Wage-Price Dynamics: Are They Consistent with Cost Push?

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For gauging inflationary pressures, many policymakers and financial market analysts pay close attention to the behavior of wages. It is widely believed that if wage costs rise faster than productivity, the price level may rise as firms pass forward increased wage costs in the form of higher product prices. Hence changes in productivity-adjusted wages[1] are believed to be a leading indicator of future inflation.

One problem with this popular "cost-push" view of the inflation process is that it does not recognize the influences of Federal Reserve policy and the resulting inflation environment on determining the causal influence of wage growth on inflation. If the Fed follows a non-accommodative monetary policy and keeps inflation low, then firms may not be able to pass along excessive wage gains in the form of higher product prices. In fact, an alternative view is that inflation is a "monetary" phenomenon and is caused by excess aggregate demand. According to this view, the causation runs from inflation to wage growth: firms are able to raise the price of their products because of excess aggregate demand caused by an expansionary monetary policy. The resulting increase in prices leads workers to demand higher wages.

In this article, I investigate whether wage-price dynamics are consistent with the cost-push view of the inflation process. The cost-push view implies that Fed policy and the resulting inflation environment do not matter in determining the ability of firms to pass forward higher wage costs in the form of higher product prices. Higher wage growth should lead to higher future

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[1] The term "productivity-adjusted wage growth" refers to wage growth in excess of productivity gains, measured here by growth in unit labor costs. The empirical work here focuses on this measure of wage growth.

inflation irrespective of what Fed policy has been and whether inflation has been high or low. I test this implication in two ways. First, I investigate whether there exists a long-term equilibrium relation between the price level and the level of wages and, if it exists, whether that equilibrium relation can be interpreted as the long-term price equation, meaning the price level is causally related to wages. The cost-push view implies that the long-term equilibrium relation is in fact the long-term price equation in which wages can be considered exogenous. Then, the estimated coefficient that appears on the wage variable measures the long-term response of the price level to wages. Second, even if a long-term relation between the levels of price and wage series does not exist, short-term changes in them may still be correlated. If the cost-push view is correct, then wage growth should help predict inflation and such predictive content should be invariant to changes in Fed policy and the inflation regime.

I test these implications of the cost-push view using data on the U.S. sample period 1952Q1 to 1999Q2. During this sample period both the nature of monetary policy pursued by the Federal Reserve and the behavior of inflation have varied considerably. In particular, this period contains two subperiods, 1952 to 1965 and 1983 to 1999, during which inflation remained low to moderate and one subperiod, 1966 to 1982, during which inflation steadily accelerated. Furthermore, the descriptive analysis of monetary policy in Goodfriend (1993) and the monetary policy reaction functions estimated more recently in Clarida, Gali, and Gertler (2000) and Mehra (1999) indicate that since 1979 the Fed has concentrated on maintaining low inflation. It is widely believed that as a result of such policy, inflation declined sharply in the early 1980s and has remained low to moderate since then.[2] The cost-push view implies that the predictive content of wage growth for future inflation should be stable over this sample period. As in some previous research, these wage-price dynamics are investigated using techniques of cointegration, Granger-causality, and weak exogeneity.

Other studies have previously investigated whether wage growth helps predict inflation. Mehra (1991), Hu and Trehan (1995), and Gordon (1998) report evidence that indicates wage growth has no predictive content for future inflation. Emery and Chang (1996) and Hess (1999) point out that the find-

[2] The breakpoints used here are suggested by a cursory look at inflation data, measured by the behavior of the GDP deflator. The hypothesis that holds that breaks in inflation are related to changes in monetary policy has been tested in Webb (1995). Based on his reading of FOMC minutes and fiscal and political commentary, Webb points out monetary policy changed first around the mid-1960s and then the early 1980s. He sees monetary policy making a discrete move toward more inflation at some point in the middle of the 1960s and another move toward lower inflation in the early 1980s. Thus three periods identified are: an early low inflation period from 1952Q2 to 1966Q4; a middle inflationary period from 1967Q1 to 1981Q2; and a disinflationary period from 1981Q3 to 1990Q4. The three sample periods are close to those studied here. However, one is likely to get qualitatively similar results if instead these breakpoints are used.

ing that wage growth helps predict inflation is sensitive to the sample period chosen. In contrast, Ghali (1999) reports Granger-causality test results that indicate wage growth does predict inflation, implying the cost-push view is correct. The main criticism of the previous empirical work, including the one in Ghali (1999), is the absence of discussion about the influences of Fed policy and the resulting inflation environment on determining the causal influence of wage growth on inflation. Hence the issue of the stability of wage-price dynamics has essentially been ignored. Furthermore, the predictive content in previous work is generally investigated using tests of Granger-causality summarized by the conventional F-statistic. However, it is important to assess the quantitative size of the predictive content. I therefore provide evidence on the size of the feedback between wages and prices, reporting the "magnitude" of the sum of coefficients that appear on lagged wage growth in predicting inflation.[3]

The empirical work presented here does not favor the cost-push view. The results indicate that the price level and the productivity-adjusted wage (measured here by the level of unit labor costs) are indeed cointegrated over the full sample period 1952Q1 to 1999Q2, meaning there exists a long-term, equilibrium relation between prices and wages. However, this equilibrium (cointegrating) relation cannot be interpreted as the long-term price equation because wages are not found to be exogenous. Thus, the estimated coefficient that appears on the wage variable does not measure the long-term response of the price level to wages, as implied by the cost-push view. The evidence rather indicates this equilibrium relation is the wage equation, in which prices can be considered exogenous.

