^P_t and W^C_t is an average weekly earnings series built on Charles Feinstein's (1990) earnings estimates from 1880 to 1913 that covered manual workers principally. The contemporary series is the AWE (Whole Economy Total Pay from the Office of National Statistics). This nominal earnings series is divided by a GDP deflator at factor cost to arrive at W^P_t and is deflated by a consumer price index to arrive at W^C_t. X_t is labour productivity per worker-hour and the index is set to 100 in 2013. Between 1893 and 2016, the consumer price index rose slightly less than the GDP deflator at factor cost so W^C_t rose slightly more than W^P_t as evident in Figure 1.

were deleted from the set of observations and equations (1) and (2) were estimated to this trimmed set of observations. The consequences are shown in equations (1b) and (2b) of Table 2. These equations are little different from equations (1a) and (2a).

Although, of course, labour productivity is much higher today than in 1893, this does not mean that ΔX_t was positive in every year. Indeed, between 1893 and 2016, there are 20 years in which ΔX_t is not positive. Equations (1a) and (2a) imply that, in these years, real wages should be non-positive. In fact, of these 20 years, ΔW^P_t was not positive in 13 years (including 5 years when ΔW^P_t was zero) and ΔW^C_t was not positive in 14 years (in none of these years was ΔW^C_t zero). Would the description of real wage movements be improved if these 20 years of non-positive values of ΔX_t were distinguished from the years when ΔX_t was positive?

To address this question, the observations were divided into two groups: one group consists of the 20 years when $\Delta X_t \leq 0$ and the other group consists of the 104 years in which $\Delta X_t > 0$; equations (1) and (2) are fitted to each group separately. The least-squares estimates of equations (1) and (2) fitted to the 20 years in which $\Delta X_t \leq 0$ are given by equations (1c) and (2c) in Table 2 while the corresponding estimates for the 104 years in which $\Delta X_t > 0$ are given by equations (1d) and (2d). Equations (1d) and (2d) are not very different from those fitted to the entire set of 124 observations In all the equations in Table 2, the point estimate of the elasticity of real product wages with respect to productivity is larger than the corresponding estimate of the elasticity of consumption wages with respect to productivity.

Variations in labor productivity remove more of the observed variation in real product wages than of real consumption wages. However, in all the equations estimated, changes in labor productivity account for only a relatively small fraction of the observed variation in real wage changes.

II. EXTENDING THE ANALYSIS TO OTHER EXPLANATORY VARIABLES

A rationale for the empirical work in the previous section rests on the micro-economic model of the price-taking and wage-taking net revenue maximizing firm which sets its use of labour such that the marginal product of labour (MP_L) is equal to the real product wage W^P. There is now considerable evidence from Manning (2003) and others to suggest that many firms are not wage-takers but are monopsonists. This has consequences for the specification of the estimating equations here. In particular, the first-order profit-maximization condition for the monopsonistic firm in its labour market is no longer $W^P = MP_L$ but $W^P = (1 + \eta)^{-1} MP_L$ where η is the elasticity of labour supply with respect to wages that the monopsonist faces. If $\eta > 0$, $W^P < MP_L$. and factors affecting the supply elasticity intrude between real wages and the marginal product of labour. Expressing this amended first-order condition in logarithms and taking first differences over time results in

$$\Delta W^P_t = \Delta MP_{L\,t} - \Delta(1 + \eta)_t$$

where Δ denotes the per cent change in year t from the previous year. Variables that alter the wage elasticity of labor supply stand between proportional changes in real product wages and proportional changes in productivity; changes in labour productivity alone are no longer sufficient to account for movements in real wages. What are the variables that affect the wage-elasticity of the supply of labour to a wage-setting monopsonist?

An initial step would be to allow the labour supply elasticity to have a trend and to move with cycles in economic activity. An indicator of these cycles is the per cent annual change in total employment, ΔE_t; this will tend to be positive in an expansion and negative in a contraction.

In addition, a natural supply-side variable relevant to wages is the bargaining power of trade unions. Of course, trade unions have been very concerned with real wages: increases in consumer prices that reduce the value of nominal wages have been an impetus for unions to agitate for higher money wages. Higher nominal wages is the means to the principal objective: higher real wages.

The ability of trade unions in Britain to affect workers' wages has been demonstrated in the many cross-section studies in which proportional differences in wages at a given time have been related to differences in trade union density and other variables which are interpreted sometimes as differences in productivity. The observations in these studies may be workplaces (as in Blanchflower (1984) or may be individual workers (as, for example, in Stewart (1983)). The observations my be from recent years or from the nineteenth century (as in Hatton *et al.* (1994), but in all cases workers whose wages are covered by agreements covered by trade union negotiations have enjoyed a premium. Therefore, consider whether indicators of trade union bargaining power and other supply-side variables are associated with changes in real wages.

In his *History of British Trade Unions* Clegg (1994, p. 410) tentatively concluded that "the most appropriate measure of union strength [is] union density - the proportion of potential members who have been recruited into the unions". Others (Hines (1964) and Lewis (1963, pp.212-3)) have proposed that the bargaining effectiveness of unions rises when they are growing. Here, as a measure of trade union bargaining power, these two hypotheses are combined into one, the annual percentage change in trade union density expressed as ΔD_t where density is defined as trade union membership as a percent of total employment.[4] Descriptive statistics of D_t and ΔD_t (and of E_t and ΔE_t) are reported in Table 3 and annual values of trade union density and of per cent changes in trade union

[4] From1892 to 2014, trade union membership is based on administrative data from the Registrar of Friendly Societies. For 2015 and 2016 these are spliced with trade union membership among all in employment from the LFS (ONS).

density from 1893 to 2016 are drawn in Figures 5 and 6 respectively. As shown in Figure 5, there were two periods of growth in union density (from 1893 to 1920 and from 1934 to 1979) and two periods of retrenchment (the years from1926 to 1933 and from1980 to the present).

