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Wage Growth and the Inflation Process: An Empirical Note

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Abstract

A central proposition in the Phillips curve view of the inflation process is that prices are marked up over productivity-adjusted labor costs. If that is true, then long-run movements in prices and labor costs must be correlated. If long-run movements in a time series are modeled as a stochastic trend, then the above noted implication of the 'price markup' view is related to the concept of cointegration discussed in Granger (1986), which says that cointegrated multiple time series share common stochastic trends. The evidence reported here shows that time series measuring rates of change in prices and labor costs are cointegrated. Furthermore, this cointegration appears consistent with Granger-causality running from the rate of change in prices to the rate of change in labor costs, but not vice versa as suggested by the 'price markup' view.

A popular theoretical model of the inflation process is the expectations-augmented Phillips curve model, which generally assumes that prices are set as a markup over productivity-adjusted labor costs, the latter being determined by expected inflation and the degree of demand pressure.[1] It is assumed further that expected inflation depends on past inflation. This model thus implies that wages and prices are causally related with feedbacks in both directions.

However, in a recent contribution Gordon (1988) has presented evidence consistent with the inference that changes in wages and prices are not related in the Granger-causal sense. This finding is in sharp contrast to the results reported in the early empirical work (see, for example, Barth and Bennett (1975) and Mehra (1977))[2], which had found wages and prices are related with Granger-causality running either in both directions or only from prices to wages.

This article reexamines the relationship between productivity-adjusted wages and prices using the recent technique of cointegration. The essence of the 'price markup' hypothesis stated above is that long-run movements in prices are related to long-run movements in productivity-adjusted

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[1]This version has been closely associated with the work of Gordon (1982, 85, 88). See also Stockton and Glassman (1987).

[2]The sample periods and the data used in these studies are different. Barth and Bennett (1975) studied causal patterns between prices and wages over the period 1947Q1 to 1970Q4. The measures of prices used were wholesale and consumer prices, and wages were measured by the hourly wages of production workers. They found Granger-causality only from prices to wages. Mehra (1977) found feedbacks in both directions between consumer prices and money wages at the two-digit level manufacturing industries over the period 1954Q1 to 1970Q4. Gordon (1988) measures prices by the fixed-weight GNP deflator and wages by hourly earnings adjusted for overtime, employment mix, and fringe benefits. In addition, Gordon (1988) also adjusts earnings for productivity. The sample period covered in this study is 1954Q2 to 1987Q3.

wages. If long-run movements in a time series are modeled as a stochastic trend, then the implication above is related to the concept of cointegration discussed in Granger (1986), which states cointegrated multiple time series share common stochastic trends. It is shown that variables measuring the rates of growth in wages and prices are cointegrated. However, the presence of this long-run relationship between the rates of change in wages and prices appears consistent with Granger-causality existing from the rate of change in prices to the rate of change in wages, not vice versa as suggested by the 'price markup' view. Thus, the results reported here are more in line with those in Barth and Bennett (1975) than in Gordon (1988).

The plan of this article is as follows. Section 1 presents a Phillips curve model of the inflation process and discusses its implications for the relationship between wages and prices. It also discusses how tests for cointegration and Granger-causality can be used to examine such wage-price dynamics. Section 2 presents the empirical results and Section 3 contains the concluding observations.

I

1. A Phillips Curve Model and its Implications for Wage-Price Dynamics

The view that systematic movements in wages and prices are related derives from the expectations-augmented Phillips curve model of the inflation process. To explain, consider the following price and wage equations that typically underlie such Phillips curve models (Gordon (1982, 1985) and Stockton and Glassman (1987))

$$\Delta p_t = h_o + h_1 \, \Delta(w_t - q_t) + h_2 \, x_t + h_3 \, S_{pt} \tag{1}$$

$$\Delta(w_t - q_t) = k_o + k_1 \, \Delta p^e_t + k_2 \, x_t + k_3 \, S_{wt} \tag{2}$$

$$\Delta p_t^e = \sum_{j=1}^{n} \lambda_j \, \Delta p_{t-j} \tag{3}$$

where all variables are in natural logarithm and where p is the price level; w, the wage rate; q, labor productivity; x, a demand pressure variable; p^e, the expected price level; S_{pt}, supply shocks affecting the price equation and S_{wt}, supply shocks affecting the wage equation. Δ is the first difference operator. Equation (1) describes the price markup behavior. Prices are marked up over productivity-adjusted labor costs (w-q) and are influenced by cyclical demand (X) and the exogenous relative price shocks (S_p). This equation implies that productivity-adjusted wages determine the price level, given demand pressures. Equation (2) is the wage equation. Wages are assumed to be a function of cyclical demand (x) and expected price level, the latter modeled as a lag on past prices as in equation (3). The wage equation implies that wages depend upon past prices, ceteris paribus.

