Do rising real wages increase the rate of labor-saving technical change? Some econometric evidence.

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Abstract

In this paper we investigate the long run relationship between real wage and labor productivity through 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 tying real wage and labor productivity in the long run. Moreover, there is one-to-one relationship in the growth rate of these variables. The non-causality tests showed unidirectional Granger causality from real wage to labor productivity. It corroborates the conception that increases in real wage drives 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 perceive technical change as being induced by the relative factor share.

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1. INTRODUCTION

The purpose of this paper is to study the empirical relationship between real wage and labor productivity. First, we investigate if the constancy of the wage share corresponds to a stylized fact of economic growth (Kaldor, 1961). In this case real wage and labor productivity are cointegrated and there is a long run relationship between these variables. This hypothesis is tested looking at the US economy during the period 1869-1999.

Second, we investigate the causal linkages between real wage and labor productivity. It is the central aspect of the present study. The basic conception is that increases in real wage raise the labor share reducing profitability, forcing profit seeking capitalists to invest in labor saving technical changes in order to reduce the share of wages. In fact, the higher the increase in real wage, the higher the reward and the pressure on the capitalists to search for and adopt a new technique with greater labor productivity. This view is consistent with a tradition among economists that perceive the technical change as induced by the relative factor share. The hypothesis is that innovations in real wage precede the movements in labor productivity.

Thus, Granger (1969) non-causality tests are well-suited to study the causal relationship between real wage and labor productivity in this theoretical conception. Granger (1969) non-causality is defined in terms of predictability of the time series, causality is tested in the sense of which variable, real wage or labor productivity, helps to forecast the other. Non-causality tests are performed for the US 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 wage to labor productivity. It supports the conception that increases in real wage might drive the profit seeking capitalists to invest in labor-saving technical change to defend their profitability.

The paper is organized as follow: section 2 presents the theoretical basis, section 3 describes the methodology, section 4 provides the results and an interpretation and section 5 offers a conclusion.

2. THEORETICAL BASIS

The theoretical basis in this paper follows a long tradition among the economists that see technical change in capitalist production taking a biased form in order to economize in the relatively expensive input. Perhaps, Hicks (1932, pp. 124-

125) observation 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 the most well-know sentence about the biased technical change.

Samuelson (1965, p. 354) pointed out that Hicks in this aspect had a position similar to Marx. For both authors innovations tend to be labor biased due to incentives to reduce the share of wages in total costs. Moreover, for Marx the dispute between capitalist and worker over the value added also plays a role in the technical change to follow a labor-saving pattern. For example, Marx (1979, pp. 121-122) 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".

Kennedy (1964), following this tradition, presents a model of induced technical change in which the innovation possibility frontier provides a labor-saving bias in technical change. In his analysis a wage raise might incite a spur in the search for labor saving techniques if the wage comprises a large share of total cost. Each firm faces a menu of possible technical change represented by a concave technical progress function where the rate of technical change in the inputs, labor and capital, are negatively correlated. Thus, an increase in the labor augmenting technical change can only be obtained by a decrease in the rate of technical change in capital and vice-versa. Profit-maximizing capitalist will choose the pattern of technical change that maximizes the rate of reduction in total costs. These are composed of wages paid to workers and rents paid to capital owners. The bias of technical change results from the economic incentives that firms have to economize in the input with the higher share in total cost. A labor share above fifty percent explains the pattern of technical change that is labor biased and, perhaps, capital-using.

In this framework, an increase in real wage further raises the labor share and intensifies the search and adoption of labor-saving technical change. On the other hand, a decline in the labor share reduces the incentives to search and adopt technical innovation causing a slow down in the growth rate of labor productivity. This conception is consistent, for example, with Gordon (1987, p. 729). He attributes substantial quota of the decline in productivity growth after 1972 in U.S. non-manufacturing and after 1979 in Japan and Europe to a shift from high to moderate real wage growth.

Duménil and Lévy (1995) develop a stochastic model of induced technical change. 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 employed technique. The selection of new technologies is based on the profitability criterion, just that techniques yielding a higher profit rate than the present rate are 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 if the ratio between the factor shares is different from one. If the labor share is larger than capital share, then the savings in labor will tend to be larger than in capital. Besides, a raise in real wage increases the labor share and probability of the selected new technology to be labor-saving.