The test results for Granger-causality indicate that over the full sample period 1952Q1 to 1999Q2, higher wage growth does lead to higher future inflation, as predicted by the cost-push view. However, the estimated, short-run feedback from wage growth to inflation is quantitatively modest and quite unstable during the sample period. In particular, the full sample result that wage growth helps predict future inflation is mainly due to the inclusion of observations from the high inflation subperiod 1966 to 1983. Wage growth does not help predict inflation during two low inflation subperiods, 1952Q1 to 1965Q4 and 1984Q1 to 1999Q2. In contrast, inflation always helps predict future wage growth, this result holding in all subperiods. Furthermore, the estimated, short-run feedback from inflation to wage growth is quantitatively large, with the estimated feedback coefficient close to unity, indicating wage growth has adjusted one-for-one with inflation. Consequently, the result that wage growth helps predict inflation only during the subperiod of high and rising inflation does not favor the cost-push view of the inflation process. It

[3] An exception is the recent work in Gordon (1998). He does not, however, investigate the stability of the wage-price feedback.

is only during a highly inflationary environment that firms are able to pass forward higher wage costs in the form of higher product prices, suggesting causation that runs from excess aggregate demand to inflation and to wages.

The plan of the rest of the paper is as follows. Section 1 reviews the economic rationale of why wages and prices may move together over time. Section 2 presents empirical results. Section 3 contains concluding observations.

1. SHORT-RUN WAGE-PRICE DYNAMICS: ECONOMIC RATIONAL AND TESTING

The view that systematic movements in wages and prices are related can be rationalized in a number of ways. One such rationalization can be derived from the expectations-augmented Phillips curve view of the inflation process. Consider the price and wage equations that typically underlie such Phillips curve models described in Gordon (1985, 1988) and Stockton and Glassman (1987).

$$\Delta p_t = h_0 + h_1 \Delta(w - q)_t + h_2 x_1 + h_3 sp_t \tag{1}$$

$$\Delta(w - q)_t = k_0 + k_1 \Delta p_t^e + k_2 x_t + k_3 sw_t \tag{2}$$

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

where all variables are in their natural logarithms and where p is the price level, w is the nominal wage rate, q is labor productivity, x is a demand pressure variable, p^e is the expected price level, sp represents supply shocks affecting the price equation, sw represents supply shocks affecting the wage equation, and Δ is the first difference operator. Equation (1) describes the price markup behavior. Prices are marked over productivity-adjusted wage costs[4] and are influenced by cyclical demand and the exogenous, relative supply shocks. 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 and expected price level, the latter modeled as a lag on past prices as in (3). The wage equation, together with equation (3), implies that wages depend upon past prices, ceteris paribus.

[4] As shown in Nordhaus (1972), this pricing equation can be derived from the optimizing behavior of firms. Under assumptions of Cobb-Douglas production function, constant returns, the constant relative price of capital, and profit maximizing behavior, the optimal price equation looks like one as in (1), with $h_1 = 1$. The last result implies that prices adjust one-for-one with wages in the long run.

The price and wage behavior described above suggests that long-run movements in wages and prices must be related. Furthermore, if one allows for short-run dynamics in such behavior, the analysis above would also suggest that past movements in wages and prices should help predict future changes in those same variables, ceteris paribus. In previous research these implications have been tested using tests for cointegration and Granger-causality between wage and price series.[5] In this article, I also use tests for weak exogeneity proposed by Hendry, Engle, and Richard (1983). Furthermore, following Gordon (1998) I also present evidence on the magnitude of the feedback between wage growth and inflation.

To illustrate, assume that wage and price series are cointegrated, indicating that wages and the price level comove in the long run and that the cointegrating relation is given in (4).

$$p_t = a_0 + a_1(w - q)_t + U_t \tag{4.1}$$

$$(w - q)_t = -(a_0/a_1) + (1/a_1)p_t - (1/a_1)U_t, \tag{4.2}$$

where U_t is the disturbance term. In (4.1) the cointegrating relation is normalized on the price variable, whereas in (4.2) it is normalized on the productivity-adjusted wage. That the finding wages and prices are cointegrated simply implies that these two variables are correlated in the long run, but correlation does not necessarily indicate causation. In order to investigate whether this finding about the presence of cointegration between prices and wages can be given a causal interpretation, Hendry, Engle, and Richard (1983) have proposed tests for weak exogeneity. In particular, the wage variable in the cointegrating regression (4.1) can be considered given in determining the response of the price level to wages if wages are weakly exogenous with respect to the long-term parameter a_1. In that case, one can causally interpret (4.1) as the long-term price equation, the parameter a_1 measuring the long-term response of the price level to wages. Conversely, if wages are not weakly exogenous but the price level is, then one can reformulate (4.1) as (4.2) and interpret it as the long-term wage equation with the parameter $(1/a_1)$ measuring the long-term response of wages to prices. If the "price markup" hypothesis holds in the long run, and hence the popular cost-push view of the inflation process is correct, then wages should be weakly exogenous in (4.1).