Note that union density D_t is a measure of the minimum coverage of union-negotiated wages - "minimum" because other wage-setting institutions such as Wages Councils and government agencies used union-negotiated wages as a guide or reference for their own decisions. In this way, in 1939, when union membership was 6.2 million workers, Clegg (1994, p.415) estimates the number covered by collective bargaining agreements was 12.5 million. In other words, twice the number of union members had their wages covered by collective bargained agreements.

Also, when unionism was spreading, some non-union employers chose to discourage their workers from unionising by paying them wages that unionised employers had negotiated in collective bargaining with unions. Hence a monopsony-inspired description of the growth in real product wages in Britain has the following form:

$$(3) \qquad \Delta W^P_t = \kappa_3 + \beta_1 \Delta X_t + \beta_2 \Delta D_t + \beta_3 \Delta E_t + \beta_4 T_t + \varepsilon_{3t}$$

where ΔD_t is the annual per cent change in trade union density, ΔE_t is the annual per cent change in employment, T_t is a linear time trend, and ε_{4t} is a stochastic term accounting for errors in measuring real wage changes and the effects on real product wage changes of omitted variables. The corresponding monopsony-based real consumption wage change equation is

$$(4) \qquad \Delta W^C_t = \kappa_4 + \delta_1 \Delta X_t + \delta_2 \Delta D_t + \delta_3 \Delta E_t + \delta_4 T_t + \varepsilon_{4t}$$

Equations (3) and (4) do not deny the relevance for real wage changes of changes in labor productivity, but they do propose that changes in labor productivity are not a sufficient explanation for real wage movements. β_1 and δ_1 are partial elasticities of real wages with respect to labor productivity while β_2 and δ_2 are partial elasticities of real wages with respect to trade union density. Least-squares estimates of equations (3) and (4) fitted to the years from 1893 to 2016 are given by equations (3a) and (4a) respectively in Table 4. In these equations the partial elasticities of real wages with respect to productivity are 0.488 for real product wages and 0.369 for real consumption wages while the partial elasticity of real wages with respect to trade union density are between 0.048 and 0.071 for real product and real consumption wages respectively.

To this point, all of the relationships have been fitted using all the years from 1893 to 2016. Consider now whether there are differences across sub-periods. Divide the entire period into three non-overlapping sub-periods of approximately 41 years each: from 1893 to 1938; from 1939 to 1979; and from 1980 to 2016. [5] Per cent compound annual growth rates of real wages, productivity, trade union density and employment variables in each of these three sub-periods are presented in Table 5. Note that, of these three sub-periods, the years when productivity grew the most (from 1939 to 1979) were also the years when real wages grew the most. Also the sub-period in which productivity grew the least (from 1893 to 1938) was also the period during which real wages grew the least. The decline in trade union density in the years from 1980 to 2016 was almost the same as the increase in union density from 1893 to 1938.

The least-squares estimates of equations (3) and (4) fitted to the sub-periods are also reported in Table 4. The positive association between changes in real wages and changes in labour productivity holds in all periods. The elasticity of real wages with respect to productivity is largest in the years from 1939 to 1979. The elasticity of real wages with respect to union density is also

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[5] Phelps Brown and Browne (1968) also divided their years from 1860 to 1960 into three sub-periods.

positive in all periods although its magnitude is smaller than that of productivity.

Consider whether the estimates for these sub-periods allow pooling the observations across sub-periods. First consider the null hypothesis of no difference in the structures between those fitted to the 1893-1938 years and those fitted to the 1939-1979 years. Applying conventional F tests, this hypothesis cannot be rejected for the real consumption wage equations but it is rejected for the real product wage equations. The resulting equations fitted for the 1893-1979 years are shown in equations (3e) and (4e) in Table 4.

Now consider whether the structures fitted to the 1980-2016 years reveal a sufficiently similar structure to those fitted to the 1893-1979 years that they may be combined to form the 1893-2016 structures. Again the answer differs according to which of the two real wages are examined: the null hypothesis of no significant difference between the two periods cannot be rejected for the real product wage but it can be rejected for the real consumption wage equations. In other words, the 1980-2016 years were distinct for consumption wages, the dimension of real wages that matter to workers and their agents, trade unions.

To this point, the estimating equations have treated trade union density as something that is exogenous to labour market outcomes, but of course trade unions respond to and are affected by their economic and social environment. For this reason, in analysing the activities of unions, scholars have employed methods that recognise this inter-relation. For instance, among time-series studies of unionism, Ashenfelter *et al.*(1972) and Hines (1964), have found that changes in trade union membership are associated with changes in retail prices ΔP_t and the unemployment rate (U_t). To pursue this line of analysis, determine whether movements in ΔD_t are related to other labour market variables by estimating equation (5) below:

(5) $$\Delta D_t = \gamma_0 + \gamma_1 U_t + \gamma_2 \Delta P_t + \gamma_3 \Delta E_t + \gamma_4 T_t + \varepsilon_{5t}$$

where controls for changes in employment (ΔE_t) and a linear time trend are included in addition to consumer price changes and the unemployment rate. As a description of movements in British trade union density over time, this specification omits the effects of statutory legislation and of judicial decisions (such as the Taff Vale decision). This is unfortunate, but this class of issues warrants further attention. Notwithstanding the Trade Disputes Act of 1906, the Trade Boards Act of 1909, the Trade Disputes and Trade Unions Act of 1927, and its repeal in 1946, it was once routine to maintain that the legal framework of unionism in Britain was distinctive by its absence and this absence was lamented by the Donovan Commission in the 1960s. Since then, the extent of labour market and trade union legislation has been remarkable, some of it devised by governments ostensibly committed to *laissez faire* in markets. Quantifying and discriminating among the effects of these many statutes is a task for a separate research programme.

