Do labor market activities help predict inflation?

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Introduction and summary

Price stability is an important element in maintaining a healthy economy. Volatile prices, especially when unanticipated, can have a negative impact on aggregate demand, as people are not able to adjust and protect the real value of their financial wealth.[1] Such uncertainty can result in disruptions in business planning and reductions in capital investment spending, which could be detrimental for the long-run growth potential of the economy. In addition, inflation can impact economic welfare as wealth and income redistributions occur among different agents (Doepke and Schneider, 2006; and Franke, Flaschel, and Proano, 2006).

As experiences of some Latin American countries with hyperinflation have shown, economic growth can be seriously impaired by very high inflation (Heyman and Leijonhufvud, 1995; and Rogers and Wang, 1993). But even at much less severe levels, inflation matters. The U.S. recessions of 1973–1975, 1980, and 1981–82 were all preceded by elevated levels of inflation (Gordon, 1993).

Because of the intrinsic role of price stability in a healthy economy, controlling inflation is a primary objective of monetary policymakers. Understanding the nature of business cycles and short-run inflation dynamics is essential for the appropriate conduct of monetary policy (Svensson, 1997; and Clarida, Galí, and Gertler, 2000). In order to control inflation effectively, policymakers need to identify key indicators that help to predict inflation. Among these factors, labor market activities and, in particular, wages are closely watched. Indeed, since Phillips' (1958) paper demonstrated that there is an inverse relationship between the rate of change in money wages and the rate of unemployment, the relevance of the labor market and, in particular, the link between wages and prices have been taken as given, as noted in Fosu and Huq (1988).

It is unclear whether wage inflation causes price inflation or vice versa. If rising demand for goods and services reduces unemployment (causing it to fall below some natural rate), inflationary pressures might develop as firms bid against each other for labor and as workers feel more confident in pressing for higher wages. Then higher wages could lead to still higher prices. (In an extreme case, this might lead to a wage–price spiral, which we saw in the United States during the 1970s [Perry, 1978]).

However, if rising demand for goods and services (for example, too much money chasing too few goods) induces firms to raise their prices, these price increases and greater profits could entice workers to demand higher wages. In such an environment, inflation could lead to wage growth (Friedman, 1956; Cagan, 1972; and Barth and Bennett, 1975).

If productivity growth drives higher wages, the firm does not have to pass on higher wages into higher prices. Increased productivity therefore should curb inflationary pressures.[2]

A large body of research has aimed to model the inflation process empirically. However, as a recent review indicates, there is no consensus view of the best explanation for inflation (Rudd and Whelan, 2005). The literature focusing on how the labor and product markets interact has also produced mixed results. Much of the evidence suggests that wage growth, even adjusted for productivity, is not a causal factor in determining price inflation. However, inflation does

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help predict wages (Mehra, 1991, 1993, and 2000; Huh and Trehan, 1995; Emery and Chang, 1996; Hess, 1999; and Campbell and Rissman, 1994).

In this article, we revisit this question by conducting an empirical analysis of the role of labor market activities in inflation, including an examination of the relationship between productivity-adjusted labor costs (unit labor costs), unemployment, and price inflation. We contribute to the body of existing evidence with our use of updated and more recent data, including data for the past ten years. After incorporating alternative empirical approaches and elements from previous studies, we reach a fairly simple conclusion. Wage inflation is not very informative for predicting price inflation, especially during the period from 1984 onward, which has been dubbed by economists as "the Great Moderation." However, price inflation does seem to help predict wages. We find that the unemployment data contain additional information for both wages and prices, which supports a Phillips curve type of relationship between them (Stiglitz, 1997).

In the next section, we provide a brief review of the theoretical and empirical approaches to modeling price and wage inflation. Then we present our data and discuss the econometric model of the wage and price relationship. Finally, we test for the direction of causality between wages and prices.

Theoretical background: Modeling inflation

Irrespective of the causes for inflation, the tight relationship between wages and prices follows the paradigm of the profit-maximizing firm. In its simplest form, the firm hires labor until the cost of hiring one additional worker equals the revenue that she generates. The cost of an extra labor unit (worker) is taken as the going wage rate (assuming that workers are homogenous and the firm hires in a spot labor market, where transactions happen immediately). The firm sells its product in a spot market. The additional revenue that the firm gets from hiring one additional worker is equal to the market price of the product times the extra output that she produces. In such a market, the output price is determined by the price of the labor inputs and their productivity. This implies productivity-adjusted nominal wages grow at the same rate as product prices. In this simplified world, where the firm is a price taker in labor and product markets, the price inflation–wage inflation gap is always equal to zero.

If these assumptions are relaxed, some conditions that arise can weaken the tight link between wages and prices in the short run. As discussed in Campbell and Rissman (1994) and Huh and Trehan (1995),

labor market imperfections and certain frictions, such as adjustment costs (for example, the cost of changing employment or the presence of nominal wage rigidities), can create a wedge between the marginal product of labor and the wage rate. Such a wedge would weaken the simple framework's strong connection between price and wage inflation. In this case, in the short run there would be a deviation away from the long-run equilibrium between price inflation and productivity-adjusted wage growth. However, over time, price and wage inflation should revert to their equilibrium relationship.