The test for weak exogeneity amounts to examining whether the residual U enters significantly in inflation and wage regressions of the forms (5) and (6).

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[5] See, for example, Mehra (1991), Hu and Trehan (1995), Gordon (1998), and Ghali (1999).

$$\Delta p_t = b_0 + \lambda_1 U_{t-1} + \sum_{j=1}^{s} b_{1j} \Delta p_{t-j} + \varepsilon_{1t} \tag{5}$$

$$\Delta (w - q)_t = c_0 + \lambda_2 U_{t-1} + \sum_{j=1}^{s} c_{1j} \Delta (w - q)_{t-j} + \varepsilon_{2t} \tag{6}$$

Wages are weakly exogenous in (4.1) if λ_2 is zero, whereas prices are weakly exogenous in (4.2) if λ_1 is zero. Intuitively, the test for weak exogeneity amounts to determining whether the long-run comovement of prices and wages is the result of wages adjusting to prices, prices adjusting to wages, or both. The cost-push view of the inflation process implies that the long-run comovement is the result of prices adjusting to wages, not wages adjusting to prices. Hence cointegrating regression (4.1) is the price equation in which the price level is causally determined by wages in the long run.

The tests for cointegration and weak exogeneity discussed above focus on the presence and the nature of the long-run correlation between wage and price series. However, even if a long-term cointegrating relation does not exist, we may still find that wage growth and inflation are correlated in the short run. If the price markup hypothesis holds in the short run, then wage growth may help predict future inflation. In previous research, this issue has been investigated using tests for Granger-causality. In particular, consider the following inflation and wage growth equations:

$$\Delta p_t = b_0 + \lambda_1 U_{t-1} + \sum_{j=1}^{s} b_{1j} \Delta p_{t-j} + \sum_{j=1}^{s} b_{2j} \Delta (w - q)_{t-j} + \sum_{j=1}^{s} b_{3j} CD_{t-j} + \varepsilon_{1t}, \tag{7}$$

$$\Delta (w - q)_t = c_0 + \lambda_2 U_{t-1} + \sum_{j=1}^{s} c_{1j} \Delta (w - q)_{t-j} + \sum_{j=1}^{s} c_{2j} \Delta p_{t-j} + \sum_{j=1}^{s} c_{3j} CD_{t-j} + \varepsilon_{2t}, \tag{8}$$

where CD stands for cyclical demand and where other variables are defined as before. These equations include the error-correction variable U_{t-1}, in case wage and price series are cointegrated. The test of the hypothesis that wages help predict inflation in the Granger-causal sense is that all $b_{2j} \neq 0$ and/or $\lambda_1 \neq 0$. In previous work this test has usually been carried out using the conventional

F-statistic, without paying much attention to the issue of whether the estimated effect of wage growth on inflation is quantitatively large or modest. Hence, in order to estimate the relative quantitative effects of lagged wage growth and inflation on each other, I consider below the following transformation of inflation and wage-growth equations (Gordon 1998).[6]

$$\Delta p_t = b_0 + \lambda_1 U_{t-1} + \sum_{j=1}^{s}(b_{1j} + b_{2j})\Delta p_{t-j} + \sum^{s} b_{2j}\Delta(w - q - p)_{t-j} + \sum_{j=1}^{s} b_{3j} CD_{t-j} + \varepsilon_{1t} \quad (9)$$

$$\Delta(w - q)_t = c_0 + \lambda_2 U_{t-1} + \sum_{j=1}^{s}(c_{1j} + c_{2j})\Delta(w - q)_{t-j} + \sum_{j=1}^{s} c_{2j}\Delta(p - (w - q))_{t-j} + \sum_{j=1}^{s} c_{3j} CD_{t-j} + \varepsilon_{2t} \quad (10)$$

Equation (9) comes about if we add and subtract $b_{2j}\Delta p_{t-j}$ terms in (7), whereas equation (10) comes about if we add and subtract $c_{2j}\Delta(w - q)_{t-j}$ terms in (8). In inflation equation (9), the "freely estimated"[7] sum of coefficients $\sum_{j=1}^{s} b_{2j}$ indicate the weight on lagged wage growth in the determination of inflation, once we control for the influence of lagged inflation. Hence, wage growth is an independent source of cost-push inflation if the estimated sum of coefficients $\sum_{j=1}^{s} b_{1j}$ is positive and statistically different from zero,

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[6] The reformulated inflation equation (9) incorporates the view that inflation and wage growth comove in the short run. Consider an increase in past wage growth. If this increase in past wage growth is simply due to past inflation, then such increase in past wage growth should have no additional effect on current inflation if the influence of past inflation is already accounted for in the inflation equation. Thus, in order to capture the additional influence of past wage growth on inflation, past wage growth in excess of past inflation is included ($(w - q) - p$) in the inflation equation, which also includes past inflation itself. Past wage growth, then, is an independent source of inflation if past wage growth measured as deviations from past inflation is significant. There are several advantages of this reformulation. First, the sum of coefficients appearing on past wage growth directly measures the magnitude of the effect of past wage growth on inflation. Second, one can impose and test restrictions on the sum of coefficients appearing on lagged inflation. For example, the "natural-rate hypothesis" implies coefficients on past inflation sum to unity. One can test whether past wage growth is still relevant when the natural-rate hypothesis holds, as in Gordon (1998). Third, including wage growth measured as deviations from inflation reduces the degree of multicolinearity among right-hand-side variables, enabling more precise estimation by ordinary least squares. Fourth, if one estimates without imposing any restrictions on the coefficients that appear on past inflation, tests for Granger-causality conducted using the reformulated inflation equation should yield results similar to those conducted using the conventional inflation equation (7). Similar considerations hold for the reformulated wage-growth equation (10). The empirical work reported here does not impose any restrictions on coefficients in the inflation equation, meaning wage-growth coefficients are "freely estimated."

