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DO RISING REAL WAGES INCREASE THE RATE OF LABOR-SAVING TECHNICAL CHANGE? SOME ECONOMETRIC EVIDENCE

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ABSTRACT

The long-run relationship between real wages and labor productivity is investigated using cointegration and Granger non-causality tests for the US economy over the period 1869–1999. The series are cointegrated, indicating that there is a link between real wages and labor productivity in the long run. Granger non-causality tests support unidirectional causation from real wages to labor productivity. This outcome corroborates the conception that increases in real wages drive profit-seeking capitalists to raise labor productivity as their main weapon in defending their profitability. This result is consistent with a long tradition among economists that perceives technical change as being biased toward labor-saving.

1. INTRODUCTION

The purpose of this paper is to study the empirical relationship between real wages and labor productivity. First, we investigate whether labor productivity increased at a similar rate to real wages, corresponding to constancy of the wage share. Kaldor (1961) called the constant wage share a stylized fact of economic growth. In this case, real wages and labor productivity are cointegrated and there is a long-run relationship between them. This hypothesis is tested looking at the US economy during the period 1869–1999.

Second, we investigate the causal linkages between real wages and labor productivity. This is the central aspect of the present study. The basic conception is that increases in real wages reduce profitability, inducing

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profit-seeking capitalists to invest in labor-saving technical changes in order to decrease the share of wages in total costs. In fact, the higher the increase in real wages, the higher the reward and the pressure on capitalists to search for and adopt new techniques with greater labor productivity. This view is consistent with a tradition among economists that perceives technical change as being biased toward labor-saving. The hypothesis is that changes in real wages precede the movements in labor productivity.

Granger non-causality tests (1969) are well suited for studying the causal relationship between real wages and labor productivity in this theoretical framework. Granger non-causality is defined in terms of the predictability of the time series; causality is tested in the sense of which variable—real wages or labor productivity—helps to forecast the other. Non-causality tests are performed for the USA over the period 1869–1999. Granger (1988) pointed out that, in the case of cointegration between a pair of series, there exists a long-run causality in at least one direction. The results show unidirectional Granger causality from real wages to labor productivity. This supports the conception that increases in real wages might drive profit-seeking capitalists to invest in labor-saving technical change to defend their profitability.

The paper is organized as follows: section 2 presents the theoretical basis, section 3 provides the results and an interpretation and section 4 offers a conclusion.

2. THEORETICAL BASIS

The theoretical basis in this paper follows a long tradition among economists that sees technical change in capitalist production taking a biased form in order to economize on the relatively expensive input. Hicks's observation (1932, pp. 124–5) that 'a change in the relative share of factors of production is itself a spur to innovation and inventions of a particular type—directed at economizing the use of a factor which has become relatively expensive' is perhaps the best-known expression of biased technical change.

Samuelson (1965, p. 354) pointed out that Hicks held a position similar to that of Marx in this regard. For both authors, innovations tend to be labor biased due to incentives to reduce the share of wages in total costs. Marx, for example (1979, pp. 121–2), considers the effects of 'the rise in England of agricultural wages from 1849 to 1859. What was its consequence? The farmers . . . during these eleven years introduced machinery of all sorts, adopted more scientific methods, converted part of arable land into pasture, increased the size of farms, and with this the scale of production, and by these and other processes diminishing the demand for labor by increasing its productive power. . . . Ricardo has justly remarked that machinery is in constant competition with labor, and can often be only introduced when the price of labor has reached a certain height.'

Duménil and Lévy (1995), following this tradition, develop a stochastic model of induced technical change that provides a labor-saving bias in technical innovation. In their model, a new technology is defined by the rates of labor-saving and capital-saving technical change that are generated by a random process. Firms search for new technologies in the vicinity of the technique already employed. The selection of new technologies is based on the profitability criterion, with only techniques yielding a profit rate higher than the present being adopted. The selection criterion defines a profitability frontier whose slope is the negative ratio between capital share and labor share. The profitability frontier confers a bias to technical change whenever the ratio between the factor shares is different from unity. If the labor share is larger than the capital share, then the savings in labor will tend to be larger than in capital. A rise in real wages also increases the labor share and the probability of the selected new technology being labor-saving.

In this framework, an increase in real wages intensifies the search for and adoption of labor-saving technical change. On the other hand, a decline in the growth rate of real wages reduces the incentives to search for and adopt technical innovation, causing a slowing in the growth rate of labor productivity. This conception is consistent, for example, with Gordon (1987, p. 729), who regards the shift from high to moderate real wage growth as responsible for a substantial proportion of the decline in productivity growth in non-manufacturing sectors in the USA after 1972 and in Japan and Europe after 1979.