The original Phillips curve model was formulated as a wage equation relating wage inflation to the unemployment gap. But the idea that systematic movements in prices and wages may be correlated is linked to the rationalization of other formulations of the model, such as the expectation-augmented Phillips curve. Attributed to versions of work by Robert J. Gordon and also known as the Gordon triangle model of inflation, the expectation-augmented Phillips curve suggests that prices are set as a markup over productivity-adjusted wages and are affected by cyclical demand dynamics, such as unemployment gaps or output gaps, and supply shocks, such as oil price shocks. In turn, wages are a function of expected prices and demand and supply shocks. Expected prices depend on past prices (Gordon, 1982, 1985; and Stockton and Glassman, 1987). The Gordon triangle model implies a relationship between wages and prices that runs in both directions in the long run. If the proposition is correct (and assuming the markup is constant or slow-moving), then long-run movements in prices and labor costs are correlated. In the short run, if prices are slow to respond to shocks in the labor market (and we allow for short-term dynamics in such behavior), we should also further expect that short-run movements in labor costs would help predict short-run movements in prices. A number of previous researchers have sought to establish the direction of causation between wages and prices, using the framework of the expectation-augmented Phillips curve and Granger causality tests[3] (Mehra, 1991, 1993, 2000; Huh and Trehan, 1995; Gordon, 1988, 1998; Emery and Chang, 1996; Hess, 1999; Campbell and Rissman, 1994; and Ghali, 1999).[4]

As noted by Stock and Watson (2008, p. 1), the traditional backward-looking Phillips curve "continues to be the best way to understand policy discussions about the rates of unemployment and inflation." Much of the evidence in the empirical literature based on the backward-looking Phillips curve suggests that wages are not a causal factor in determining inflation. However, price inflation does help predict wages.

As in much of the literature, Campbell and Rissman (1994) and Mehra (2000) find that wages do not help predict prices. Ghali (1999), a rare exception, finds that they do. In terms of econometric methodology, all three papers include an error correction (EC) term in the Gordon triangle model to accommodate some nonstationarity in the series and allow for co-integration (the long-run relation between prices and wages). Once they establish a relationship, they test for the direction of the causality via Granger causality tests. The measures of prices and wages in the three papers are similar. Prices are measured by the gross domestic product (GDP) price deflator, and productivity-adjusted wages are measured by unit labor costs.

In these papers, the authors consider different sample periods. Campbell and Rissman (1994) use data that cover 1950:Q1–1993:Q3; Mehra (2000) uses data for 1952:Q1–1999:Q2 and considers some subsample periods; and Ghali (1999) uses data covering 1959:Q1–1989:Q3. The analyses also differ in the way they transform the data to ensure stationarity.[5] As we mentioned previously, to accommodate the co-integration relation of the time series, all three papers use error correction models (ECM); however, Campbell and Rissman assume a known (one-to-one) error correction, while Mehra and Ghali assume that the EC is unknown and estimate the co-integration equation. The papers differ in the ways they capture short-run dynamics of supply and demand factors. Campbell and Rissman consider only demand, which they proxy with an unemployment rate variable. Mehra also uses only demand, but proxies it with the output gap and changes in unemployment rates. Ghali uses both demand (output gap) and supply (relative import prices). The papers also differ in their assumptions regarding the exogeneity of the demand and supply variables. Campbell and Rissman and Mehra assume that the demand factors are exogenous in the long-run equilibrium relation, so their variables do not enter the co-integration equation. But Ghali allows both demand and supply variables to enter the co-integration equation. Finally, they use different estimation methods. Campbell and Rissman use ordinary least squares (OLS). Mehra also uses OLS, but includes a first-step estimation of the co-integration equation between prices and wages. Ghali uses full maximum likelihood estimation (MLE), a technique that allows for multiple co-integration equations among prices, wages, and the demand and supply variables.

In this article, we incorporate various elements of these three papers to conduct (in-sample) forecasting of wage and price inflation within an expectation-augmented Phillips curve framework. To be consistent with the literature that suggests that the time period matters, we conduct the analysis on both a full sample (which includes updated data for the past ten years), 1960:Q1–2009:Q2, and a subsample, 1984:Q1–2009:Q2. We then conduct in-sample causality tests of several versions of the error correction model: 1) assuming a known versus an unknown co-integration relation; 2) including both supply shocks and demand dynamics with alternative measures; and 3) treating supply shocks and demand as exogenous versus endogenous.

A number of studies have looked into a new version of the Phillips curve model, the so-called new Keynesian Phillips curve, or NKPC (Chadha, Masson, and Meredith, 1992; and Fuhrer and Moore, 1995); however, this approach is not within the scope of our work in this article. This new model emphasizes staggered (spread out over time) nominal wages and assumes price setting by forward-looking agents. The main difference between the traditional Phillips curve and the NKPC is that in the latter, expected future inflation is the determinant of current inflation, whereas in the traditional expectation-augmented Phillips curve, lagged inflation plays a major role. As formalized in Yun (1996), the Calvo (1983) model of staggered pricing and the Taylor (1980) model of staggered contracts are the workhorses of the NKPC. For example, Galí and Gertler (1999) and Mehra (2004) use a specification of the NKPC inflation model in which current inflation is modeled as a function of contemporaneous demand factors and of both lagged and expected inflation. Sbordone's (2002) model also emphasizes staggered nominal wage and price setting by forward-looking agents, but allows for imperfect competition with nominal price rigidity, implying an equilibrium pricing condition whereby current inflation is linked to lagged inflation and expected future real marginal costs. In sum, the main differences among these different studies are both the degree to which forward-looking, as opposed to backward-looking, elements matter and the way in which the inertia in prices is introduced (Calvo prices versus Taylor contracts).