In the Duménil and Lévy's model the real wage affects the trajectory of technical change through the profit rate. An increase in real wage reduces profitability, driving profit seeking capitalist to implement labor saving technologies in order to reduce labor cost. This conception of technical change gives an independent and determinant role to real wage in the evolution of technical change. Increases in real wage induce a pattern of technical change that is labor saving and, probably, capital using. Moreover, innovations in real wage precede the movements of labor productivity.

In this respect, the analysis of cointegration and Granger non-causality test are quite convenient to investigate the long run relationship between real wage and labor productivity. Cointegration tests answer if the labor productivity is raising at rates similar to real wage, while Granger non-causality tests answer if innovations in real wage lead or lag the movements of labor productivity.

3. UNIT ROOT TESTS, COINTEGRATION AND GRANGER NON-CAUSALITY

As is well known Ordinary Least Squares (OLS) regressions are, in most cases, spurious for non-stationary series. However, OLS regressions are not spurious when the series follow stochastic trends and move together. In this case the series are said to be cointegrated, that is, they drift together and exhibit a long run equilibrium relationship.

The cointegration tests in this paper follow the two-step procedure suggested by Engle and Granger (1987). This procedure is very appropriate for systems of only two variables with one possible cointegration vector (Hatanaka, 1996, p. 200).

Initially, the variables are tested if they present a stochastic trend through a unit root test. Phillips and Xiao (1998) present a review of literature on unit root tests.

The unit root test provides a framework to distinguish between deterministic trend and stochastic trend. Random walk type processes are an appropriate representation of this latter. In most of the cases the determinist trend is a component of the series. The question is not if the series have a deterministic or a stochastic component, but if the latter component is present though a unit root test. The process is made stationary subtracting the trend when the stochastic component is not present. In a trend stationary process any exogenous shock will die out and the variance is constant. If the stochastic component is present, the process is made stationary differencing the variable. In a difference stationary process any exogenous shock will have a permanent effect in the series and the variance is time dependent. The terminology integrated process of order one, I(1), is employed to represent the series that are stationary after one difference. A stationary process is called integrated of order zero, I(0).

In a time series the basic test for unit root is to estimate a Dickey-Fuller regression, the DF test, when the error terms are independent and identically distributed, iid, or an augmented Dickey-Fuller regression, ADF test, when the error term is not iid. The ADF regression in the presence of intercept and deterministic time trend is given by:

$$\Delta y_t = \alpha + \beta t + \rho y_{t-1} + \sum_{j=1}^{p} \theta \Delta_j y_{t-1} + e_t \quad , \tag{1}$$

where $\Delta y = y_t - y_{t-1}$, y is a macroeconomic variable as real wage and labor productivity, t is a trend variable, e is a white noise term, and $j = 1,\ldots, p$ is the ADF lags. The null hypothesis is H_0: $\rho = 0$ and y is said to possess the unit root property if one cannot reject H_0.

If the variables are unit roots, I(1), then it is possible to test for cointegration. The first step in the Engle and Granger procedure consists of testing if the stochastic trends in the variables are connected. It is investigated by estimating the following regression:

$$y_t = \alpha + \beta x_t + e_t \qquad (2)$$

in which *y* and *x* are I(1). The second step is to test if the residuals are stationary, I(0), or unit root, I(1). If the residuals are stationary, then the series are cointegrated.

The two-step procedure by Engle and Granger (1987) provides the information needed to test the non-causality hypotheses in a bivariate error-correction model. Granger (1988) pointed out that in the case of cointegration between a pair of series there exist a causality in at least one direction. Granger causality tests are, in fact, temporal causation tests based on two axioms: the cause will temporally precede the event, the cause has unique information about the event. If the event X is the cause of the event Y, then X must precede the event Y. Actually, a Granger-causality test is answering a forecasting question, whether the event X is capable of forecasting the event Y. In the present paper we are asking whether innovations in real wage lead to movements in labor productivity or vice-versa.