In the Duménil and Lévy model, real wages affect the trajectory of technical change through the profit rate. An increase in real wages reduces profitability, driving profit-seeking capitalists to implement labor-saving technologies in order to reduce labor costs. This conception of technical change gives an independent and determinant role to real wages in the evolution of technical change. Increases in real wages induce a pattern of technical change that is labor-saving and probably capital-using. Moreover, changes in real wages anticipate the movements of labor productivity.

In this respect, analysis using cointegration and the Granger non-causality test is quite suitable for investigating the long-run relationship between real wages and labor productivity. A unit root test can be used to address the question of whether labor productivity and the real wage both follow a random walk. Cointegration asks if the two time series follow a similar random walk. If so, Granger non-causality can be used to rule out causes that do not precede effects, in this case whether a rise in labor productivity can be said to cause an increase in the real wage.

3. DATA AND EMPIRICAL RESULTS

In this section we investigate the existence of a long-run relationship and the direction of the Granger non-causality between real wages and labor productivity for the US economy over the period 1869–1999. These variables were obtained from Duménil and Lévy (1993) for 1869–1989 and extended to 1999, following the same methodology. The real wage is the total compensation per hour worked by an employee deflated by the gross national product (GNP) deflator. Labor productivity is the ratio between private GNP and total number of hours worked, deflated by the GNP deflator.

First, we test whether real wages and labor productivity are cointegrated. The cointegration tests in this paper follow the two-step procedure suggested by Engle and Granger (1987). This procedure is very appropriate for systems with only two variables and one possible cointegration vector (Hatanaka (1996, p. 200)).

The analysis is performed with the variables log-transformed and non-transformed to show the robustness of the results. The time-series plots of both series, both log-transformed and non-transformed, are presented in figure 1. The inspection of the two plots suggests the presence of basically the same trend in both series. Figure 2 plots the pair labor productivity and real wages, log-transformed (LLP, LW) and non-transformed (LP, *W*). Figure 3 presents the stochastic component of these pairs. The observation of the scatter plots indicates the existence of a stable and linear relationship

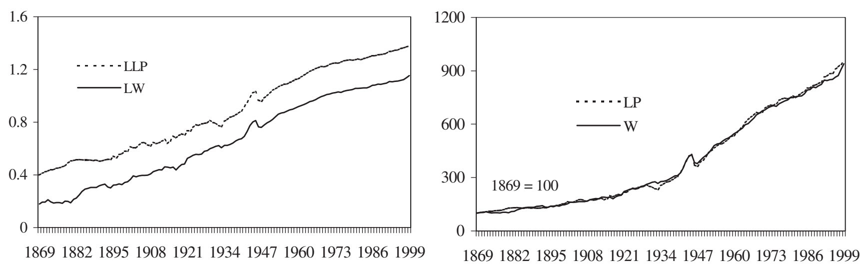

Figure 1. Time series plots of labor productivity and real wages—log-transformed (LLP, LW) and non-transformed (LP, W)—for the US economy, 1869–1996, show that the series have a very similar trend (Duménil and Lévy, 1993).

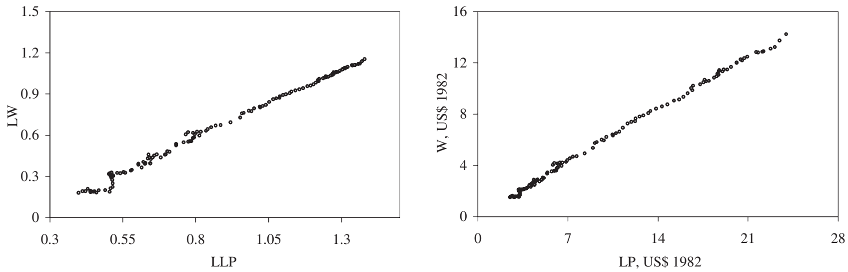

Figure 2. Plots of the pair labor productivity and real wages—log-transformed (LLP, LW) and non-transformed (LP, W)—for the US economy, 1869–1999, display a stable linear relationship between the variables (Duménil and Lévy, 1993).