Data

As a starting point, we take a look at the data on wages and prices and the other demand and supply economic indicators for our sample period, 1960:Q1–2009:Q2. We define prices as the GDP deflator consistent with the three papers we discussed earlier—Campbell and Rissman (1994), Mehra (2000), and Ghali (1999).[6] For wages, we use unit labor costs for the nonfarm business sector (ULC). ULC is nominal wages, adjusted for labor productivity ($ULC = W \times L/Y$, where W equals nominal wages, L equals hours per

$p =$ log(GDP deflator), where GDP is gross domestic product

$w =$ log(ULC), where ULC is unit labor costs for the nonfarm business sector

$\pi^p =$ Δp, quarter-to-quarter growth rate of GDP deflator

$\pi^w =$ Δw, quarter-to-quarter growth rate of ULC

$g =$ log(real GDP/potential GDP); that is, the output gap

$u =$ unemployment rate – nonaccelerating inflation rate of unemployment (NAIRU); that is, the unemployment gap

$imp =$ log(relative import price deflator inclusive of oil/GDP deflator)

worker, and Y equals output, implying $ULC = W/(Y/L)$). Box 1 summarizes the definition of the variables used in this analysis.
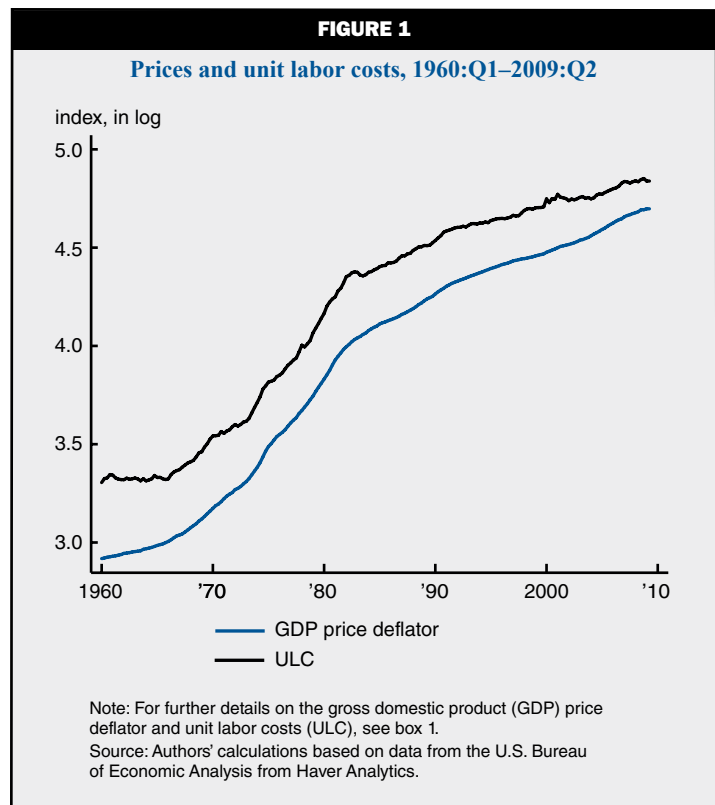
Figure 1 charts the time series of the GDP price deflator and ULC over the period 1960:Q1–2009:Q2. This chart clearly shows the correlation between the two series.

In figure 2, we report the quarter-to-quarter change (annualized) in the two series.[7] We note two distinctive periods: Inflation and wage growth increased in quite dramatic fashion in the 1970s (this is the period known for the wage–price spiral phenomenon). From the mid-1980s onward, we see a tapering off of inflation and wage growth.[8] Looking more closely at the co-behavior of the two series, from the mid-1960s up to 1984, the two series show quite a lot of co-movement. From 1984 onward, there appears to be much less co-movement between wage growth and price inflation. In fact, while wage growth continues to fluctuate, price inflation remains markedly low and stable. This figure suggests that the relationship between the two series may not be stable over the full sample period and that, as others analyzing trends in inflation and wage growth have suggested, these series may not have a "normal," or built-in, level and therefore shocks to them could be quite persistent (Fuhrer and Moore, 1995; and Benati, 2008).

The difference between the quarter-to-quarter inflation rate of the GDP deflator (π^p) and growth rate of ULC (π^w) is shown in figure 3. The difference can be viewed as representing a deviation from the long-run equilibrium (assuming a one-to-one or unit relationship, $EC = \pi^p - \pi^w$). This is clearly a simplifying assumption. We later consider versions of the model that assume constrained co-integration, where we impose unit coefficients, but we also consider a version of the model with unconstrained co-integration, where we estimate the coefficients for the error correction term.

Following the theoretical proposition of the profit-maximizing firm, such a deviation should revert to its mean in the long run. Consistent with this, in figure 3 we note that the disequilibrium term has been fluctuating around a mean of zero (that is, it has not gone up or down over time in a discernible trend). There is clearly a long-term relation between the two series, but it is unclear whether there is a causal relationship or, if there is, which one causes the other.

Figures 4 and 5 report the measures of excess demand or slack in the economy—that is, the unemployment gap and output gap. As noted in box 1, the unemployment gap is the difference between the civilian unemployment rate and the nonaccelerating inflation rate of unemployment (NAIRU). The NAIRU is provided by the Congressional Budget Office (CBO),

FIGURE 1

Prices and unit labor costs, 1960:Q1–2009:Q2

Note: For further details on the gross domestic product (GDP) price deflator and unit labor costs (ULC), see box 1.
Source: Authors' calculations based on data from the U.S. Bureau of Economic Analysis from Haver Analytics.