As it is, estimates of equation (5) will be used to make changes in trade union density endogenous to the growth of real wages. The least-squares estimates of equation (5) are given in Table 6. These estimates suggest that union density contracted when unemployment rose as it did in the Great Depression and the depreciation of workers' real wages effected by increases in retail prices resulted in increases in trade union membership that, as shown above, led to offsetting increases in wages and subsequent rises in real wages. Changes in employment had mixed effects on union density: the first-order effect of increases in employment is to reduce density in so far as increases in employment are in the non-union sector. Approximately one-third of the annual variation in ΔD_t is removed by the linear combination of right-hand side variables of equation (5).

The estimates of equation (5) are now used in re-estimating equations (3) and (4) and these are reported in Table 7. The effects of increases in union density on real wages tend to be higher in Table 7 than in the corresponding estimates in Table 4 although this is not always the case. The estimates of the elasticity of real wages with respect to labour productivity in Table 7 are similar to those on Table 4.

IV. SUMMARY AND CONCLUSION

This reconsideration of Phelps Brown and Browne's claim that "the increase in real wages depended mainly on that of productivity" has found support for it. They added "we cannot treat the rise in real wages as effectively dependent upon productivity alone" (1968, p.170) and they recognised a "number of instances of wage changes that were not to be expected from the market forces of the time but were explicable by the current strength or weakness of the unions" (p.104) Their conclusion is consistent with the analysis here that covers a different period and that uses different methods.

In understanding the increases in real wages since the end of the 19th century, the simultaneous relevance of increases in labour productivity and trade union pressure is consistent with a rent-sharing interpretation of the labour exchange. That is, an organization whose labour productivity rises is one that can produce and sell more output with the same labour inputs. Who enjoys the higher incomes that flow from this and other increases in productivity and sales?

Insofar as the owners of the capital and these owners' agents are the exclusive residual claimants, they enjoy these higher incomes. As agents of the rank-and-file workers, trade unions have agitated for a portion of these higher incomes. When unions are growing, they are more likely to be successful in their attempts to claim a portion of higher organizational incomes; when union membership is falling, the income gains from higher productivity pass to the owners and to the owners' agents. This process has been demonstrated in other research (such as that of Van Reenen (1996), and Blanchflower, Oswald, and Sanfey (1996)) and it has been shown here that this process is evident in the course of British workers real wages since the end of the nineteenth century. It confirms Alfred Marshall's observation (1920, pp. 520-521) that "in some cases and for some purposes, nearly the whole income of a business may be regarded as a .....composite quasi-rent divisible among the different persons in the business by bargaining supplemented by custom and by notions of fairness........there is *de facto* some sort of profit-and-loss sharing between almost every business and its employees".

At the same time, changes in labour productivity and movements in trade union bargaining power do not remove more than half the variation in real wage changes. There remains more to be learned about why British workers' real wages at the beginning of the 21st century were six times those at the end of the 19th century.

Note also, the findings with respect to movements in real product wages are not the same as those corresponding to movements in real consumption wages. This is shown by the summary of the estimates of the elasticities of real wages with respect to productivity $\mathscr{E}(W,X)$ and the elasticities of real wages with respect to trade union density $\mathscr{E}(W,D)$ in Table 8. In this table, for almost all of the pairs of estimates of $\mathscr{E}(W,X)$, the elasticity of real wages with respect to productivity is higher with changes in W^P as the dependent variable than those with changes in W^C as the dependent variable. This is to be expected insofar as W^P is the concept of real wages more pertinent to cost-conscious employers.

By contrast, for most of the estimates of $\mathscr{E}(W,D)$, the elasticity of real wages with respect to union density are higher when changes in W^C are the dependent variable than when changes in

W^P are the dependent variable. Again, this is to be expected as W^C is the concept of real wages more relevant to workers and trade unions. Also, the ΔW^C equations and the ΔW^P equations differ in their ability to pool the estimated structures across the years. In ten of the fourteen real wage specifications reported in this paper, the fitted equation removes more of the variation in real product wage changes than in real consumption wage changes. One should not assume that movements describing variations in one real wage will also hold for variations in the other real wage. For instance, using the language of Meloni and Stirati (2023), in the years from 1980 to 2016, a "decoupling" between real wages and labour productivity may be evident when changes in real consumption wages are the dependent variable, but not when changes in real product wages are the dependent variable.

With respect to trade unions, it was written above that higher nominal wages are the means to the principal objective: higher real wages. If trade unions contributed to higher real wages, they must have also contributed to higher nominal wages. Indeed, there is evidence to this effect. Define ΔW^N_t as the per cent change in nominal weekly earnings in year t, ΔD_t as the per cent change in trade union density, and U_t as the unemployment rate in year t, then the least-squares estimates of changes in nominal wages on changes in union density and unemployment between 1893 and 2016 are

$$\underset{}{\Delta W^N_t} = \underset{(1.201)}{8.661} + \underset{(0.110)}{0.283}\,\Delta D_t - \underset{(0.183)}{0.598}\,U_t$$

Increases in union density induced increases in nominal wages which resulted in increases in real wages. In this way, when they were growing, trade unions were a critical element , in addition to increases in labour productivity, in labour market outcomes.