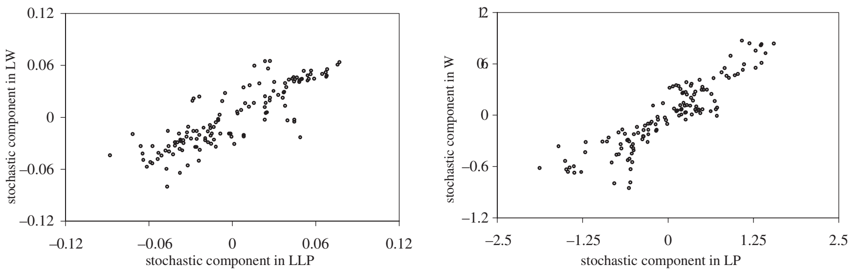

Figure 3. Plots of the stochastic component of the pair labor productivity and real wages—log-transformed (LLP, LW) and non-transformed (LP, W)—for the US economy, 1869–1996, display a linear relationship between the variables (Duménil and Lévy, 1993).

between real wages and labor productivity. The figures also suggest a possibility of cointegration between the series.

The variables are tested for stochastic trend using an augmented Dickey–Fuller (ADF) test. Phillips and Xiao (1998) present a review of the literature on unit root tests. Table 1 presents the unit root tests for both series, both log-transformed and non-transformed. The number of lag lengths p employed in the tests was chosen on the basis of the Akaike information criterion (AIC). This method tends to give parsimonious models with zero and one lags; hence tests with two lags in the ADF regressions are also presented. The tests also consider the hypothesis that the data-generating process follows either a drift model or a trend model. The hypotheses of a unit root for log-transformed real wages (LW) and labor productivity (LLP) and for non-transformed real wages (W) and labor productivity (LP) cannot be rejected at a 1 per cent significance level. The unit root tests therefore indicate that it is possible to apply cointegration tests to the data.

Table 1. Unit root tests for real wages and labor productivity for the US economy, 1869–1999

Test statistic for	*Variable*	*Constant, no trend ADF lags*			*Constant and trend ADF lags*		
		0 lag	*1 lag*	*2 lags*	*0 lag*	*1 lag*	*2 lags*
No unit root	LW	–0.003	0.01	–0.09	–2.06	–2.53	–2.46
	LLP	–0.04	–0.01	0.02	–1.92	–2.15	–2.11
	W	4.15	2.94	2.89	–1.01	–1.19	–1.19
	LP	3.81	2.82	2.92	–0.95	–1.1	–1.08
One unit root	ΔLW	–9.53*	–7.25*	–6.43*	–9.49*	–7.22*	–6.41*
	ΔLLP	–10.4*	–7.91*	–6.4*	–10.36*	–7.89*	–6.39*
	ΔW	–7.46*	–5.73*	–5.75*	–8.51*	–6.86*	–7.36*
	ΔLP	–8.3*	–6.66*	–5.58*	–9.26*	–7.78*	–6.85*

LW, log-transformed real wages; LLP, log-transformed labor productivity; *W*, non-transformed real wages; LP, non-transformed labor productivity. The ADF regression with constant α and time trend t is $\Delta y_t = \alpha + \beta t + \rho y_{t-1} + \Sigma_{j=1}^{p} \theta \Delta_j y_{t-1} + e_t$, where y is the variable of interest, e is a white noise term and $j = 1, \ldots, p$ are the ADF lags.
* Significant at 1 per cent.
Source: Duménil and Lévy (1993).

Further unreported tests showed that non-transformed labor productivity and non-transformed real wages show a deterministic trend with no drift, while log-transformed real wages show only a drift, and log-transformed labor productivity shows a drift and a deterministic trend. Thus, the following hypotheses cannot be rejected: non-transformed real wages follow a random walk about a nonlinear trend, log-transformed real wages follow a random walk about a linear trend; log-transformed and non-transformed labor productivity follow a random walk about a nonlinear trend.

The Engle and Granger approach for cointegration consists of two steps. The first step is to test whether the stochastic trends in the variables are connected. For the bivariate case the following equation is estimated:

$$y_t = \alpha + \beta x_t + e_t \tag{1}$$

where y_t and x_t are the variables of interest and e_t are the residuals. The second step is to test whether the estimated residuals are either stationary or unit root. If the estimated residuals are stationary, then the series are cointegrated.