The question of Granger non-causality in cointegrated time series has been subject to intense debate, mainly over the distribution of the Wald tests. Toda and Phillips (1993) suggested that the increase in the dimension of the cointegration space might complicate the testing procedure with the parameters assuming nonstandard limit distribution. However, in the context of a vector error correction model under certain conditions the Wald statistics are free of nuisance parameter (Caporale and Pittis, 1999, p. 22). A vector error correction model in a bivariate system with one cointegration vector meets these conditions.

The non-causality test in a vector error correction model is subject to pre-testing bias. Toda and Yamamoto (1995) proposed an alternative method for testing Granger non-causality in non-stationary vector autoregressive model in levels for processes in which the variables might be cointegrated or not.

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

$$\Delta y_t = \alpha_0 + \alpha_y \hat{e}_{t-1} + \sum_{j=1}^{p} \alpha_{1j} \Delta y_{t-j} + \sum_{j=1}^{p} \alpha_{2j} \Delta x_{t-j} + \varepsilon_{yt} \tag{3}$$

$$\Delta x_t = \beta_0 + \beta_x \hat{e}_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta y_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta x_{t-j} + \varepsilon_{xt} \tag{4}$$

in which y_t and x_t represent real wage and labor productivity, $\hat{e}$ are the residuals obtained in the cointegration regressions, and α_y and β_x denote the speed of adjustment to the long run level of equilibrium. Real wage does 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 wage if the hypothesis H_0: $\beta_{11} = \beta_{12} = \ldots = \beta_{1p} = 0$ and $\beta_x = 0$ is not rejected.

4. 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 wage and labor productivity for the US economy over the period 1869-1999. These variables were obtained in Duménil and Lévy (1993) for 1869-1989 and extended, following the same methodology, until 1999. Real wage is the total compensation per hour worked by employee deflated by the Gross National Product (GNP) deflator. Labor productivity is the ratio between the private Gross National Product and total number of hours worked deflated by the GNP deflator.

The time-series plots of both series in level and logarithm are presented in Figure 1. The inspection of both plots suggests the presence of basically the same trend in the series. Figure 2 plots the pair labor productivity and real wage in level (LP, W) and in logarithm (LLP, LW). Figure 3 presents the stochastic component of these pairs. The observation of both scatter plots points to the existence of a stable and linear relationship between real wage and labor productivity. The Figures also indicate a possibility of cointegration between the series.

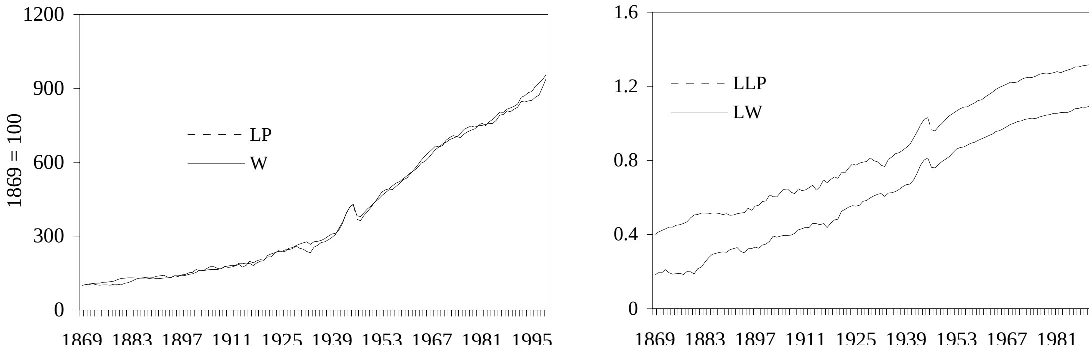

Figure 1. The time series plots of the real wage and labor productivity in level, respectively W and LP, and in logarithm, respectively LW and LLP, for the US economy, 1869-1996. The series in level and logarithm display a very similar trend (Duménil and Lévy, 1993).