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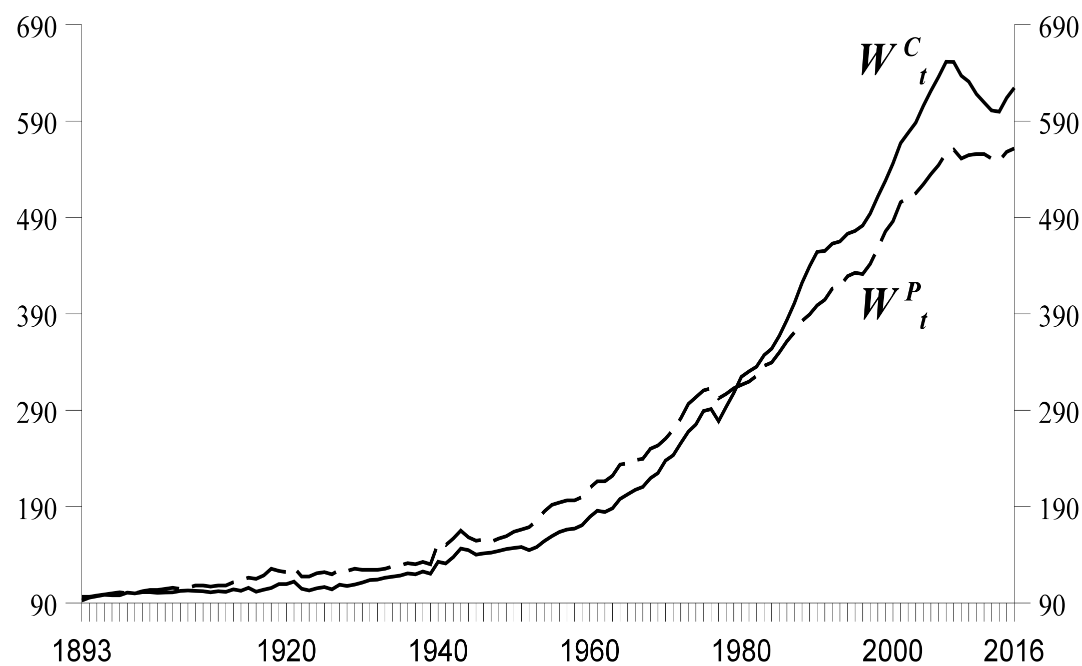
FIGURES

Figure 1

Values of Index Numbers of Two Real Wages from 1893 to 2016

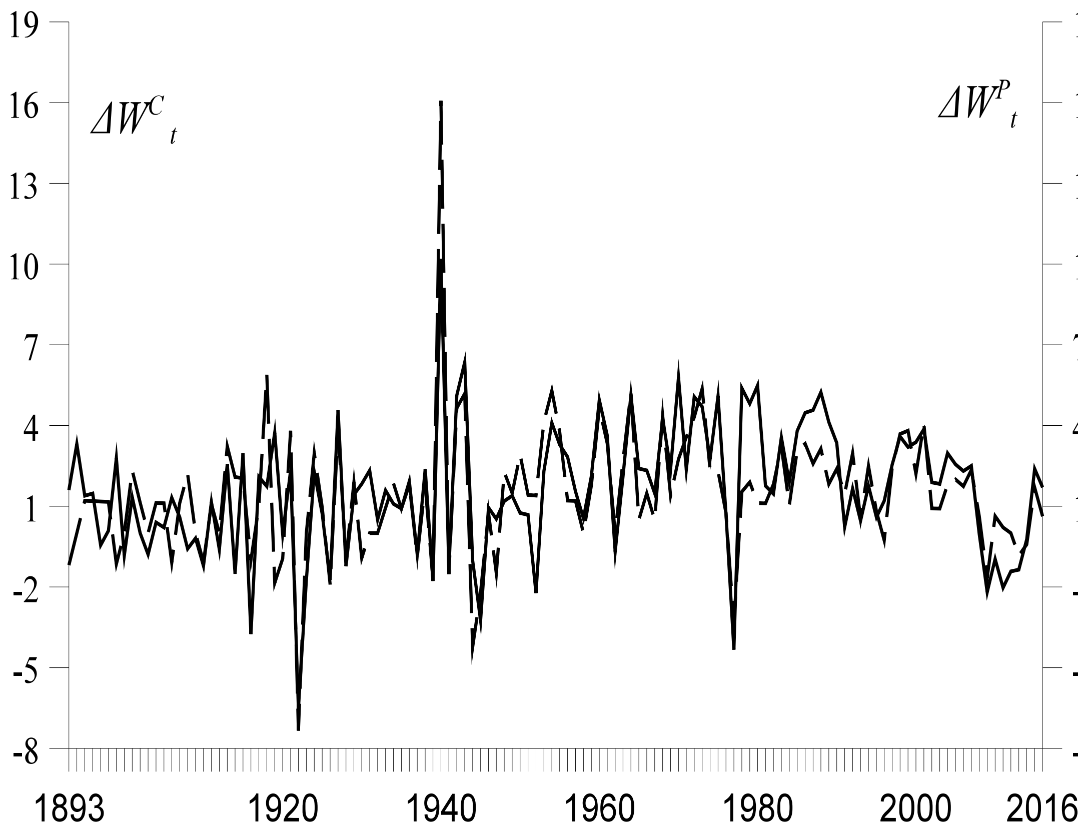


The consumption wage W^{C}_{t} is the solid series in the figure and the product wage W^{P}_{t} is the dashed series. Both series assume the value of 100 in 1900. As reported in Table 1, the maximum value of W^{C}_{t} was registered in 2007 and the maximum value of W^{P}_{t} was registered in 2016. The minimum values were recorded in 1893 for both W^{P}_{t} and for W^{C}_{t}. The correlation coefficient between annual values of W^{C}_{t} and W^{P}_{t} from 1893 and 2016 is 0.99.

Figure 2

Annual Per Cent Changes in Real Consumption Wages $\Delta W^{C}{}_{t}$ and in Real Product Wages $\Delta W^{P}{}_{t}$

