# Long-run labor market dynamics and short-run inflation

**Jeffrey R. Campbell and Ellen R. Rissman**

Looking back on the experience of the 1970s, Arthur Okun commented that "some insidious ratchet has gone into operation, giving inflation a far greater degree of persistence than it ever had before."[1] His observation appears just as insightful today as when it first appeared. With nominal productivity-adjusted wage growth averaging only 4.1 percent over the 1980s, why has inflation remained stubbornly at 4.5 percent?

The tangled relation between price and wage inflation has been the subject of much debate and little consensus among macroeconomists. The Keynesian revolution provided a somewhat unified view of the macroeconomy but gave aggregate demand issues more attention than aggregate supply. As a result, inflation and its relation to nominal wage growth remained poorly understood aspects of the economy. Although monetarists such as Friedman (1968) were quick to point out the potential difficulties of ignoring nominal issues, the point was not of central concern to macroeconomists until the 1970s, when inflation inexplicably picked up. The relative indifference until that time was probably due partly to the fact that Keynesianism and its derivatives were reasonably able to explain the pre-1970s workings of the macroeconomy. Also, since aggregate supply was more or less stable through the 1960s, inflation was not an important issue.

Until the 1970s, wage growth was successfully explained by a short-run Phillips curve in which nominal wage growth is assumed to depend on the degree of labor market tightness, usually measured as some function of the unemployment rate. Although not formally developed in a cohesive theoretical structure, the conceptual appeal of the Phillips curve is quite apparent. As the labor market becomes tighter (that is, the unemployment rate declines), it becomes increasingly difficult for firms to find and keep qualified workers at the existing wage rate, and employers are forced to raise their salary offers. Knowing that wages are rising and that other jobs are available at higher wages, workers can successfully demand higher wages. The converse is also assumed, namely, that as the unemployment rate rises, wages decline—although whether they decline as quickly as they rise is open to debate. The typical theoretical model linked wages to prices via some sort of markup in which inflation equals nominal wage growth net of productivity growth. Furthermore, productivity was believed to grow at a roughly constant rate.

The stable 1960s gave way to the stagflation of the 1970s, in which inflation remained high in the face of an apparently excess aggregate supply. It appeared that the Phillips curve

Jeffrey R. Campbell is a doctoral candidate at Northwestern University, department of economics, and Ellen R. Rissman is an economist at the Federal Reserve Bank of Chicago. The authors would like to thank Ken Kuttner and Steve Strongin for their helpful comments and suggestions. Campbell also thanks the Alfred P. Sloan Foundation for financial support through a doctoral dissertation fellowship.

was no longer stable, and that lower inflation could be achieved only with ever higher levels of unemployment, as inflationary expectations caused workers to demand increasing compensation. The weak link in the Keynesian model had failed.

During the 1970s and early 1980s, in an attempt to "fix" the Phillips curve, economists sought to shed light on the relationship between nominal wage growth and inflation. They recognized that in addition to measures of labor market activity, inflationary expectations were also potential determinants of nominal wage growth.[2] Economic thinking of this period suggested that if workers care only about their real compensation, then they incorporate their expectations for inflation into their wage demands. If their current expectations of inflation depend on previous inflation, then past inflation would determine nominal wage growth, which in turn would determine current inflation via a markup.[3]

In addition to emphasizing the joint determination of wages and prices through an expectations mechanism, several researchers including Gordon (1977), Perry (1980), and Hamilton (1983) have suggested that the instability of the Phillips curve in the 1970s was the result of special factors such as the acceleration and termination of the Vietnam War, the implementation of wage and price controls, and the oil price shocks. These hypotheses have met with only modest empirical success in that even after such factors have been accounted for, the parameters of the Phillips curve still appear to have shifted.

Other economists such as Sachs (1980), Barro (1977), and Taylor (1980) have theorized that underlying structural changes occurred in the inflation process that caused the instability of the Phillips curve. An increase in the use of longer-term labor contracts and a public belief that monetary and fiscal policy would be used to promote high employment and stable prices worsened the trade-off between inflation and unemployment. Finally, Rissman (1993) suggests that the instability of the Phillips curve is the result of structural changes in the economy that have altered the relative importance of cyclical and structural unemployment, and that cyclical unemployment is the relevant determinant of nominal wage growth.