2. Testing Wage-price Dynamics: Issues of Cointegration and Granger-Causality

The price and wage behavior described above suggest that long-run movements in wages and prices must be related. Furthermore, if we allow for short-run dynamics in such price and wage behavior, the analysis presented above would also suggest that past changes in wages and prices should contain useful information for predicting future changes in prices and wages, ceteris paribus. These implications could be easily examined using tests for cointegration and Granger-causality between wage and price series.

In particular, if long-term components in wage and price series are modeled as stochastic trends and if they move together, then these two time series should be cointegrated as discussed in Granger (1986). Thus, the long-run comovement of wages and prices is examined using the test for cointegration proposed in Engle and Granger (1987). This test consists of two steps. The first step tests whether each of the variables of interest (such as p_t, w_t and x_t) has a stochastic trend. That is investigated by performing the unit root tests on the variables. The second step tests whether stochastic trends in these variables are related. That is investigated here by estimating the cointegrating regression (4) or (5) given below

$$p_t = \gamma_o + \gamma_1 w_t + \gamma_2 x_t + V_{1t} \tag{4}$$

$$w_t = \delta_t + \delta_t p_t + \delta_t x_t + V_{2t} \tag{5}$$

and then testing whether the residual V_{1t} in (4) or V_{2t} in (5) has a unit root or not. If the residual in (4) or (5) does not appear to have a unit root while dependent and independent variables had each a unit root, then price and wage series are said to be cointegrated.

Granger (1988) also points out that if a pair of series are cointegrated, then there must be causation in at least one direction. To illustrate, suppose that p_t and w_t are cointegrated. Then, as shown in Granger (1988), these series satisfy an error-correction model of the form

$$\Delta p_t = (\text{lagged } \Delta p_t, \Delta w_t, \Delta x_t) + \lambda_1 V_{t-1}$$

$$\Delta w_t = (\text{lagged } \Delta p_t, \Delta w_t, \Delta x_t) + \lambda_2 V_{t-1}$$

where V_t is the residual from the cointegrating regression (4) or (5) and where one of λ_1, $\lambda_2 \neq 0$. Since V_{t-1} depends upon lagged levels of p and w, the model above implies that either Δp or Δw (or both) must be caused by lagged levels of the variables. The intuition behind this result is that if there is a long-run relationship between p and w, then there must be causation between them to provide necessary dynamics.

II

This section presents empirical results. The data used are quarterly and cover the period 1959Q1 to 1988Q4. I have examined the dynamic interactions between wages and prices in a tri-variable system consisting of the general price level, productivity-adjusted wage and a demand pressure variable. The general price level (p) is measured by the log of the fixed-weight GNP deflator; productivity-adjusted wage (w), by the log of the index of unit labor costs of the non-farm business sector; and the demand pressure variable, by the log of real GNP over potential (denoted as g). The potential real output series used is from the Board of Governors.

Test Results for Unit Roots and Cointegration

The test used to detect a unit root in a given time series y_t is the Augmented Dickey-Fuller test (ADF) and is performed estimating the following regression

$$\Delta y_t = a + bT + \sum_{s=1}^{n} C_s \, \Delta y_{t-s} + d \, y_{t-1} + \epsilon_t \tag{6}$$

where ϵ_t is the i.i.d. disturbance. n is the number of lagged values of first-differenced y that are included to allow for serial correlation in the residuals. If there is a unit root in y, then the estimated coefficient d in (6) should be zero. The results of estimating (6) for levels as well as for first differences of price, wage and output-gap regressors are presented in Table 1. These test results are consistent with the presence of two unit roots in each price and wage regressors (p_t and w_t) and a single unit root in the output gap variable (g_t). They suggest that variables measuring the rate of growth in wages and prices (Δw and Δp) have each a stochastic trend.

Table 2 presents estimates of the cointegrating regressions using levels as well as growth rates of prices and wages. In addition, the results of applying the ADF test for detecting a unit root in the residuals of the cointegrating regressions are also reported there. These unit root tests results are consistent with the inference that while levels of wage and price variables are not cointegrated,[3] first differences are. Hence, long-run movements in the growth rates of wages and prices appear to be correlated.