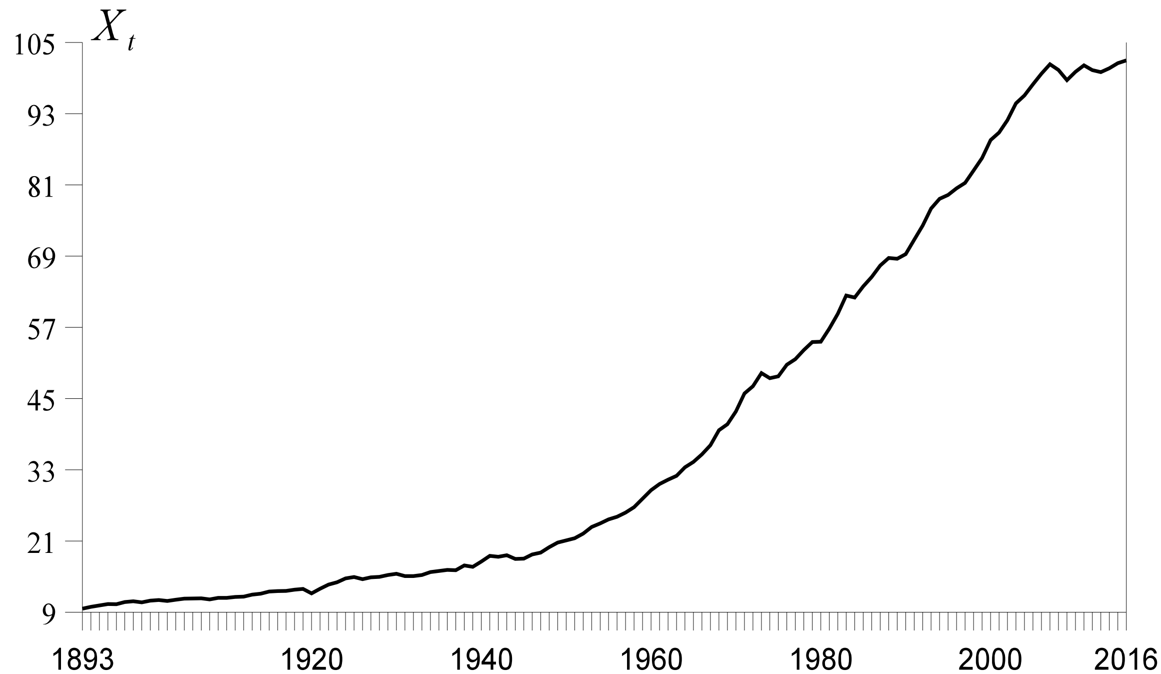
from 1893 to 2016



Insofar as they can be distinguished, annual per cent changes in the consumption wage, $\Delta W^{C}{}_{t}$ is the solid series in this figure and annual per cent changes in the product wage $\Delta W^{P}{}_{t}$ is the dashed series. The correlation coefficient between annual values of $\Delta W^{C}{}_{t}$ and $\Delta W^{P}{}_{t}$ is 0.76 .

Figure 3

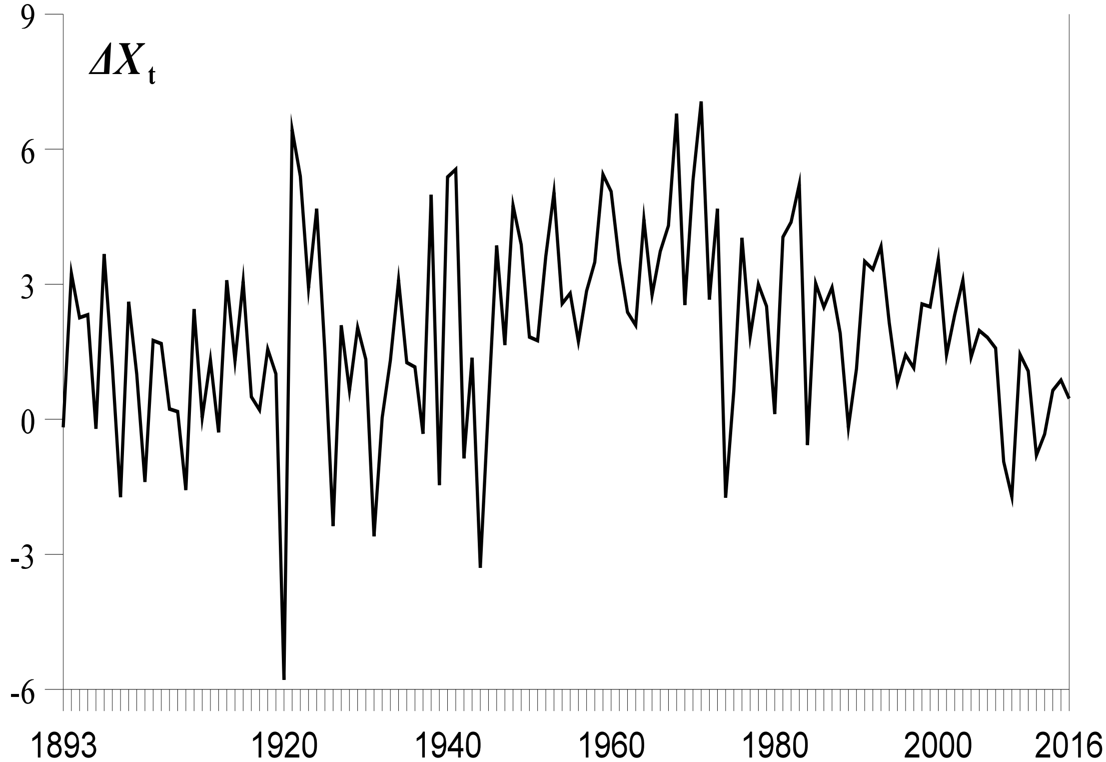
Annual Values of Labour Productivity from 1893 to 2016



The index of labour productivity, X_t, assumes the value of 100 in 2013. As reported in Table 1, the maximum value of X_t was registered in 2016 and the minimum value was recorded in 1893.