[7] See footnote 6.

its estimated magnitude measuring the size of the feedback from wage growth to inflation. Similarly, in wage growth equation (10) the freely estimated sum of coefficients $\sum_{j=1}^{s} c_{2j}$ measures the feedback from inflation to wage growth, once we control for the influence of lagged wage growth. Therefore, inflation is an independent source of wage growth if the estimated sum $\sum_{j=1}^{s} c_{2j}$ is positive and statistically different from zero. I test these hypotheses using the conventional F- and t-statistics, besides reporting the estimated sum of coefficients to gauge the quantitative significance of the feedback.

2. EMPIRICAL RESULTS

The price level is measured by the log of the chain-weighted GDP deflator (p); the productivity-adjusted wage by the log of the index of unit labor costs of the non-farm business sector $(w - q)$; and the cyclical demand (CD) by the log of real-over-potential GDP or by first differences of the civilian unemployment rate. Since supply shocks could have short-term effects on wages and prices, tests of predictive content are conducted including some of these in the system. The supply shocks considered here include the relative price of imports. Dummy variables for the period of President Nixon's wage and price controls and for the period immediately following the wage and price controls are also included. Potential GDP is the series generated using the Hodrick-Prescott (1997) filter. The data used are quarterly and cover the sample period 1952Q1 to 1999Q2.

A Preliminary Look at the Data

Figure 1 takes a preliminary look at prices and unit labor costs. It charts year-over-year growth rates of productivity-adjusted wages measured by unit labor costs and the general price level over 1952Q1 to 1999Q2. This figure clearly indicates that in the short run, productivity-adjusted wage growth and inflation appear to comove closely only over a subperiod that begins in the mid 1960s and ends in the early 1980s. This subperiod is the one during which inflation steadily accelerated. In the remaining subperiods, there does not appear to be much strong comovement between wage growth and inflation, at least in the short run. During these two subperiods, inflation remained low to moderate. Figure 1 clearly suggests that the relationship between inflation and wage growth may not be stable during the sample period considered here.

Figure 2 is similar to Figure 1 except that it charts wage growth measured by compensation per hour. It also reveals that wage growth and inflation do not comove strongly over the full sample period. Sometime since the early 1980s, however, the short-run relationship between inflation and wage growth appears to have weakened significantly.

Figure 1 Year-over-Year Unit Labor Costs Growth and Inflation: 1952Q1–1999Q2

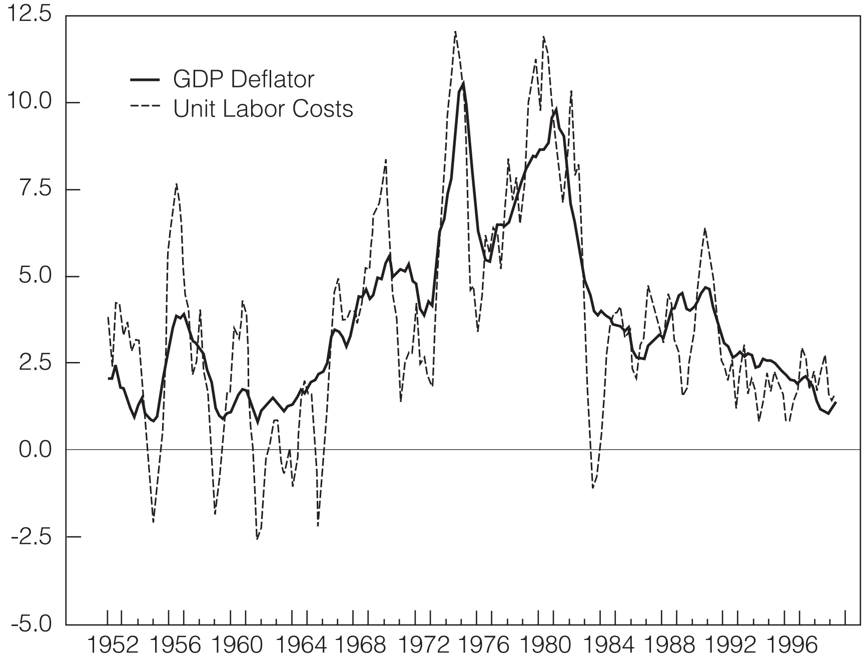
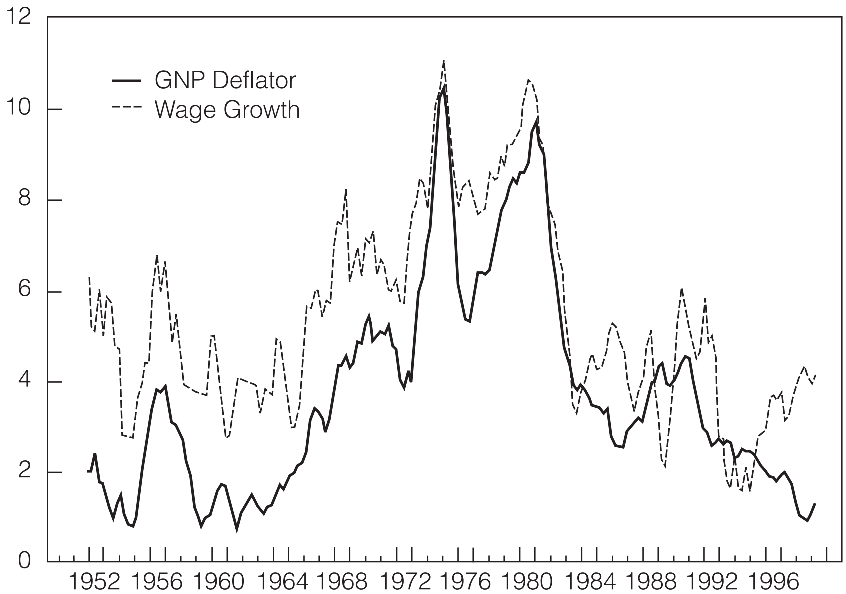