Test Results for Granger-Causality

Table 3 presents results of testing for the presence of Granger-causality between wages and prices. The recent work by several analysts[4] shows that the asymptotic distributions of causality tests are sensitive to the presence of unit roots and time trends in the time series. In many such cases it might be necessary to conduct causality tests using appropriately differenced variables. The unit root test results presented in Table 1 would suggest that wage and price data need to be differenced twice. However, the existence of cointegration between wage growth and the rate of inflation implies that Granger-causality tests should be done using first differences of wage and price regressors. To illustrate, the results presented here so far

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[3]Engle and Granger (1987) also find that levels of wage and price variables are not cointegrated. They however did not examine the possibility that first differences of wages and prices could contain stochastic trends and be cointegrated.

[4]Sims, Slock and Watson (1986), Phillip (1987), and Ohanian (1988).

imply that wage and price variables satisfy an error-correction model of the form

$$\Delta^2 p_t = a + \sum_{s=1}^{n1} b_s \ \Delta^2 p_{t-s} + \sum_{s=1}^{n2} C_s \ \Delta^2 w_{t-s} + \sum_{s=1}^{n3} d_s \ \Delta g_{t-s} + \lambda_1 \ V_{t-1} + \epsilon_{1t} \quad (7)$$

$$\Delta^2 w_t = \tilde{a} + \sum_{s=1}^{n1} \tilde{b}_s \ \Delta^2 p_{t-s} + \sum_{s=1}^{n2} \tilde{c}_s \ \Delta_2 wt\text{-}s + \sum_{s=1}^{n3} d_s \ \Delta g_{t-s} + \lambda_2 \ V_{t-1} + \epsilon_{2t} \quad (8)$$

where all variables are as defined before and where V_{t-1} is the lagged value of the residual from the 'cointegrating regression' of the form[5]

$$\Delta p_t = d_o + d_1 \ \Delta w_t + d_2 \ \ g_t + V_t \qquad (9)$$

The presence of cointegration between Δp and Δw implies that at least one of λ_i, i=1, 2, is different from zero. So, even if second differences of price and wage regressors do not enter (7) and (8), first differences might through the residual and hence Granger-cause prices and/or wages.

The test results of Granger-causality are reported in Table 3. In panel A of Table 3, the price and wage regressors are in second differences and the demand pressure regressor as measured by the output gap in first differences. In panel B of Table 3, wage and price regressors enter also in first difference form satisfying the error-correction mechanism described in (7) and (8). In panel C, wage and price regressors are in first differences and the output gap regressor in levels, a specification similar to the one reported in Gordon (1988). It is also known that Granger test results are sensitive to the selection of lag lengths on the regressor. Hence, in

[5]Equivalently, one could use the residual from the 'cointegrating regression' with Δw_t as the dependent variable.

addition to the results for the lag length selected by the final prediction error criterion, I also present results for some arbitrarily selected lag lengths.

The F1- and t1-values, reported in panels A, B, and C of Table 3, test for the presence of Granger-causality from wage growth to the rate of inflation.[6] These values are not statistically significant and thus consistent with the inference that the rate of wage growth has no incremental predictive content for the rate of inflation. The F2-values (also reported in Table 3) test for the presence of Granger-causality from the output gap regressor to the rate of inflation. Here, the F2-values provide mixed results. These values imply that inflation depends upon past output gap when the output gap regressor is in levels, but not when the output gap regressor is in first differences. Since level of the output gap regressor does have a unit root, the F2-values for this regressor are however suspect.[7]

The F3- and t2-values, reported in panels A, B, and C of Table 3, test for the presence of Granger-causality from inflation to wage growth. These values are statistically significant and thus consistent with the inference that inflation does have an incremental predictive content for wage growth. The F4-values (also reported in Table 3) test for Granger-causality from the output gap regressor to wage growth. These values are generally

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[6]Alternatively, we could interpret the t1 statistic as testing whether the long-run relationship found between the rates of change in wages and prices constraints the short-run behavior of the rate of inflation.

[7]That is so because the restrictions being tested involve coefficients that appear on levels of the output gap regressor, which is not stationary. Hence, the F2-value might not have the usual F distribution (Sims, Stock and Watson (1986)).

statistically significant and imply that output gap does contribute to the explanation of wage growth.[8]

III

Concluding Observations

A central proposition in the expectations-augmented Phillips curve model of the inflation process is that prices are marked up over productivity-adjusted labor costs. If that is true, then long-run movements in prices and labor costs must be correlated. If the long-run component in a time series is modeled as a stochastic trend, then the above noted implication of the 'price markup' view is related to the concept of cointegration discussed in Granger (1986). The evidence reported here shows that long-run movements in the rate of growth in prices and labor costs are correlated over time. But the presence of this correlation appears to be due to Granger-causality running from inflation to wage growth, not from wage growth to the rate of inflation. These results thus do not support the 'price markup' view of the inflation process. As for monetary policy, these results imply that anti-inflationary policy need not respond to labor cost data because such data contain no additional information about the future rate of inflation.