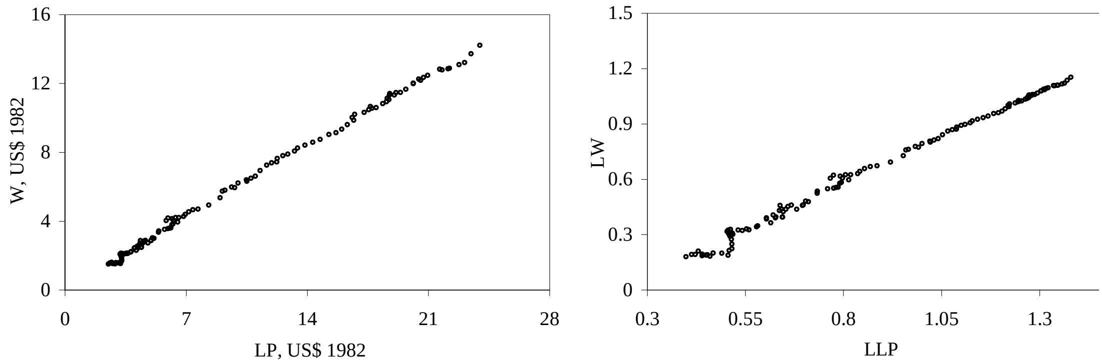

Figure 2. The plot of the pair labor productivity and real wage in level (LP, W) and in logarithm (LLP, LW) for the US economy, 1869-1999, display a linear and stable relationship between the variables (Duménil and Lévy, 1993).

Table 1 presents the unit root tests for both series in level and logarithm. The number of lag length *p* employed in the tests was chosen based on Akaike Information Criterion (AIC). This method tends to give parsimonious models with 0 and 1 lags, hence test with 2 lags in the ADF regressions are also presented. The tests also consider the hypothesis that the data generating process follows either a drifted model, $\alpha \neq 0$ and $\beta = 0$, or a trended model, $\alpha \neq 0$ and $\beta \neq 0$. The hypotheses of unit root for real wage in level and logarithm, respectively W and LW, as well as for labor productivity in level and logarithm, respectively LP and LLP, cannot be rejected at 1 percent significance level. Therefore, it is possible to apply the cointegration tests.

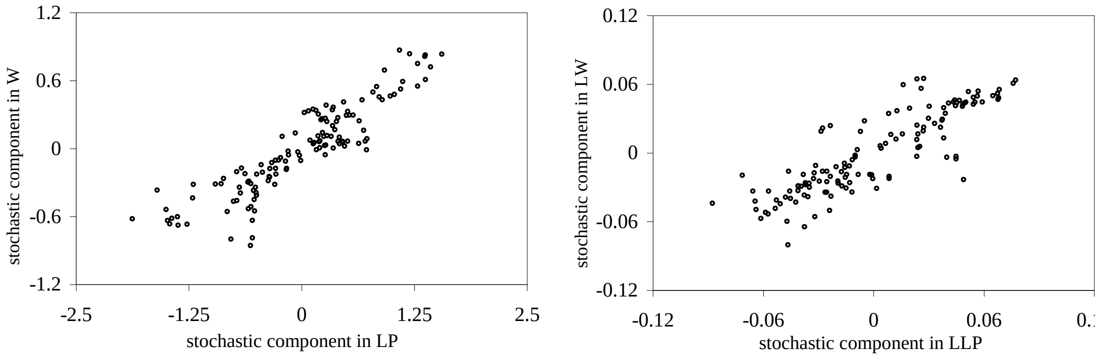

Figure 3. The plots of the stochastic component of the pair labor productivity and real wage in level (LP, W) and in logarithm (LLP, LW) for the US economy, 1869-1996, display a linear relationship between both variables (Duménil and Lévy, 1993).

Further tests, not reported, showed that both labor productivity and real wage in level have a deterministic trend without drift, while the logarithm of real wage has just a drift and the logarithm of labor productivity has a drift and a deterministic trend. Thus, we can't reject the following hypotheses: real wage in level is described as a random walk process about a non-linear trend and in logarithm as a random walk about a linear trend; labor productivity is described in both level and logarithm as a random walk about a non-linear trend.

Table 1. Unit root tests for real wage and labor productivity in level, respectively W and LP, and logarithm, respectively LW and LLP, for the US economy, 1869-1999.