Figure 4

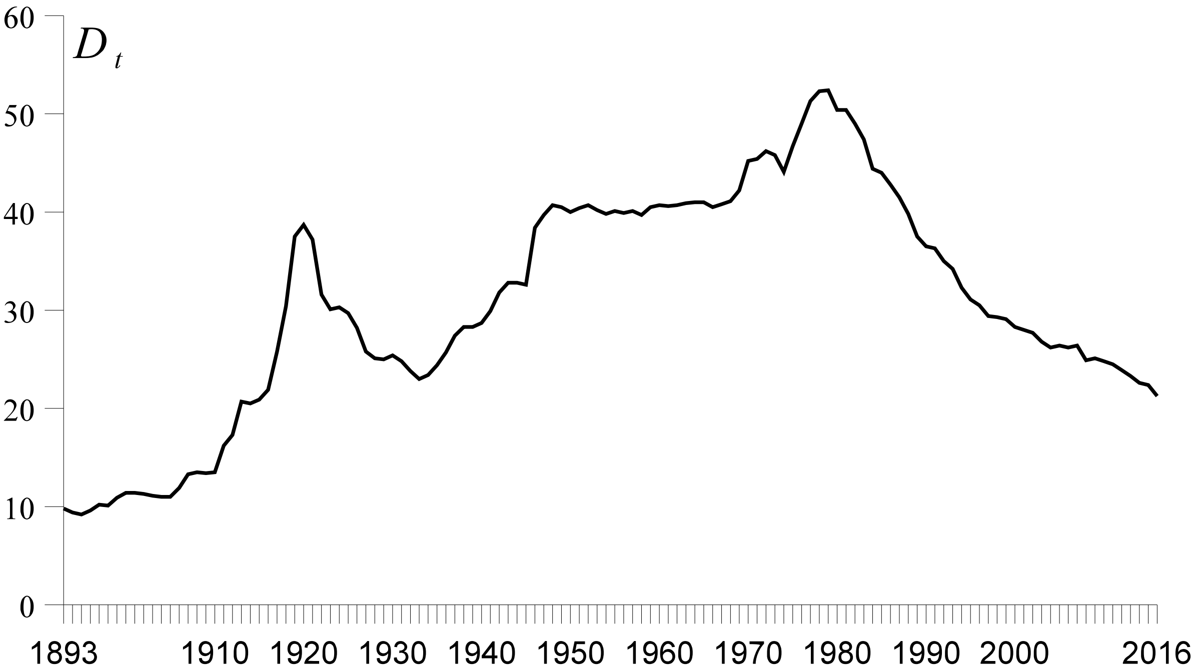
Annual Per Cent Changes in Labour Productivity from 1893 to 2016



As given in Table 1, the minimum value of ΔX_t was recorded in 1920 and the maximum in 1971.

Figure 5

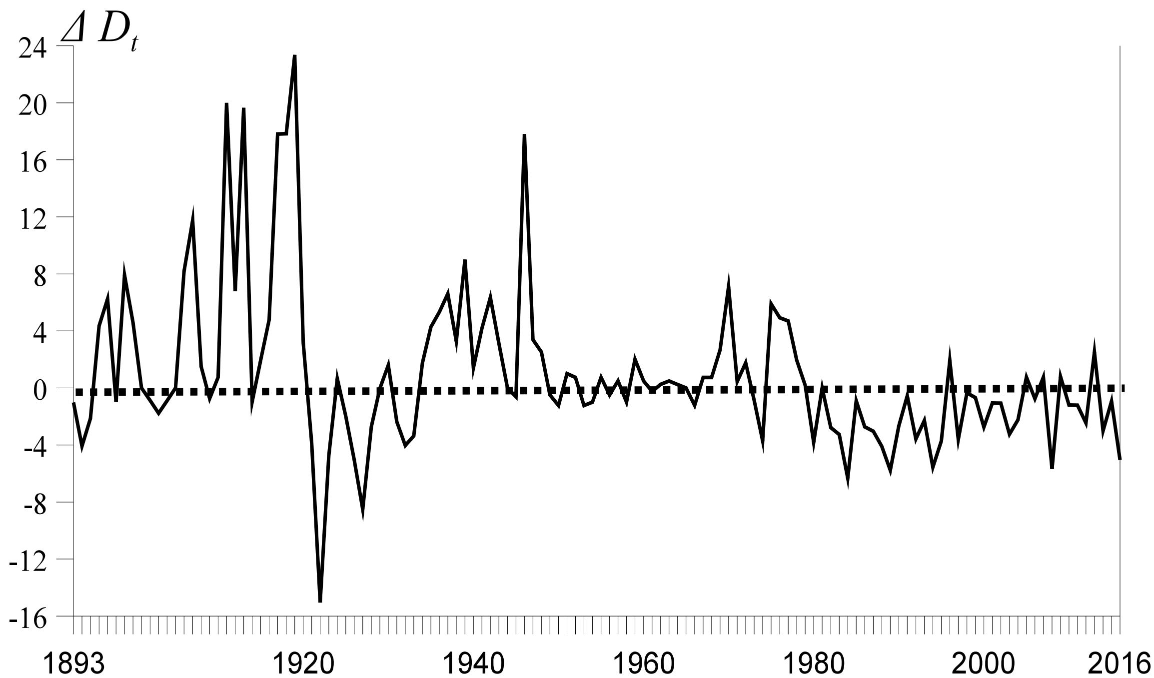
Trade Union Membership as a per cent of Employment, D_t 1893-2016



The minimum value of D_t was in 1895 and its maximum in 1979.

Figure 6

Annual Per Cent Changes in Trade Union Density ΔD_t from 1893 to 2016



The minimum vale of ΔD_t was recorded in 1922 and its maximum value in 1919.

TABLES

Table 1

Descriptive Statistics on Real Wages and Labour Productivity and their annual per cent changes from 1893 to 2016 (124 annual observations)

	W^P_t	ΔW^P_t	W^C_t	ΔW^C_t	X_t	ΔX_t
mean μ	250.25	1.428	254.7	1.592	39.90	1.94
stan. dev. σ	153.6	2.422	183.4	2.399	31.33	2.157
minimum	96.512 [1893]	-7.34 [1922]	92.63 [1893]	-6.53 [1922]	9.6 [1893]	-5.79 [1920]
Q_L = 31st position	122.09	0	106.5	0.09	14.05	0.64
median *M*	188.37	1.208	156.7	1.681	24.32	1.875
Q_U = 93rd position	361.6	2.5	383.6	2.97	65.49	3.33
maximum	561.63 [2016]	16.07 [1940]	651.62 [2007]	10.2 [1940]	101.98 [2016]	7.06 [1971]
range	465.118	23.41	558.9	16.73	92.38	12.85
σ / μ	0.614	1.696	0.720	1.507	0.785	1.153
QD/M	0.636	1.035	0.884	0.857	1.058	0.717
CAGR %	1.44		1.56		1.94	