Table 2 reports the results for the cointegration regressions with the series, both log-transformed and non-transformed. The first line presents the

Table 2. Cointegration tests between real wages and labor productivity for the US economy, 1869–1999

Dependent variable	Regressor	Coefficients		ADF tests for no unit root			
		Constant	Beta	No constant, no trend		Constant, no trend	
				1 lag	2 lags	1 lag	2 lags
LW	LLP	–0.228	1.007	–3.58**	–3.35***	–3.56**	–3.34***
		–0.006	–0.007				
LLP	LW	0.23	0.986	–3.58**	–3.35***	–3.57**	–3.34***
		–0.005	–0.006				
W	LP	0.093	0.591	–3.8**	–3.41***	–3.78**	–3.4***
		–0.029	–0.002				
LP	*W*	–0.135	1.689	–3.8**	–3.41***	–3.78**	–3.4***
		–0.049	–0.007				

LW, log-transformed real wages; LLP, log-transformed labor productivity; *W*, non-transformed real wages; LP, non-transformed labor productivity. Critical values for cointegration were obtained from Mackinnon (1991).
** Significant at 5 per cent.
*** Significant at 10 per cent.

cointegration regression and statistics when the logarithm of real wages is regressed on the logarithm of labor productivity; the second line shows the cointegration equation and statistics for the reverse regression. The third and fourth lines show the cointegration regressions normalized by labor productivity and real wages, respectively, and the statistics for the presence of a unit root in the residuals. Tests indicated the presence of serial correlation in the residuals. The ADF tests were done considering the non-intercept model and the drift model. The number of lags was determined by the AIC. The null hypothesis of a unit root in the estimated residuals is rejected in all the tests for the variables. Real wages and labor productivity in the US economy during the period 1869–1999 are therefore cointegrated for both log-transformed and non-transformed series. There is a long-run equilibrium relationship between these variables.

Moreover, the coefficients in the logarithm of labor productivity and in the logarithm of real wages indicate that there is a one-to-one relationship between the growth of these variables. The null hypothesis that the estimated coefficients for these variables are equal to 1 cannot be rejected at 5 per cent statistical significance. Real wages and labor productivity tended to grow at similar rates in the US economy in the period 1869–1999. This result is also consistent with Kaldor's (1961) stylized fact that wage share is constant in the long run.

In the presence of cointegration, the Granger non-causality test for the bivariate case based on the vector error correction model is defined as follows:

$$\Delta y_t = \alpha_0 + \alpha_y \hat{e}_{t-1} + \sum_{j=1}^{p} \alpha_{1j} \Delta y_{t-j} + \sum_{j=1}^{p} \alpha_{2j} \Delta x_{t-j} + \varepsilon_{yt} \quad (2)$$

$$\Delta x_t = \beta_0 + \beta_x \hat{e}_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta y_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta x_{t-j} + \varepsilon_{xt} \quad (3)$$

in which y_t and x_t represent real wages and labor productivity, $\hat{e}_t$ the residuals obtained in the cointegration regressions, and α_y and β_x the terms of adjustment to the long-run level of equilibrium (Hamilton (1994, p. 581)). Real wages do not Granger-cause labor productivity if the hypothesis H_0: $\alpha_{21} = \alpha_{22} = \ldots = \alpha_{2p} = 0$ and $\alpha_y = 0$ is not rejected. Similarly, labor productivity does not Granger-cause real wages if the hypothesis H_0: $\beta_{11} = \beta_{12} = \ldots = \beta_{1p} = 0$ and $\beta_x = 0$ is not rejected.[1]

Table 3 displays the non-causality Granger tests in the vector error correction model. The number of lags to perform the tests was selected by the AIC. Three lags were employed in the vector error correction model. Results for four lags are also presented since the AIC tends to give parsimonious models. We cannot reject the hypothesis that labor productivity does not Granger-cause real wages (both log-transformed and non-transformed); however, we can reject the hypothesis that real wages do not Granger-cause labor productivity (both log-transformed and non-transformed). There is therefore unidirectional Granger causality from real wages to labor productivity in the US economy between 1869 and 1999.

Real wages seem to lead the movements in labor productivity. This supports the conception that real wage pressure drives profit-seeking capitalists to increase labor productivity as a weapon to defend their profitability. In the US economy, there was a bias toward labor-saving in the search for and adoption of technical change induced by rises in real wages. This result is

[1] The tests of Granger non-causality in a vector error correction model have been subject to debate over the distribution of the Wald tests and the pre-testing bias. The increase in the dimension of the cointegration space might complicate the testing procedure, with the parameters assuming nonstandard limit distribution (Toda and Phillips (1993)). However, in the context of a bivariate system with one cointegration vector, the Wald statistics are free of nuisance parameters (Caporale and Pittis (1999, p. 22)). Toda and Yamamoto (1995) proposed an alternative method for testing Granger non-causality in a non-stationary vector autoregressive model for processes in which the variables might be cointegrated or not. This procedure reduces the problem of pre-testing bias.