and it is an equilibrium rate that does not tend to increase or decrease the inflation rate. The output gap is the logarithm of the ratio of real GDP to potential real GDP. Potential real GDP is also estimated by the CBO. As can be expected, we note in these figures that unemployment increased and the output gap decreased in periods of economic slowdown (for example, in the 1970s, 1980s, and early and late 2000s).
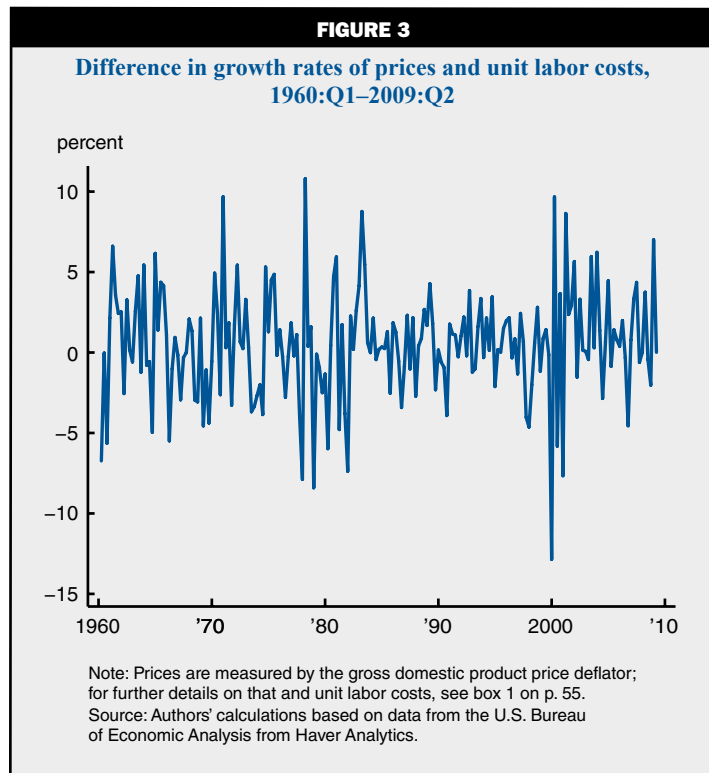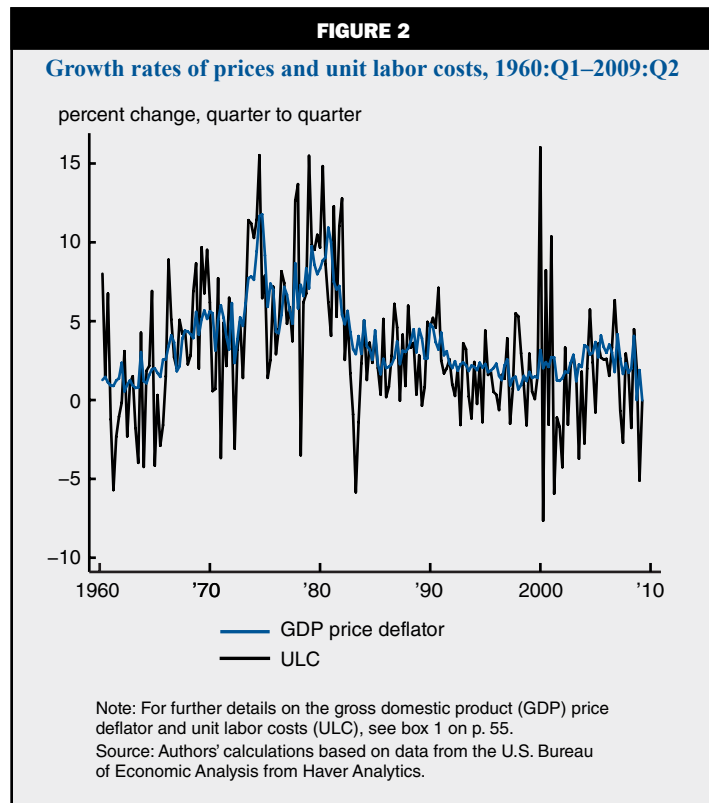
Finally, figure 6 shows the time series of the relative prices of imports, a measure of supply shocks. The role of import prices is fairly obvious. The aggregate supply curve should shift when input prices change, and input prices are affected by the prices of imports. The figure shows that prices of imports changed very little in the 1960s and early 1970s. They increased substantially in 1974 and again in 1979–80. Since 1981, relative import prices have changed very little. We would therefore expect that this variable should be relatively less important for explaining inflation in the past three decades.
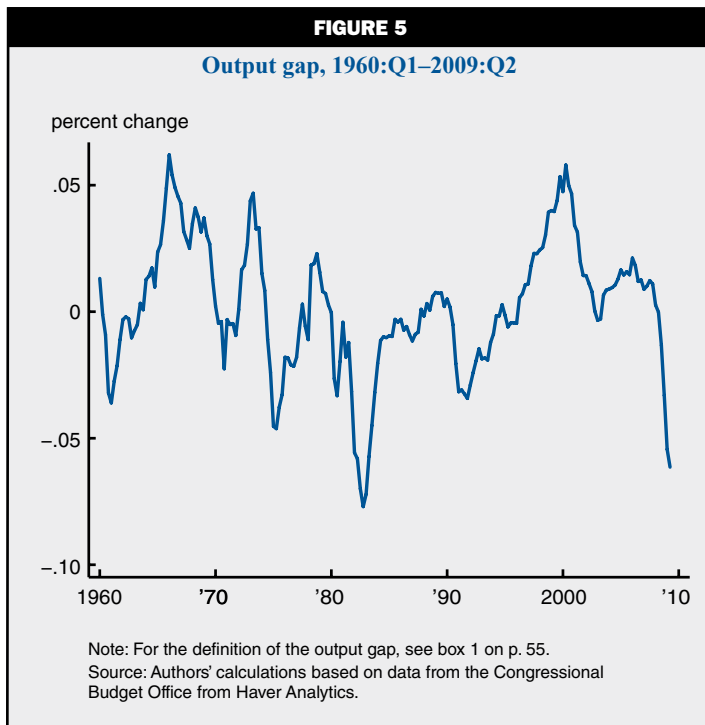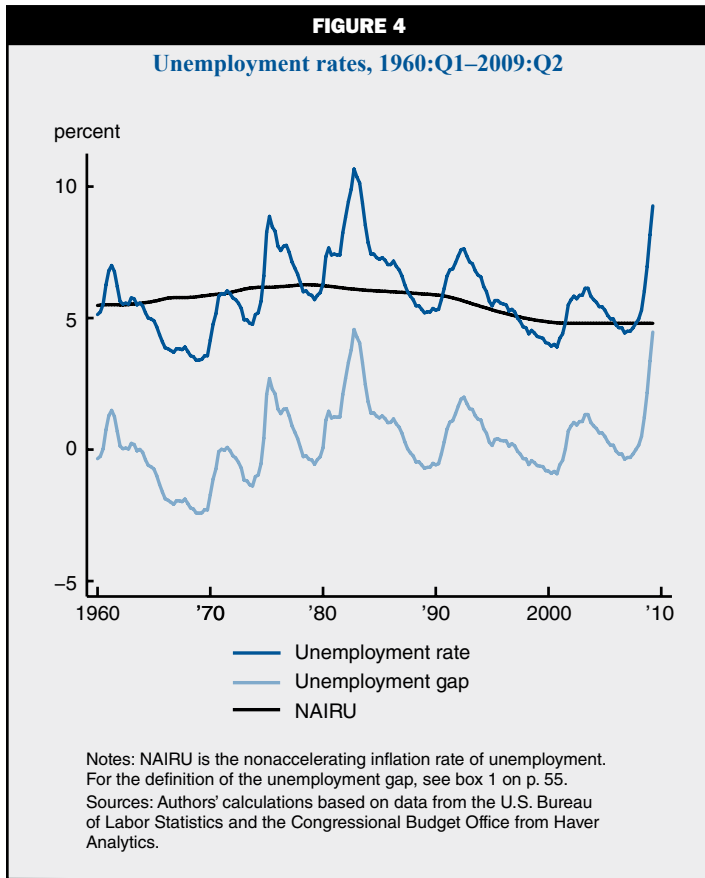
Empirical estimation