Figure 3 provides a perspective on the long-run relation between the price level and the level of unit labor costs. As in previous research, the evidence discussed below indicates that the price level and unit labor costs series $(p, w-q)$ are cointegrated over the full sample period 1952Q1 to 1999Q2 (Engle and Granger 1987). Table 1 presents the estimated cointegrating regression. Figure 3 charts the actual price level and the price level predicted by the cointegrating regression, which includes only the level of unit labor costs. As can be seen, these two series move together over most of the sample period, even during the period since the early 1980s when short-run correlation between the growth rates of these two series weakened significantly. However, one still cannot tell from Figure 3 whether this long-run comovement is the result of the price level adjusting to the level of unit labor costs, unit labor costs adjusting to the price level, or both. In order to determine the source of the long-run comovement, I now turn to results from tests performed for Granger-causality and weak exogeneity.

Figure 2 Year-over-Year Wage Growth and Inflation: 1952Q1–1999Q2



Tests for Weak Exogeneity

Before I perform tests for Granger-causality, I need to investigate whether there exists a cointegrating relation between the price level and unit labor costs during the sample period studied here. Though in many previous studies it has been shown that these two series are indeed cointegrated,[8] I repeat the test because the sample period covered in previous research differs from the one used here.

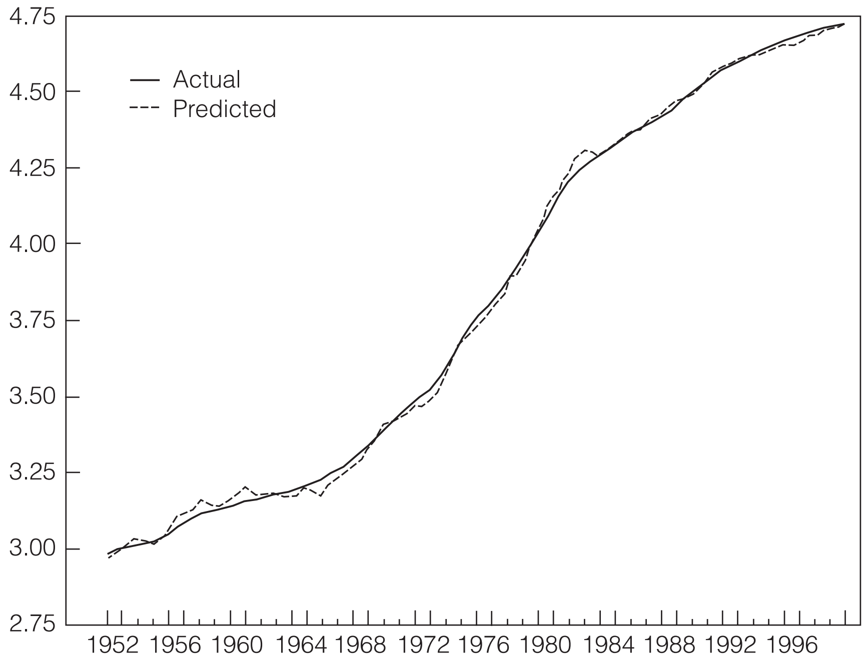
Panel A in Table 1 presents the Engle and Granger (1987) test for cointegration.[9] The test results indicate that the price level and unit labor costs are cointegrated over 1952Q1 to 1999Q2, implying the presence of a long-run equilibrium relation between the level of unit labor costs and the price level as in (4).

In order to determine if this cointegrating regression can be interpreted as the long-term price or wage equation, I present test results for weak exogeneity in panel B of Table 1. Those results indicate that in the system $(p_t, (w - q_t))$, unit labor costs are not weakly exogenous but the price level is, meaning

[8] See, for example, Mehra (1993), Hu and Trehan (1995), Hess (1999), and Ghali (1999).

[9] The unit root tests (not reported) indicate that wage and price series are integrated of order one, meaning these series are stationary after differencing once.