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[8]The kind of caution noted in footnote 8 applies to the F4-values reported in panel C of Table 3.

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Table 1

Unit Root Test Statistics

Augmented Dickey-Fuller Equation $\Delta y_t = a + b\,T + \sum_{s=1}^{n} C_s\, \Delta\, y_{t-s} + d\, y_{t-1}$

y	Lag Length (l)	d	t value (d=0)	$T.R^2(1)$	$T.R^2(2)$	$T.R^2(4)$	Q(sl)
p	7	-.01	-2.41	.39	.61	.83	35.5(.22)
w	3	-.02	-2.28	.77	1.84	3.46	20.9(.89)
g	2	-.08	-2.90	.03	.47	1.37	23.7(.78)
Δp	6	-.14	-2.40	.16	.17	.58	36.1(.20)
Δw	2	-.31	-3.24	.08	.57	2.01	19.4(.93)
Δg	1	-.60	-5.23*	.29	.30	1.53	22.3(.84)

Notes: All data is quarterly and covers the period 1959Q1 to 1988Q4. p is the log of the fixed-weight gnp deflator; w, the log of unit labor cost; and g, the log of real output minus potential real output. Δ is the first difference operator. The number of own lags (n) included in the Augmented Dickey-Fuller Equation was chosen by the 'final prediction error' criterion due to Akaike (1969). Q(sl) is the Ljung-Box Q-statistic based on 30 autocorrelations of the residuals and sl is the significance level. $T.R^2(1)$, $T.R^2(2)$ and $T.R^2(4)$ are Godfrey test statistics for first-, second-, and fourth- order serial correlation and are distributed Chi Square x^2 with one, two and four degrees of freedom, respectively. The 5% critical values for t (d=o) is 3.45 (Fuller (1976), Table 8.5.2). The 5% critical values for $x^2(1)$, $x^2(2)$ and $x^2(4)$ are 3.84, 5.99 and 9.49, respectively.

Table 2

Test Statistics for Cointegration between Wages and Prices; 1959Q1-1988Q4

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1. Cointegrating Regression: $p_t = .14 + .89\, w_t + .004\, g + \hat{v}_t$

   Augmented Dickey-Fuller Regression: $\Delta\hat{v}_t = b\, \hat{v}_{t-1} + \sum_{s=1}^{n} C_s\, \Delta\hat{v}_{t-s}$

   Lag length n:2 Estimated $\hat{b} = -.03$ Test Statistic For $\hat{b} = 0$:-1.31

   $Q(sl) = 15.06(.98)$ $T.R^2(1) = 1.3$ $T.R^2(2) = 1.9$ $T.R^2(4) = 2.1$

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2. Cointegrating Regression: $w_t = -.14 + 1.1\, p_t - .001g + \hat{v}_t$

   Augmented Dickey Fuller Regression: $\Delta\, \hat{v}_t = b\, \hat{v}_{t-1} + \sum_{s=1}^{n} C_s\, \Delta\hat{v}_{t-s}$

   Lag length n:2 Estimated $\hat{b} = -.03$ Test Statistics For $\hat{b} = 0$:-1.5

   $Q(sl) = 15.17(.98)$ $T.R^2(1) = 1.74$ $T.R^2(2) = 2.6$ $T.R^2(4) = 2.8$

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3. Cointegrating Regression: $\Delta p = 2.1 + .43\, \Delta w - .16\, g + \hat{v}_t$

   Augmented Dickey Fuller Regression: $\Delta\, \hat{v}_t = b\, \hat{v}_{t-1} + \sum_{s=1}^{n} C_s\, \Delta\hat{v}_{t-s}$

   Lag length n:1 Estimated $\hat{b} = -.55$ Test Statistics For $\hat{b} = 0$:-4.96*

   $Q(sl) = 32.4$ $T.R^2(1) = 1.6$ $T.R^2(2) = 2.0$ $T.R^2(4) = 2.3$

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4. Cointegrating Regression: $\Delta w = -4.7 + 1.2\, \Delta p - .20\, g + \hat{v}_t$

   Augmented Dickey Fuller Regression: $\Delta\, \hat{v}_t = b\, \hat{v}_{t-1} + \sum_{s=1}^{n} C_s\, \Delta\hat{v}_{t-s}$

   Lag length n:1 Estimated $\hat{b} = -.96$ Test Statistics For $\hat{b} = 0$:-7.25*