To make clear the hypotheses that we will be testing, it is useful to describe in more specific terms the expectation-augmented Phillips curve model. The basic relationships are represented by the following system of equations:

1) $\quad \pi_t^p = h_0 + h_1 \pi_t^w + h_2 DD_t + h_3 SS_{pt},$

2) $\quad \pi_t^w = k_0 + k_1 \pi_t^{e,p} + k_2 DD_t + k_3 SS_{wt},$

3) $\quad \pi_t^{e,p} = \sum_j \lambda_j \pi_{t-j}^p,$

where π_t^p is the first difference of the log of the price level; π_t^w is the first difference of the log of the nominal rate of ULC; DD_t is a vector of demand pressure variables, which include g (the output gap) and/or u (the unemployment gap) as defined previously.[9] The term $\pi_t^{e,p}$ is the expected inflation level, SS_{pt} represents supply shocks affecting the price equation, and

FIGURE 2

Growth rates of prices and unit labor costs, 1960:Q1–2009:Q2

percent change, quarter to quarter

Note: For further details on the gross domestic product (GDP) price deflator and unit labor costs (ULC), see box 1 on p. 55.
Source: Authors' calculations based on data from the U.S. Bureau of Economic Analysis from Haver Analytics.

FIGURE 3

Difference in growth rates of prices and unit labor costs, 1960:Q1–2009:Q2

percent

Note: Prices are measured by the gross domestic product price deflator; for further details on that and unit labor costs, see box 1 on p. 55.
Source: Authors' calculations based on data from the U.S. Bureau of Economic Analysis from Haver Analytics.

FIGURE 4

Unemployment rates, 1960:Q1–2009:Q2

percent

Unemployment rate
Unemployment gap
NAIRU

Notes: NAIRU is the nonaccelerating inflation rate of unemployment.
For the definition of the unemployment gap, see box 1 on p. 55.
Sources: Authors' calculations based on data from the U.S. Bureau
of Labor Statistics and the Congressional Budget Office from Haver
Analytics.

FIGURE 5

Output gap, 1960:Q1–2009:Q2

percent change

Note: For the definition of the output gap, see box 1 on p. 55.
Source: Authors' calculations based on data from the Congressional
Budget Office from Haver Analytics.

SS_{wt} represents supply shocks affecting the wage equation. Such supply shocks are proxied by *imp* (the relative import prices inclusive of oil) and two period dummies indicating President Nixon's price and wage control periods. (The first period is 1971:Q3 –1972:Q4, and the second period is 1973:Q1–1974:Q4.)