Figure 3 Actual and Predicted Price Level: 1952Q1–1999Q2



wages, not prices, adjust in response to deviations in the long-run cointegrating relation. Hence the cointegrating regression here cannot be interpreted as the price equation and thus contradicts the cost-push view.

If we rewrite the estimated cointegration regressions reported in panel A of Table 1 as wage regressions, we get (11).

$$\begin{aligned} \textit{Without Trend} &: \quad (w-q)_t = .25 + .94p_{t;} \qquad (11) \\ \textit{With Trend} &: \quad (w-q)_t = -.05 + .001TR_t + 1.0p_t \end{aligned}$$

The test results for weak exogeneity imply that one can interpret (11) as the long-run wage equation. The estimated coefficient that appears on the price level in (11) is not different from unity, indicating that unit labor costs have adjusted one-for-one with the price level in the long run. Together these results suggest that the long-run comovement of the price level and unit labor costs charted in Figure 3 has arisen mainly as a result of unit labor costs adjusting to the price level rather than the other way around.

Table 1 Engle-Granger Test for Cointegration

Panel A: Cointegrating Regressions: 1952Q1–1999Q2

Without Trend	With Trend
$p_t = -.26 + 1.06(w-q)_t$; ADF $= -3.52$*	$p_t = .05 + .001TR_t + .94(w-q)_t$ ADF $= -5.02$*

Panel B: Error-Correction Coefficients: Test for Weak Exogeneity

	Inflation Regression λ_p(t-statistic)	Unit Labor Costs Regression λ_w(t-statistic)
Without Trend	.017(1.9)	.16(5.2)
With Trend	.007(.58)	.27(5.9)

*Significant at the 5 percent level.

Notes: p is the chain-weighted GDP deflator; w is compensation per man hour; q is output per man hour; and TR is a linear trend. All variables except TR are in their natural logarithms, so that $w-q$ is unit labor costs. ADF is the augmented Dickey-Fuller statistic; it tests $\rho = 0$ in regressions of the form

$\Delta U_t = \rho U_{t-1} + \sum_{s=1}^{k} b_{t-s} \Delta U_{t-s}$;

where U is the residual from the cointegrating regression reported in panel A. The coefficients reported in panel B are from error-correction regressions of the form

$\Delta p_t = b_0 + \lambda_p U_{t-1} + \sum_{j=1}^{k} b_{1j} \Delta p_{t-j}$; $\Delta(w-q) = c + \lambda_w U_{t-1} + \sum_{j=1}^{k} c_{1j} \Delta(w-q)_{t-j}$,

where all variables are defined as above. The optimal lag length k used is 4, as indicated by the Akaike information criterion plus 2 (Pantula, Gonzalez-Farias, and Fuller 1994).

Granger-Causality Tests

The discussion above has focused on sources of the presence of the long-run correlation between the price level and unit labor costs as reflected in the cointegrating regression. Now I present results on the nature of the short-run feedback between the growth rates of these variables, using tests for Granger-causality. The short-run inflation and wage equations that underlie these tests are given in (9) and (10), which include one-period lagged value of the residual from the cointegrating regression reported in Table 1 (the cointegrating regression used is the one without trend).[10] I present results for the full sample 1953Q1 to 1999Q2 as well as for subsamples 1953Q1 to 1965Q4, 1966Q1 to 1983Q4, and 1984Q1 to 1999Q2.[11] Table 2 presents results with the cyclical demand measured by the output gap, and Table 3 contains results with the cyclical demand measured by changes in the civilian unemployment rate.

[10] I get qualitatively similar results if the cointegrating regression used is the one with trend.

[11] The estimation period for inflation and wage growth regressions begins in 1953Q1, earlier observations being used to capture lags in these equations.

Table 2 Testing for Short-Run Feedback: GDP Deflator and Unit Labor Costs

	Output Gap as a Measure of Cyclical Demand					
	Inflation Equation			Unit Labor Costs Growth Equation		
Sample Period	λ_p (t-value)	F1	SUM_w (t-value)	λ_w (t-value)	F2	SUM_p (t-value)
1953Q1–1999Q2	0.01 (0.5)	3.5*	0.08 (1.2)	0.03 (1.0)	7.7*	0.93 (4.9)
1953Q1–1965Q4	0.01 (1.0)	1.1	0.04 (0.4)	−0.01 (0.2)	4.2*	1.7 (4.0)
1966Q1–1983Q4	0.01 (0.9)	2.4**	0.17 (1.3)	0.03 (0.6)	2.5**	0.73 (2.1)
1984Q1–1992Q2	−0.01 (0.4)	1.1	0.00 (0.09)	0.1 (1.6)	2.4**	0.83 (2.3)

*Significant at the .05 percent level.