   $Q(sl) = 28.8(.52)$ $T.R^2(1) = .11$ $T.R^2(2) = 1.9$ $T.R^2(4) = 6.6$

Notes: All variables are defined as in Table 1. Godfrey test statistics ($T.R_2(i)$ =, 1, 2, 4) test for the presence of serial correlation in the residual from the relevant Augmented Dickey-Fuller Regression. 5% critical value of the test statistics for $\hat{b}=0$ is 3.62 (Engle and Yoo (1987), Table 3)

Table 3

Granger Causality Test Statistics

Lag Length (n_1, n_2, n_3)	F1	F2	λ_1(t1)	Q(sl)	F3	F4	λ_2(t2)	Q(sl)
	Price Equation				Wage Equation			
A. $\Delta^2 p_t = a + \sum_{s=1}^{n1} b_s \Delta^2 p_{t-s} + \sum_{s=1}^{n2} C_s \Delta^2 w_{t-s} + \sum_{s=1}^{n3} d_s \Delta g_{t-s}$					$\Delta^2 w_t = \tilde{a} + \sum_{s=1}^{n1} \tilde{b} \Delta^2 w_{t-s} + \sum_{s=1}^{n2} \tilde{c} \Delta^2 p_{t-s} + \sum_{s=1}^{n3} \tilde{d} \Delta g_{t-s}$			
(4,4,4)	1.03(4,97)	1.37(4,97)		42.3(.07)	1.45 (4,97)	8.43*(4,97)		18.3(.95)
(8,4,4)	.72(4,93)	1.59(4,93)		33.1(.32)	1.68 (4,93)	7.3* (4,93)		15.9(.98)
(8,8,8)	.98(8,85)	1.59(8,85)		29.4(.49)	2.40**(8,85)	4.6* (8,85)		24.5(.74)
(3,3,3)[a]	1.79(3,100)	2.17(3,100)		44.6(.04)	1.65 (3,100)	12.6* (3,100)		23.6(.79)
B. $\Delta^2 p_t$ = variables as above + $\lambda_1 \hat{v}_{t-1}$					$\Delta^2 w_t$ = variables as above + $\lambda_2 \hat{v}_{t-1}$			
(8,0,0)			-.13(-1.6)	37.9(.15)			-1.02(-6.2)	20.7(.89)
(8,4,4)	.98(4,92)	1.79(4,92)	-.21(-1.8)	33.1(.31)	2.44**(4,92)	.93(4,92)	-1.24(-3.41)	17.6(.96)
(8,8,8)	.91(8,84)	1.51(8,84)	-.14(-1.1)	29.9(.47)	1.65 (8.84)	1.22(8,84)	-.81)(-1.6)	21.7(.86)
(1,1,1)[a]					.25 (1,105)	2.73(1,105)	-.78(-4.6)	27.0(.62)
C. $\Delta p = a + \sum_{s=1}^{n1} b \Delta p_{t-s} + \sum_{s=1}^{n2} C_s \Delta w_{t-s} + \sum_{s=1}^{n3} d_s g_{t-s}$					$\Delta w = \tilde{a} + \sum_{s=1}^{n1} \tilde{b} \Delta w_{t-s} + \sum_{s=1}^{n2} \tilde{c} \Delta p_{t-s} + \sum_{s=1}^{n3} \tilde{d} g_{t-s}$			
(4,4,4)	1.44(4,97)	2.63**(4,97)		41.2(.08)	5.87*(4,97)	10.3* (4,97)		24.3(.75)
(8,4,4)	1.35(4,93)	1.88 (4,93)		35.4(.23)	4.64*(4,93)	9.7* (4,93)		22.7(.82)
(8,8,8)	1.83(8,85)	2.3** (8,85)		31.7(.38)	1.90 (8,85)	3.88*(8,85)		23.8(.78)
(5,5,5)[a]	2.18(5,94)	2.51**(5,94)		40.0(.10)				
(4,4,4)[a]					5.87*(4,97)	10.3* (4,97)		24.4(.75)

See Table 1 for definition of variables and the sample period. F statistics tabulated have degrees of freedom indicated in parentheses. F1 tests that all c_s are jointly zero; F2, all d_s are jointly zero; F3, all $\tilde{c}_s$ are jointly zero; and F4, all d_s are jointly zero. λ_{is} , i=1,2 are the coefficients that appears on the error-correction variable v_{t-1}, which is the residual from the relevant cointegrating regression reported in panels 3 and 4 of Table 2. t statistics tabulated tests that λ_{is} (i= 1,2) are zero.

a. Lag length selected by the FPE criterion
* significant at .01 level
** significant at .05 level