As can be seen, equation 1 reflects the idea that prices are a markup over productivity-adjusted wages and are affected by cyclical demand and relative supply shocks. Equation 2 shows that wages are affected by demand and supply and expected price level. Equation 3 shows that expected inflation is a function of past prices. Further, to accommodate the statistical features of the time series, we include an error correction term in the Gordon triangle model (equations 1–3). We also keep the demand and supply variables to affect the short-run dynamics of prices and wages. This is represented as follows:

$$\Delta \pi_t^p = \alpha^1 \left(\pi_{t-1}^p - \pi_{t-1}^w \right) + \sum_{l=1}^{L} \gamma_l^1 \Delta \pi_{t-l}^p$$

$$+ \sum_{l=1}^{L} \lambda_l^1 \Delta \pi_{t-l}^w + \sum_{l=1}^{L} \rho_l^1 DD_{t-l}^p$$

$$+ \sum_{l=1}^{L} \phi_l^1 SS_{t-l}^p + \varepsilon_t^1,$$

$$\Delta \pi_t^w = \alpha^2 \left(\pi_{t-1}^p - \pi_{t-1}^w \right) + \sum_{l=1}^{L} \gamma_l^2 \Delta \pi_{t-l}^p$$

$$+ \sum_{l=1}^{L} \lambda_l^2 \Delta \pi_{t-l}^w + \sum_{l=1}^{L} \rho_l^2 DD_{t-l}^w$$

$$+ \sum_{l=1}^{L} \phi_l^2 SS_{t-l}^w + \varepsilon_t^2.$$

The error correction term $(EC = \pi_{t-1}^p - \pi_{t-1}^w)$ allows for a long-run equilibrium relationship between price and wage inflation. The parameter α therefore reflects long-run dynamics, and γ and λ capture short-run dynamics. The term ε_t^1 is the residual from the price equation, while ε_t^2 is the residual from the wage regression. L is the maximum number of lags on the various variables needed to make the random disturbances serially uncorrelated. Again, as previously noted, *DD* and *SS* are vectors of variables representing

demand and supply shocks affecting price and wage inflation, as in some previous studies (for example, Mehra, 2004; and Hess and Schweitzer, 2000).

We have the following hypotheses concerning the joint short-run and long-run equilibrium relationships in wages and prices: Hypothesis 1 is that wages do not predict prices ($H_0 : \alpha^1 = 0, \lambda_1^1 = 0, ..., \lambda_L^1 = 0$). Hypothesis 2 is that prices do not predict wages ($H_0 : \alpha^2 = 0, \gamma_1^2 = 0, ..., \gamma_L^2 = 0$).

Recalling that the parameter α reflects long-run dynamics, while γ and λ capture short-run dynamics, we test for the hypotheses and determine the sources of the short-run and long-run co-movements between wages and prices, using Granger causality tests. Our test for Granger causality involves examining whether lagged values of one series (that is, wages) have significant explanatory power for another variable (that is, prices). In this exercise, both variables may Granger-cause one anoth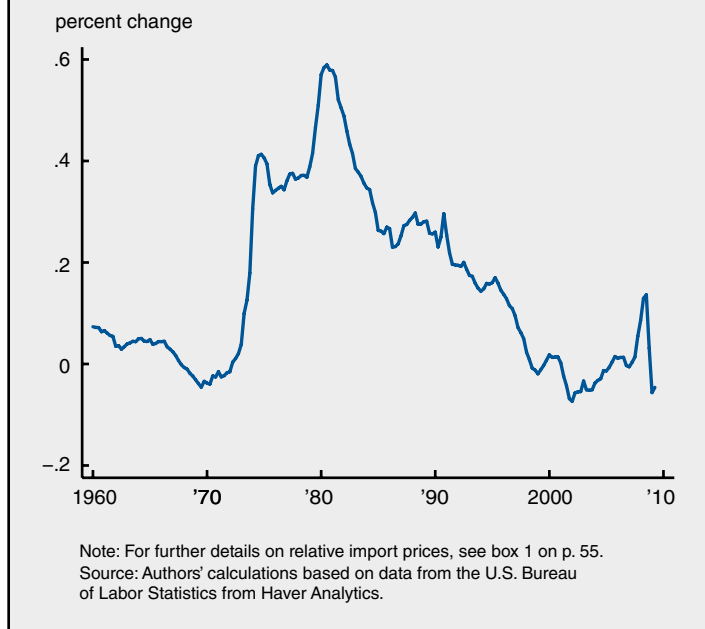er.[10] Both series in question may also be co-integrated. Recall that by incorporating an error correction term in the Granger causality tests, we allow the series in levels to catch up with or equal one another. The significance of the error correction term in the Granger causality test would signal the fact that the series in question are driven to return to a long-run equilibrium relationship that is causal.

Granger causality test results

Before conducting the Granger causality tests, we examined the stationarity of the series. The results of the augmented Dickey–Fuller (ADF) unit root tests for price inflation and wage inflation confirmed that we cannot reject the null hypothesis of a unit root at the 1 percent level—that is, the growth rates of prices and wages are both integrated of order one, I(1). Also, for the full sample period (1960:Q1–2009:Q2), the relative import prices (*imp*), unemployment gap (*u*), and output gap (*g*) are also all I(1).

Table 1 presents the results of our tests for Granger causality between wages and prices for the full sample period, 1960:Q1–2009:Q2, and for a subsample period, 1984:Q1–2009:Q2. In this bivariate model, we assume that $DD = 0$ and $SS = 0$. The regression includes lagged prices and lagged unit labor cost growth. The number of lags for each variable is set to four ($L = 4$). Panel A of table 1 reports the evidence on whether the column variables Granger-cause price inflation, while panel B

FIGURE 6

Relative import prices, 1960:Q1–2009:Q2

percent change

Note: For further details on relative import prices, see box 1 on p. 55.
Source: Authors' calculations based on data from the U.S. Bureau of Labor Statistics from Haver Analytics.

shows the evidence for whether the column variables Granger-cause wage growth. The error correction column refers to the long-run effect; the wages column (in panel A) and prices column (in panel B) refer to the short-run effect; and the joint hypothesis column refers to the long- and short-run effects. Each column reports the *p* value, the level of statistical significance with which one can reject the null hypothesis. A high *p* value should be taken as evidence that the column variable does *not* Granger-cause price or wage inflation.