**Significant at the .10 percent level.

Notes: The coefficients reported above are from regressions of the form

$\Delta p_t = b_0 + \lambda_p U_{t-1} + \sum_{j=1}^{4} b_{1j}\Delta p_{t-j} + \sum_{j=1}^{4} b_{2j}\Delta(w-q-p)_{t-j} + \sum_{j=1}^{4} b_{3j} CD_{t-j} + \varepsilon_{1t}$

$\Delta(w-q)_t = c_0 + \lambda_w U_{t-1} + \sum_{j=1}^{4} c_{1j}\Delta(w - q_{t-j}) + \sum_{j=1}^{4} c_{2j}\Delta(p-(w-q))_{t-j} + \sum_{j=1}^{4} c_{3j} CD_{t-j} + \varepsilon_{2t},$

where CD is cyclical demand measured by the output gap; and U is the residual from the cointegrating regression (without the trend) reported in Table 1. F1 tests $\lambda_p, b_{2j} = 0$; F2 tests $\lambda_w, c_{2j} = 0$; $SUMw$ is the sum of b_{2j} coefficients and $SUMp$ is the sum of c_{2j} coefficients. The lag length used is indicated by the Akaike information criterion plus 2 (Pantula, Gonzalez-Farias, and Fuller 1994).

As indicated before, wage growth is an independent source of cost-push inflation if the sum of estimated coefficients $\sum_{j=1}^{s} b_{2j}$ that appear on lagged wage growth in (9) is positive and statistically different from zero, its estimated magnitude measuring the size of the feedback from wage growth to inflation. Table 2 presents the pertinent F- and t-statistics, as well as estimates of the sum of coefficients $\sum_{j=1}^{s} b_{2j}$. If we focus on full sample estimates, the estimated coefficients, b_{2j}, $j = 1, 4$, are significant by the conventional F-statistic, indicating that wage growth Granger-causes inflation (see the F1-statistic in Table 2).[12] However, the full sample estimates also indicate that the estimated sum $\sum_{j=1}^{s} b_{2j}$ is small in magnitude and not different from

[12] The lag length used here is selected by the Akaike information criterion plus 2 (Pantula, Gonzalez-Farias, and Fuller 1994). With this selection of lag length, tests discussed in Pantula, Gonzalez-Farias, and Fuller (1994) are shown to have more power. Nevertheless, results here are robust to changes in lag length.

Table 3 Testing for Short-Run Feedback: GDP Deflator and Unit Labor Costs

Unemployment Rate as a Measure of Cyclical Demand						
	Inflation Equation			Unit Labor Costs Growth Equation		
Sample Period	λ_p (t-value)	F1	SUM_w (t-value)	λ_w (t-value)	F2	SUM_p (t-value)
1953Q1–1999Q2	0.00	2.5*	0.02	0.07	7.1*	0.70
	(0.3)		(0.4)	(2.1)		(3.9)
1953Q1–1965Q4	0.02	0.8	0.03	−0.02	1.8*	0.83
	(0.8)		(0.4)	(0.1)		(2.2)
1966Q1–1983Q4	0.01	1.7	0.04	0.05	2.3*	0.67
	(0.9)		(0.4)	(0.8)		(1.9)
1984Q1–1992Q2	−0.02	0.8	−0.01	0.17	3.2*	0.91
	(1.0)		(0.1)	(1.6)		(2.9)

Notes: See notes in Table 2. Table 3 is similar to Table 2, except that cyclical demand (CD) is measured instead by changes in the civilian unemployment rate.

zero (see the t-statistic in Table 2). These results indicate that the short-run feedback from wage growth to inflation, though statistically significant, is quantitatively small and transient in nature, disappearing within a year. In contrast, the estimated sum of coefficients ($\sum_{j=1}^{s} c_{2j}$) that appear on lagged inflation in wage growth equation (10) is statistically significant and large in magnitude (see F2- and t-statistics in Table 2). In fact, the estimated sum of these coefficients $\sum_{j=1}^{s} c_{2j}$ is not different from unity, indicating that wage growth adjusts one-for-one with inflation. Together the full sample results are consistent with the presence of a bi-directional feedback between inflation and wage growth, though the size of the feedback from wage growth to inflation is quantitatively modest and transitory in nature.

If we focus on subsample estimates, we find that they indicate the result above: Wage growth Granger-caused inflation is not robust to changes in the sample period. In particular, wage growth does not Granger-cause inflation over two low inflation subperiods considered here, 1953Q1 to 1965Q4 and 1984Q1 to 1999Q2, and the sum of estimated coefficients $\sum_{j=1}^{s} b_{2j}$ that appear on lagged wage growth is also zero (see F1- and t-statistics in Table 2). However, if we consider the high inflation subperiod 1966Q1 to 1983Q4, then results indicate wage growth does Granger-cause inflation. Moreover, the estimated sum $\sum_{j=1}^{s} b_{2j}$ is large, indicating the presence of a significant feedback from wage growth to inflation. Together these results indicate that wage growth is not an "independent" source of inflation because it helps predict inflation only during the sample period of high and rising inflation. In contrast, the subperiod estimates of the coefficients, $c_{2j}\, j = 1, 4$, that measure feedback from inflation to wage growth are not sensitive to changes in the sample period. In all three subperiods considered here, inflation does Granger-cause wage growth. Furthermore, the estimated sum $\sum_{j=1}^{s} c_{2j}$ is always statistically significant and mostly close to unity, implying that wage growth adjusts one-for-one with inflation (see F2- and t-statistics in Table 2).