Variable	Drifted Model			Trended Model		
	ADF lags			ADF lags		
	0 lag	1 lag	2 lags	0 lag	1 lag	2 lags
W	4.15	2.94	2.89	-1.01	-1.19	-1.19
ΔW	-7.46*	-5.73*	-5.75*	-8.51*	-6.86*	-7.36*
LW	-0.003	0.01	-0.09	-2.06	-2.53	-2.46
ΔLW	-9.53*	-7.25*	-6.43*	-9.49*	-7.22*	-6.41*
LP	3.81	2.82	2.92	-0.95	-1.1	-1.08
ΔLP	-8.3*	-6.66*	-5.58*	-9.26*	-7.78*	-6.85*
LLP	-0.04	-0.01	0.02	-1.92	-2.15	-2.11
ΔLLP	-10.4*	-7.91*	-6.4*	-10.36*	-7.89*	-6.39*

Source: Duménil and Lévy (1993).
Note: * denotes significance at 1 percent.

Table 2 reports the results for the cointegration regressions with the series in level and logarithm. The first line presents the cointegration regression and the statistics when labor productivity is regressed on labor productivity, while the second line shows the cointegration equation and the statistics for the reverse-order regression. The third and fourth lines show the cointegration regressions normalized, respectively, by the logarithm of labor productivity and real wage as well as the statistics for the presence of unit root in the residuals. The ADF tests were done considering the non intercept model, $\alpha = 0$ and $\beta = 0$, and the drifted model, $\alpha \neq 0$ and $\beta = 0$. The number of lag was determined by AIC. The null hypothesis of a unit root in the estimated residuals is rejected in all the tests for the variables in both levels and logarithms. Therefore, real wage and labor productivity are cointegrated in levels and logarithms for the US economy during the period 1869-1999. 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 wage 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 percent of statistical significance. Real wage and labor productivity tended to growth at similar rates in the US economy in the period 1869-1999. This results is also consistent with Kaldor's (1961) stylized fact that wage share is constant in the long run.

Table 2: Cointegration tests between real wage and labor productivity for the US economy, 1869-1999.

Dependent Variable	Regressor	Coefficients Constant	Beta	Unit root tests No Intercept Model			Drifted Model		
				0 lag	1 lag	2 lags	0 lag	1 lag	2 lags
W	LP	0.093 (0.029)	0.591 (0.002)	-3.33*	-3.8*	-3.41*	-3.32**	-3.78*	-3.4**
LP	W	-0.135 (0.049)	1.689 (0.007)	-3.33*	-3.8*	-3.41*	-3.31**	-3.78*	-3.4**
LW	LLP	-0.228 (0.006)	1.007 (0.007)	-2.98*	-3.58*	-3.35*	-2.97**	-3.56*	-3.34**
LLP	LW	0.23 (0.005)	0.986 (0.006)	-2.98*	-3.58*	-3.35*	-2.97**	-3.57*	-3.34**

Note: Standard deviations are in parentheses. * denotes significance at 1 percent. ** denotes significance at 5 percent.

The cointegration between real wage and labor productivity indicates the presence of long-run Granger causality in at least one direction. 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 AIC. Three lags were employed in the vector error correction model. Results for four lags are also presented since AIC tends to give parsimonious models. We cannot reject the hypothesis that labor productivity does not Granger cause labor productivity in both levels and logarithms, however we reject the hypothesis that real wage does not Granger cause labor productivity in both level and logarithm. There is unidirectional Granger causality from real wage to labor productivity in the US economy between 1869 and 1999.

Real wage leads the movements in labor productivity. It 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 and adoption of technical change induced by raises in the real wage. This result is consistent with a long tradition among the economists that see the technical change as being induced by incentives to reduce the cost of the high-priced inputs.

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

H_0	Lag Length	F Value
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 does not Granger cause LLP	3	2.46**
	4	2.68**
LLP does not Granger cause LW	3	1.01
	4	0.47

Note: ** denotes significance at 5 percent.

5. CONCLUSION

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

The causality tests between real wage and labor productivity indicated that real wage Granger-cause labor productivity and that labor productivity does not Granger-cause real wage. The unidirectional Granger causality indicates that real wage leads the movements of labor productivity. This result is consistent with the conception that increases in real wage drives profit seeking capitalists to raise labor productivity in defending their profitability.

This result also supports a long tradition among economists that perceive the technical change following a pattern induced by the relative factor shares. 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 factor share influences the searching and adoption of technical change, then a theory of endogenous growth could be build on this basis. Thus, empirical and theoretical studies are necessary in order to further develop the theory of induced technical change.

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