Essentially, the Phillips curve in its narrowest context deals with the determination of nominal wage growth given the level of economic activity. How nominal wage growth relates to inflation is open to debate. Indeed, even the direction of causality between nominal wage growth and inflation is open to debate. Discussion of the high inflation rates that prevailed in the 1970s focused on the "wage-price spiral," and economists differentiated between two distinct types of inflation: cost-push and demand-pull. Cost-push inflation relates the rate of growth of the cost of factors of production to price increases. Depending upon the structure of production, firms are more or less able to pass on cost increases in the form of higher prices. In turn, higher output prices reduce the real income to factors of production, the owners of which attempt to raise factor prices. In this scenario, wage growth and inflation quickly spiral, with wage growth causing inflation, which in turn causes additional wage growth. Perry (1978), for example, focuses entirely on wage inflation as an underlying cause of price inflation. Okun (1981) also assigns a central role to the labor market in his model of inflation and business cycles.

Demand-pull inflation is the result of somewhat different forces. Excess aggregate demand causes output prices to increase, and consequently, real earnings to factors of production are reduced. The owners of these factors demand compensation and frequently are rewarded as firms' profits rise and firms are able to absorb the higher cost of production. In this scenario, the direction of causality runs from prices to wages.[4]

Both of these scenarios imply a direct link between nominal wages and prices. One foundation for this conviction is the paradigm of the profit-maximizing firm operating in competitive product and labor markets. Such a firm will increase employment until the cost of hiring an additional worker exactly offsets the revenues he or she generates. If workers are homogeneous and employed in a spot market for labor, the cost of an extra labor unit is simply the going wage rate. If the firm sells its product in a competitive spot market, the additional revenue generated from hiring an extra worker is the market price of the good multiplied by the extra physical output he or she produces. In such a market, the price is determined by the price of inputs and their productivity. An implication of this is that productivity-adjusted nominal wages always grow at the current rate of inflation.

This idealization of labor and product markets abstracts from potentially important market imperfections. For example, some firms enjoy monopsony power in labor markets. The employment decisions of large firms in small geographic regions impact local wage rates. Similarly, a firm which is the only employer of workers with a special skill has a degree of control over their wages. When a firm acts as the sole employer in a labor market, the labor supply curve to the firm is no longer infinitely elastic at the going wage rate. Instead, the monopsonist faces an upward-sloping supply curve of labor. In order to attract an additional worker, the monopsonistic profit-maximizing firm must increase the wage rate paid to all workers, thereby creating an additional hiring cost. This creates a wedge between the marginal product of labor and the wage rate. The wedge breaks the simple framework's tight connection between wage inflation and price inflation.

By changing the firm's level of employment, adjustment costs are another potentially important source of friction that can create a wedge between the marginal product of labor and the wage rate. On the hiring side, it may take some time to find qualified workers and then additional time to train new hires in the specifics of their jobs. When reducing its work force, the firm faces the costs of low morale, severance pay, and potentially higher unemployment insurance payments. These considerations make it prohibitively expensive to adjust employment instantaneously to its optimal level. Only in the long run after some gradual adjustment of employment will the marginal or equilibrium condition hold.

In a competitive product market with many firms producing similar products, all firms equalize the cost of producing additional output with the market price. However, a firm producing a good with no close substitute can set its price above its marginal cost of production. If only a few firms serve a market, they can collude to raise the market price above its competitive level. Changes in firms' markups also cause wage inflation to differ from price inflation. For example, if firms fight a temporary price war, then price inflation will be less than wage inflation.

These caveats suggest that the static equilibrium condition between productivity-adjusted nominal wages and prices implied by profit-maximizing behavior will not hold at every point in time. Imperfections in the labor and product markets can cause the rates of price and wage inflation to differ in the short run. There will be a tendency for the firm's static equilibrium condition to hold only in the long run. Although at any given time there will be a gap between the rate of growth of nominal wages (adjusted for productivity growth) and the inflation rate, this gap will tend to disappear over time. This observation is central for assessing the accuracy of arguments about inflationary pressures stemming from nominal wage growth; it is also important for the modeling, interpretation, and forecasting of wage and price inflation.