The Granger-causality test results presented in Table 2 are based on inflation and wage growth regressions estimated with the output gap as a measure of the cyclical demand. In order to assess whether Granger-causality results are robust to changes in the measure of the cyclical demand used, Table 3 contains results when the cyclical demand is measured instead by changes in the civilian unemployment rate. As can be seen, these alternative Granger-causality test results yield inferences about the nature of feedback between inflation and wage growth that are qualitatively similar to those produced by results in Table 2. In particular, wage growth does Granger-cause inflation in the full sample period, but then this result is not robust across all subperiods.

3. CONCLUDING OBSERVATIONS

The cost-push view of the inflation process that is implicit in the expectations-augmented Phillips curve model assigns a key role to wage growth in determining inflation. In this article, I evaluate this role by investigating empirically both the presence and stability of the feedback between wage growth and inflation during the U.S. postwar period, 1952Q1 to 1999Q2. The results indicate that wage growth does help predict future inflation over the full sample period considered here. However, this finding is very fragile, and it appears in the full sample because the estimation period includes the subperiod 1966Q1 to 1983Q4 during which inflation steadily accelerated. Wage growth does not help predict inflation in two other subperiods, 1953Q1 to 1965Q4 and 1984Q1 to 1999Q2, during which inflation remained low to moderate. In contrast, inflation always helps predict wage growth, a finding that is both quantitatively significant and stable across subperiods. These results thus do not support the view that wage growth has been an independent source of inflation in the U.S. economy.

The results here confirm what few others have found in recent work on this issue: Wage growth no longer helps predict inflation if we consider subperiods that begin in the early 1980s (Emery and Chang 1996; Hess 1999). The period since the early 1980s is the period during which the Fed has concentrated on keeping inflation low. What is new here is the finding that even in the pre-1980 period there is another subperiod, 1953Q1 to 1965Q4, during which wage growth does not help predict inflation. This is also the subperiod during which inflation remained mostly low, mainly due to monetary policy pursued by the Fed (Webb 1995).

REFERENCES

Clarida, Richard, Jordi Gali, and Mark Gertler. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics,* vol. 115 (February 2000), pp. 147–80.

Emery, Kenneth M., and Chih-Ping Chang. "Do Wages Help Predict Inflation?" Federal Reserve Bank of Dallas *Economic Review,* First Quarter 1996, pp. 2–9.

Engle, Robert F., and C. W. Granger. "Cointegration and Error-correction: Representation, Estimation, and Testing," *Econometrica,* vol. 55 (March 1987), pp. 251–76.

Engle, Robert F., David F. Hendry, and Jean-Francois Richard. "Exogeneity," *Econometrica,* vol. 51 (March 1983), pp. 277–304.

Ghali, Khalifa. "Wage Growth and the Inflation Process: A Multivariate Cointegration Analysis," *Journal of Money, Credit and Banking,* vol. 31 (August 1999), pp. 417–31.

Goodfriend, Marvin. "Interest Rate Policy and the Inflation Scare Problem 1979–1992," Federal Reserve Bank of Richmond *Economic Quarterly,* vol. 79 (Winter 1993), pp. 1–24.

Gordon, Robert J. "Foundations of the Goldilocks Economy: Supply Shocks and the Time-Varying NAIRU," *Brookings Papers on Economic Activity,* 2:1998, pp. 297–346.

______________. "The Role of Wages in the Inflation Process," *American Economic Review,* vol. 78 (May 1988), pp. 276–83.

______________. "Understanding Inflation in the 1980s," *Brookings Papers on Economic Activity,* 1:1985, pp. 263–99.

Hess, Gregory D. "Does Wage Inflation Cause Price Inflation?" Bradley Policy Research Center, Shadow Open Market Committee Policy Statement and Position Papers, September 26–27, 1999, pp. 99–102.

Hodrick, Robert J., and Edward C. Prescott. "Postwar U. S. Business Cycles: An Empirical Investigation," *Journal of Money, Credit and Banking,* vol. 29 (February 1997), pp. 1–16.

Hu, Chan G., and Bharat Trehan. "Modeling the Time-Series Behavior of the Aggregate Wage Rate," Federal Reserve Bank of San Francisco *Economic Review,* 1995, number 1, pp. 3–13.

Mehra, Yash P. "A Forward-Looking Monetary Policy Reaction Function," Federal Reserve Bank of Richmond *Economic Quarterly,* vol. 85 (Spring 1999), pp. 33–53.

______________. "Unit Labor Costs and the Price Level," Federal Reserve Bank of Richmond *Economic Quarterly,* vol. 79 (Fall 1993), pp. 35–51.

______________. "Wage Growth and the Inflation Process: An Empirical Note," *American Economic Review,* vol. 81 (September 1991), pp. 931–37.

Nordhaus, William D. "Recent Developments in Price Dynamics," in *The Econometrics of Price Determination Conference,* Board of Governors and Social Science Research Council, 1970, pp. 16–49.

Pantula, Sastry G., Graciela Gonzalez-Farias, and Wayne A. Fuller. "A Comparison of Unit-root Test Criteria," *Journal of Business and Economic Statistics,* vol. 12 (October 1994), pp. 449–59.

Stockton, David J., and James E. Glassman. "An Evaluation of the Forecast Performance of Alternative Models of Inflation," *Review of Economics and Statistics,* vol. 69 (February 1987), pp. 108–17.

Webb, Roy H. "Forecasts of Inflation from VAR Models," *Journal of Forecasting,* vol. 14 (May 1995), pp. 267–85.