Table 3. Granger non-causality tests between real wages and labor productivity for the US economy, 1869–1999

H_0	*Lag length*	*F value*
LW does not Granger-cause LLP	3	2.46**
	4	2.68**
LLP does not Granger-cause LW	3	1.01
	4	0.47
W does not Granger-cause LP	3	3.04**
	4	2.42**
LP does not Granger-cause *W*	3	2.36
	4	1.89

LW, log-transformed real wages; LLP, log-transformed labor productivity; *W*, non-transformed real wages; LP, non-transformed labor productivity.
** Significant at 5 per cent.

consistent with a long tradition among economists that sees technical change as being induced by incentives to reduce the cost of the high-priced inputs.

4. CONCLUSION

In this paper the long-run relationship between real wages and labor productivity is analyzed through cointegration and Granger non-causality tests for the US economy over the period 1869–1999. Real wages and labor productivity are cointegrated, both log-transformed and non-transformed. This result indicates that there is a link between real wages and labor productivity in the long run. Moreover, there is a one-to-one relationship in the growth rate of these variables. This is consistent with Kaldor's (1961) stylized fact that wage share is constant.

The causality tests between real wages and labor productivity indicate that real wages Granger-cause labor productivity and that labor productivity does not Granger-cause real wages. The unidirectional Granger causality shows that real wages lead the movements of labor productivity. This result supports the conception that increases in real wages pressure profit-seeking capitalists to raise labor productivity in order to defend their profitability.

This outcome is also consistent with a long tradition among economists that perceives technical change as following a pattern induced by the relative factor price. In this conception, technical change has a labor-saving bias due to the large share of wages in total costs. Additional increases in labor costs raise the incentives to search for and adopt labor-saving technical change. On the other hand, a reduction in labor costs would cause a slow down in the growth rate of labor productivity. If the relative price factor influences the searching for and adoption of technical change, then a theory of endogenous technical change could be built on this basis. Thus, empirical and theoretical studies are necessary in order to further develop the theory of induced technical change.

REFERENCES

Caporale G., Pittis N. (1999): 'Efficient estimation of cointegration vectors and testing for causality in vector autoregressions', *Journal of Economic Surveys*, 13, pp. 1–35.

Duménil G., Lévy D. (1993): *The Economics of the Profit Rate*, Edward Elgar, Aldershot.

Duménil G., Lévy D. (1995): 'A stochastic model of technical change: an application to the U.S. economy', *Metroeconomica*, 46, pp. 213–45.

Engle R., Granger C. (1987): 'Cointegration and error correction: representation, estimation and testing', *Econometrica*, 55, pp. 251–76.

Gordon R. (1987): 'Productivity, wages and prices inside and outside of manufacturing in the U.S., Japan and Europe', *European Economic Review*, 31, pp. 685–739.

Granger C. (1969): 'Investigating causal relations by econometric models and cross-spectral methods', *Econometrica*, 37, pp. 99–126.

Granger C. (1988): 'Some recent developments in a concept of causality', *Journal of Econometrics*, 39, pp. 199–211.

Hamilton J. (1994): *Time Series Analysis*, Princeton University Press, Princeton, NJ.

Hatanaka M. (1996): *Time-series-based Econometrics*, Oxford University Press, New York.

Hicks J. (1932): *The Theory of Wages*, Macmillan, London.

Kaldor N: (1961). 'Capital accumulation and economic growth', in Lutz F., Hague F. (eds): *The Theory of Capital*, St Martin's Press, New York.

Mackinnon J. (1991): 'Critical values for cointegration tests', in Engle R., Granger C. (eds): *Long Run Economic Relationships*, Oxford University Press, Oxford.

Marx K. (1979): *Value, Price and Profit*, Charles H. Kerr, Chicago, IL.

Phillips P., Xiao Z. (1998): 'A primer on unit root testing', *Journal of Economic Surveys*, 12, pp. 423–69.

Samuelson P. (1965): 'A theory of induced innovation along Kennedy–Weisäcker lines', *Review of Economics and Statistics*, 47, pp. 343–56.

Toda H., Phillips P. (1993): 'Vector autoregression and causality', *Econometrica*, 61, pp. 1367–93.

Toda H., Yamamoto T. (1995): 'Statistical inference in vector autoregressions with possibly integrated processes', *Journal of Econometrics*, 66, pp. 225–50.

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