W^P_t and W^C_t , the index of real product wages and the index of real consumption wages take the value of 100 in 1900. X_t , the index of labour productivity (GDP at factor cost per worker-hour) takes the value of 100 in 2013. σ / μ is the coefficient of variation, that is, the standard deviation (σ) of a variable divided by the arithmetic mean (μ) of that variable. When arranging the values of a variable in ascending order of magnitude, Q_L is the value at the lower quartile or 25th percentile and Q_U is the value at the upper quartile or 75th percentile. *QD/M* is the quartile deviation divided by the median value where the quartile deviation (*QD*) is ½ (Q_U - Q_L). The years in which the minimum and maximum values of a variable were observed are entered in square brackets beneath their values. *CAGR* % is the Compound Annual Growth Rate in per cent from 1893 to 2016.

Table 2

Wages and Labour Productivity: Least-Squares Estimates of the Real Wage Equations (1) and (2) fitted to the years from 1893 to 2016.

equation ⇓	dependent variable	estimated coefficients (and estimated standard errors) on......................				
		intercept	ΔX_t	R^2	*D-W*	nobs
(1a)	ΔW^P_t	0.558 (0.270)	0.449 (0.093)	0.160	2.12	124
(2a)	ΔW^C_t	0.925 (0.277)	0.344 (0.096)	0.096	1.66	124
(1b)	ΔW^P_t	0.528 (0.212)	0.448 (0.077)	0.221		120
(2b)	ΔW^C_t	0.859 (0.261)	0.387 (0.095)	0.122		120
(1c)	ΔW^P_t	0.729 (0.603)	0.500 (0.311)	0.126		20
(2c)	ΔW^C_t	0.541 (0.684)	0.233 (0.352)	0.024		20
(1d)	ΔW^P_t	0.476 (0.429)	0.472 (0.141)	0.099		104
(2d)	ΔW^C_t	1.107 (0.435)	0.290 (0.143)	0.039		104

Estimated standard errors are in parentheses beneath their estimated coefficients. *D-W* is the Durbin-Watson statistic, not calculated for equations in which some years are omitted. "nobs" is the number of observations used to estimate the equation. Equations (1b) and (2b) are estimated with data trimmed by the deletion of four years (1920, 1922, 1940 and 1971) . Equations (1c) and (2c) are fitted to the 20 observations where $\Delta X_t \leq 0$. Equations (1d) and (2d) are fitted to the 104 observations where $\Delta X_t > 0$.

Table 3

Descriptive Statistics on trade union density D_t, annual per cent change in trade union density ΔD_t, total employment E_t, and annual per cent change in total employment ΔE_t in the years from 1893 to 2016 (124 annual observations).

	D_t	ΔD_t	E_t,	ΔE_t
mean μ	30.7	0.805	22,915	0.626
stan. dev. σ	11.54	5.545	4,141.9	1.858
minimum	9.2 [1895]	-15.05 [1922]	14,987.4 [1893]	-11.77 [1921]
Q_L = 31st position	23.8	-2.286	19,057	0.064
median *M*	30.0	-0.143	24,142	0.886
Q_U = 93rd position	40.5	2.015	25,239	1.488
maximum	52.4 [1979]	23.36 [1919]	31,741 [2016]	4.118 [1939]
range	43.2	38.41	16,753.6	15.89
σ / μ	0.376	6.627	0.181	2.97
QD/M	0.278	107.5	0.128	0.804
CAGR %	0.63		0.61	

D_t is trade union density, the membership of trade unions as a per cent of total employment. ΔD_t is the annual per cent change in D_t. E_t, is total employment in thousands, and ΔE_t is the annual per cent change in E_t. The years in which the minimum and maximum values of a variable are observed are entered in square brackets beneath their values. See the notes to Table 1 for definitions of σ / μ , *QD/M* and *CAGR* % .

Table 4

Wages, Productivity and Trade Unionism; Least-Squares Estimates of Equations (3) and (4)

years	equation	dependent variable	intercept	estimated coefficients (and estimated standard errors) ΔX_t	ΔD_t	ΔE_t	T_t	R^2	$D\text{-}W$
1893-2016	(3a)	ΔW^P_t	-0.327 (0.462)	0.488 (0.094)	0.048 (0.037)	0.259 (0.109)	0.009 (0.006)	0.218	2.34
	(4a)	ΔW^C_t	-0.308 (0.468)	0.369 (0.095)	0.071 (0.038)	0.228 (0.110)	0.016 (0.006)	0.179	1.76
1893-1938	(3b)	ΔW^P_t	0.075 (0.638)	0.245 (0.137)	0.081 (0.039)	-0.053 (0.129)	0.004 (0.022)	0.145	2.49
	(4b)	ΔW^C_t	0.052 (0.613)	0.189 (0.131)	0.102 (0.037)	-0.065 (0.124)	0.007 (0.021)	0.178	2.07
1939-1979	(3c)	ΔW^P_t	0.572 (2.769)	0.661 (0.208)	0.007 (0.143)	0.752 (0.305)	-0.010 (0.040)	0.311	2.78
	(4c)	ΔW^C_t	-3.063 (2.591)	0.316 (0.195)	0.128 (0.134)	0.686 (0.286)	0.059 (0.038)	0.218	2.40
1980-2016	(3d)	ΔW^P_t	5.123 (2.445)	0.456 (0.134)	0.037 (0.099)	0.427 (0.142)	-0.042 (0.021)	0.485	2.09
	(4d)	ΔW^C_t	13.585 (3.070)	0.332 (0.168)	0.081 (0.125)	0.844 (0.178)	-0.119 (0.026)	0.620	1.33
1893-1979	(3e)	ΔW^P_t	-0.454 (0.591)	0.456 (0.126)	0.056 (0.045)	0.242 (0.137)	0.014 (0.012)	0.206	2.40
	(4e)	ΔW^C_t	-0.650 (0.545)	0.275 (0.116)	0.089 (0.042)	0.157 (0.126)	0.028 (0.011)	0.211	2.14