Referring back to the ECM, to be co-integrated, at least one of the α_s in the two equations should not be equal to zero. Looking at panel A of table 1 for the full sample period, 1960:Q1–2009:Q2, the high *p* value in the error correction column means that $\alpha^1 = 0$. Therefore, we can say that prices do not catch up with wages in the long run. But rather wages adjust to catch up with prices ($\alpha^2 \neq 0$), per the low *p* value for error correction in panel B. The high *p* value for hypothesis 1 of the joint test of error correction and wages (panel A, third column) suggests that wages don't help predict prices in either the short run or the long run (at a 5 percent significance level).

To summarize the results in table 1, wages do not cause price inflation in our Granger causality tests. However, prices do cause wage inflation. Wages, but not prices, adjust to maintain the long-run equilibrium relationship. This is true for both the full sample (1960:Q1–2009:Q2) and the subsample (1984:Q1–2009:Q2).

TABLE 1

Granger causality test: Bivariate model

Period	A. Are prices caused by			B. Are wages caused by		
	Error correction	Wages	Hypothesis 1: Joint test of error correction and wages	Error correction	Prices	Hypothesis 2: Joint test of error correction and prices
1960:Q1–2009:Q2	0.32	0.34	0.06	0.00	0.06	0.00
1984:Q1–2009:Q2	0.82	0.29	0.27	0.00	0.38	0.00

Notes: The number of lags for each variable is set to four. Each column reports the *p* values, indicating the level of statistical significance for the test that the column variable does not Granger-cause either price inflation or wage inflation. See the text for details on hypothesis 1 and hypothesis 2.
Sources: Authors' calculations based on data from the U.S. Bureau of Labor Statistics from Haver Analytics.

Besides the price–wage inflation gap, our model stipulated that there are other short-run demand and supply determinants of price and wage inflation. To allow for these cyclical (that is, excess) demand factors to additionally affect wages and prices in the short run, we add the unemployment gap (and, alternatively, the output gap, which we do not report in the table) to our regressions. We also add supply variables, as proxied by the relative import prices and dummy variables for the Nixon price and wage control periods. We run the regressions with these demand and supply control variables in differences, as we found that they were I(1). Both demand and supply control variables include their lags, which were set to four. And again, we include the error correction term.

Table 2 reports the *p* values from the Granger causality tests for this augmented model. The results in both panels A and B of this table suggest that wages do not predict prices; however, prices do predict wages. In the long run, wages adjust to the error correction, while prices do not. In other words, price and wage inflation move together in the long run because wages adjust to close the gap, and not because price inflation responds to wage growth.

As for the additional regressors, for the full sample, the unemployment gap has additional predictive power for both price and wage inflation, while the relative import prices only help predict price inflation. For the subsample, 1984:Q1–2009:Q2, the unemployment gap only helps predict price inflation, while the relative import prices do not help predict either. Using alternative measures of excess demand (for example, changes in the unemployment rate or the output gap) yields qualitatively similar results, which we do not report here.

We find the result of the informational content of the unemployment gap for both wage and price inflation interesting; it suggests that such cyclical variables

play an important short-term role in determining inflation (Campbell and Rissman, 1994). In the tradition of a Phillips curve type of relationship, price inflation thus appears to be still very much a labor market phenomenon (Stiglitz, 1997).

The two models that we have discussed thus far constrain the co-integration relationship between price inflation and wage inflation to be one to one, which can be justified by theory under the assumption of perfect competition and a Cobb–Douglas production function (for example, as in Campbell and Rissman, 1994). However, this might be too restrictive an assumption.

We relax this restriction and consider a generalized model, allowing for an unconstrained co-integration relationship between prices and wages (that is, in the unconstrained case, we estimate the coefficients for the error correction terms). Moreover, we also allow the supply and demand variables to enter the long-run equilibrium relation. In other words, the supply and demand variables are now treated as endogenous and could enter the error correction. (For simplicity, we do not reproduce the new augmented generalized ECM, but note that this means our model now gets augmented by two more equations with the demand and supply variables on the left-hand side). First, looking at the *p* value results for the joint short-run and long-run hypothesis between wages and prices based on the unconstrained model in table 3, panels A and B, we note that similar to the results in table 2, wages do not help predict prices, but prices do help predict wages.

Recall that in this new unconstrained model, the coefficients for all the variables are being estimated. This ECM was estimated by the maximum likelihood estimation technique. For the full sample, the model was found to be co-integrated with rank 2 (that is, it has two unique co-integration relationships). The two estimated co-integration relationships, with the standard errors in parentheses, are as follows:

TABLE 2

Granger causality test: Multivariate model

| | A. Are prices caused by | | | | | B. Are wages caused by | | | | |
Period	Error correction	Wages	Unemployment gap	Relative import prices	Hypothesis 1: Joint test of error correction and wages	Error correction	Prices	Unemployment gap	Relative import prices	Hypothesis 2: Joint test of error correction and prices
1960:Q1–2009:Q2	0.26	0.63	0.00	0.00	0.29	0.00	0.00	0.00	0.09	0.00
1984:Q1–2009:Q2	0.87	0.16	0.00	0.10	0.17	0.00	0.21	0.05	0.75	0.00

Notes: The number of lags for each variable is set to four. Each column reports the *p* values, indicating the level of statistical significance for the test that the column variable does not Granger-cause either price inflation or wage inflation. See the text for details on hypothesis 1 and hypothesis 2.
Sources: Authors' calculations based on data from the U.S. Bureau of Labor Statistics and Congressional Budget Office from Haver Analytics.