Table 5

Compound Annual Growth Rates in Per Cent for five key variables during three sub-periods and for the entire period from 1893 to 2016

	1893-1938	1939-1979	1980-2016	1893-2016
W^P_t	0.708	2.215	1.61	1.44
W^C_t	0.626	2.373	1.83	1.56
X_t	1.263	3.011	1.75	1.94
D_t	2.385	1.552	-2.36	0.63
E_t	0.790	0.313	0.66	0.61
nobs	46	41	37	124

Table 6

Least-Squares Estimates of Equation (5)

$$\Delta D_t = \gamma_0 + \gamma_1 U_t + \gamma_2 \Delta P_t + \gamma_3 \Delta E_t + \gamma_4 T_t + \varepsilon_{5t}$$

		estimated coefficients (and estimated standard errors)						
years	equation	intercept	U_t	ΔP_t	ΔE_t	T_t	R^2	D-W
1893-2016	(5a)	5.051 (1.146)	-0.345 (0.140)	0.347 (0.081)	-0.217 (0.222)	-0.056 (0.012)	0.346	1.52
1893-1938	(5b)	4.885 (2.827)	-0.610 (0.522)	0.459 (0.216)	0.043 (0.099)	-0.138 (0.425)	0.392	1.70
1939-1979	(5c)	9.224 (3.349)	0.684 (0.501)	0.219 (0.111)	-1.130 (0.315)	-0.156 (0.062)	0.313	1.84
1980-2016	(5d)	-7.374 (6.628)	-0.113 (0.199)	-0.035 (0.153)	-0626 (0.266)	0.061 (0.049)	0.255	2.43
1893-1979	(5e)	5.428 (1.705)	-0.258 (0.199)	0.463 (0.107)	-0.343 (0.286)	-0.085 (0.024)	0.302	1.59

Table 7

Wages, Productivity and Trade Unionism; Instrumental Variable Estimates of Equations (3) & (4)

years	equation	dependent variable	intercept	ΔX_t	ΔD_t	ΔE_t	T_t	R^2	D-W
			estimated coefficients (and estimated standard errors)						
1893-2016	(3f)	$\Delta W^P{}_t$	-0.914 (0.515)	0.481 (0.092)	0.195 (0.072)	0.261 (0.106)	0.017 (0.007)	0.252	2.36
	(4f)	$\Delta W^C{}_t$	-0.588 (0.535)	0.362 (0.095)	0.142 (0.075)	0.229 (0.110)	0.019 (0.007)	0.180	1.85
1893-1938	(3g)	$\Delta W^P{}_t$	-0.178 (0.667)	0.281 (0.139)	0.143 (0.064)	-0.074 (0.129)	0.007 (0.002)	0.156	2.36
	(4g)	$\Delta W^C{}_t$	0.220 (0.694)	0.171 (0.144)	0.059 (0.067)	-0.048 (0.135)	0.005 (0.023)	0.046	2.21
1939-1979	(3h)	$\Delta W^P{}_t$	-0.624 (3.248)	0.677 (0.207)	0.219 (0.335)	0.933 (0.399)	0.001 (0.043)	0.319	2.75
	(4h)	$\Delta W^C{}_t$	-1.515 (3.086)	0.326 (0.197)	-0.148 (0.319)	0.452 (0.382)	0.043 (0.041)	0.202	2.49
1980-2016	(3i)	$\Delta W^P{}_t$	27.823 (10.13)	0.392 (0.125)	2.140 (0.919)	1.613 (0.531)	-0.218 (0.008)	0.558	2.23
	(4i)	$\Delta W^C{}_t$	64.352 (10.192)	0.187 (0.126)	4.785 (0.092)	3.498 (0.535)	-0.511 (0.079)	0.791	1.63
1893-1979	(3j)	$\Delta W^P{}_t$	-0.994 (0.623)	0.500 (0.124)	0.212 (0.088)	0.240 (0.133)	0.017 (0.011)	0.252	2.37
	(4j)	$\Delta W^C{}_t$	-0.689 (0.602)	0.283 (0.119)	0.098 (0.079)	0.158 (0.129)	0.028 (0.011)	0.183	2.21

Table 8

Summary of Estimates of the Elasticity of Real Wages with respect to Productivity $\mathcal{E}$ *(W,X)* and the Elasticity of Real Wages with respect to Trade Union Density $\mathcal{E}$ *(W,D)*

$\mathcal{E}$ (W,X)			$\mathcal{E}$ (W,D)		
equation	W^P	W^C	equation	W^P	W^C
(1a)/(2a)	0.449	0.344	(3a)/(4a)	0.048	0.071
(1b)/(2b)	0.448	0.387	(3b)/(4b)	0.081	0.102
(1c)/(2c)	0.500	0.233	(3c)/(4c)	0.007	0.128
(1d)/(2d)	0.472	0.290	(3d)/(4d)	0.037	0.081
(3a)/(4a)	0.488	0.369	(3e)/(4e)	0.056	0.089
(3b)/(4b)	0.245	0.189	(3f)/(4f)	0.195	0.142
(3c)/(4c)	0.661	0.316	(3g)/(4g)	0.143	0.059
(3d)/(4d)	0.456	0.332	(3h)/(4h)	0.219	-0.148
(3e)/(4e)	0.456	0.275	(3i)/(4i)	2.140	4.785
(3f)/(4f)	0.481	0.352	(3j)/(4j)	0.212	0.098
(3g)/(4g)	0.281	0.171			
(3h)/(4h)	0.677	0.326			
(3i)/(4i)	0.392	0.187			
(3j)/(4j)	0.500	0.283			
average	0.464	0.290	average	0.314	0.541