TABLE 3

Granger causality test: Multivariate model with unknown co-integration parameters

| | A. Are prices caused by | | | | | B. Are wages caused by | | | | |
Period	Error correction	Wages	Unemployment gap	Relative import prices	Hypothesis 1: Joint test of error correction and wages	Error correction	Prices	Unemployment gap	Relative import prices	Hypothesis 2: Joint test of error correction and prices
1960:Q1–2009:Q2	0.25	0.40	0.00	0.00	0.06	0.00	0.00	0.09	0.01	0.00
1984:Q1–2009:Q2	0.62	0.12	0.00	0.04	0.15	0.00	0.22	0.53	0.21	0.00

Notes: The model was estimated by using the maximum likelihood estimation technique. The number of lags for each variable, chosen by the Akaike Information Criterion (AIC), is set to four. Each column reports the *p* values, indicating the level of statistical significance for the test that the column variable does not Granger-cause either price inflation or wage inflation. See the text for details on hypothesis 1 and hypothesis 2.
Sources: Authors' calculations based on data from the U.S. Bureau of Labor Statistics and Congressional Budget Office from Haver Analytics.

$$\pi^p = 2.84 - \underset{(0.35)}{1.40} u + \underset{(2.35)}{8.27} \, imp,$$

$$\pi^w = 1.89 - \underset{(0.42)}{1.98} u + \underset{(2.75)}{11.76} \, imp.$$

As can be seen, the unemployment gap and relative import prices variables enter both co-integration equations significantly. However, we find that the adjustment parameters on the error correction terms in the equations of the unemployment gap and relative import prices were statistically insignificant. (For simplicity, we do not report the unemployment gap and relative import prices equations here.) This suggests that these two variables do not adjust (as wages and prices do) to maintain the long-run equilibrium relations. In fact, the likelihood ratio test for the null hypothesis that the adjustment parameters in the unemployment gap and relative import prices equations are jointly zero has a p value of 0.68.

For the subsample, 1984:Q1–2009:Q2, the unemployment gap is I(2) instead of I(1). After replacing the unemployment gap by its first difference, the model is estimated to have one co-integration relation. In this case, the unemployment gap and the relative import prices do not even enter the co-integration equation significantly. The unemployment gap and the relative import prices appear to be exogenous in the long-run equilibrium, especially in the subsample period.

Conclusion

Much research has been devoted to not only identifying the causes of inflation but also gauging which economic indicators could best measure and predict inflation. Using more recent and updated data, we analyzed labor market indicators, namely, productivity-adjusted wages and unemployment (as well as supply shock and demand factors), to determine the extent to which they contain information to help predict inflation.

Similar to previous research, we have found that wage growth does not cause price inflation in the Granger causality sense. We found this to be particularly true for the period from 1984 onward (referred to as the Great Moderation by economists). By contrast, price inflation does cause wage growth in the Granger causality sense. Moreover, unemployment has additional predictive power for inflation for the full sample (1960:Q1–2009:Q2), as well as our subsample (1984:Q1–2009:Q2). The unemployment gap is therefore a useful indicator for inflation.

As the data indicate, in recent years wage growth has been particularly slow. Given this, some analysts think that we do not have to be overly concerned about future inflation. Our findings in this article, however, do not support the claim that slow wage growth is a harbinger of low inflation.

NOTES

[1]For further discussion of the effects of inflation, see, for example, Dossche (2009).

[2]Federal Reserve Chairman Ben S. Bernanke (2008) noted in a speech that we are unlikely to see the 1970s type of wage–price spiral in today's economy. Crucial productivity gains that help blunt inflationary forces were among the several factors cited. Also, inflation expectations, although somewhat on the rise, are much lower than they were in the mid-1970s.

[3]Granger causality is a statistical methodology for demonstrating whether a variable contains information about subsequent movements in another variable.

[4]Stock and Watson (2008) provide a survey of the literature of the past 15 years, which looks at out-of-sample forecast evaluations based on Phillips curves as well as other inflation forecasting models.

[5]Mehra (2000) and Ghali (1999) treat prices and wages as integrated of order one, I(1), while Campbell and Rissman (1994) treat the growth rates of prices and wages as I(1).

[6]We also conducted the analysis using the U.S. Bureau of Economic Analysis's Personal Consumption Expenditures Price Index as the price measure. Generally, the results were similar.

[7]The results in the subsequent analysis are largely robust to an alternative measure of inflation using a four-quarter change in price.

[8]As mentioned earlier, this period has been dubbed by economists as the Great Moderation, when macroeconomic indicators were remarkably stable (see, for example, Bernanke, 2004; Kim and Nelson, 1999; McConnell and Perez-Quiros, 2000).

[9]Several explanations have been offered in the literature to motivate unemployment in a wage and price equation. Beside the Phillips (1958) underlying model of change in wages as a function of the unemployment rate, the literature of efficiency wages provides some motivation (for example, Shapiro and Stiglitz, 1984). Huh and Trehan (1995) provide a summary of the logic of the efficiency wage approach in explaining the inclusion of unemployment in a wage and price equation. Also, see Ghali (1999) and Gordon (1988).

[10]More specifically, the Granger causality test is a two-step regression procedure used to examine the direction of causality between two series. For example, to determine whether there is causality running from p to w, w is first estimated as a function of past values of w (this is called the restricted equation). Then w is estimated as a function of past values of w and past values of p (this is called the unrestricted regression). There is causality in the Granger sense from p to w if the inclusion of the past values of p significantly improves the estimation of w (that is, by an F test).

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