This article analyzes a simple forecasting model of wage and price inflation. Economic theory affords useful insight into the long-term relationship between wage and price inflation, but less insight into their short-term dynamics. By using the error corrections framework studied by Engle and Granger (1987), the model accounts for the long-run restriction on wage and price inflation, but leaves their short-run dynamics unconstrained.

Although it is useful to examine the joint behavior of wages and prices in a bivariate context, models of the Phillips curve have long suggested that the level of economic activity has an important impact on the degree of wage inflation. In particular, greater unemployment dampens wage growth, which then translates into lower price inflation. The baseline forecasting model uses only wage and price inflation to forecast their future values. An extension of this bivariate model incorporates the unemployment rate in the analysis in keeping with the literature on the Phillips curve.

The analysis focuses on the short-run predictive power of wage inflation and price inflation using simple $F$-tests for this purpose. The estimation of the baseline model suggests that price inflation is useful for predicting wage inflation, but that the converse is *not* true. In fact, wage inflation has no discernible short-run impact on prices, so that information about current wage growth cannot help predict the path of future prices. Although in the long run the gap closes between productivity-adjusted wage growth and inflation, it is wage growth that adjusts to close the gap.

Including the unemployment rate into the model further strengthens the conclusion that wage inflation has little bearing on price inflation. Once unemployment has been admitted into the model, however, price inflation ceases to be a short-run determinant of wage growth in spite of the long-run relationship between the two. Using different methods, Gordon (1988) and Mehra (1993) reached similar conclusions. Test results indicate that the unemployment rate is a short-run determinant of both price and wage inflation. Unlike the bivariate model, wage inflation does not respond directly to the gap between wage and price growth. Rather, the unemployment rate first responds, then wage inflation reacts to the change in unemployment via a Phillips curve type of channel.

The remainder of this article is divided into four sections. The first section considers the theory of labor demand in more detail and analyzes its implications for short- and long-term behavior of wages, productivity, and prices. The next section presents the data used to estimate the forecasting model and discusses their time-series properties. The section that follows uses the model to test the short-term predictive power of wage inflation for price inflation under the maintained hypothesis that the long-run wage-inflation gap is zero. The final section provides a brief summary of the results and some concluding remarks.

## Labor demand

The paradigm of the profit-maximizing firm underlies the theory of labor demand. A firm choosing its labor force to maximize its profit will hire until the revenue generated by an additional worker equals the costs of her employment. Let $r(L)$ and $c(L)$ respectively denote the revenue received and cost incurred from hiring an additional worker when the firm already employs $L$ workers. These functions are called the marginal revenue and marginal cost of labor. The profit-maximizing firm hires additional labor up to the point where

(1) $r(L) = c(L)$.

If this equilibrium condition did not hold, then the firm could raise or lower its level of employment to attain a higher level of profits.

The marginal revenue associated with hiring an additional unit of labor is the value of the extra output generated. If a firm operates in a competitive market, it cannot influence the price of its good. In this case, the marginal revenue product of labor equals the market price, $P$, multiplied by the physical output attained from employing an additional worker. Suppose that a production function, $Q = f(L)$, describes a firm's production technology. The physical output produced with $L$ workers is $Q$. The first derivative of the production function, $f'(L)$, is the additional output produced from hiring an additional worker. With this production technology, this firm's marginal revenue is $r(L) = Pf'(L)$.

If this firm also operates in a competitive labor market without any costs of adjustment, then the cost of hiring an additional worker is her wage, $W$. In this simple case, the equilibrium condition from equation 1 can be simplified to

(2) $W = Pf'(L)$.

In an economy populated by such firms, the price of output always equals the productivity-adjusted wage, $W/f'(L)$. This also constrains the price's growth rate, price inflation, and the growth rate of the productivity-adjusted wage, wage inflation. Taking logarithms of equation 2 and subtracting it from itself across two adjacent time periods, $t$ and $t$–1, yields

(3) $\Delta w_t - \Delta z_t = \pi_t^p$,

where

$\Delta w_t = \ln W_t - \ln W_{t-1}$ and is the growth rate of nominal wages;

$\Delta z_t = \ln f'(L_t) - \ln f'(L_{t-1})$ and is the growth rate of labor's marginal physical product; and

$\pi_t^p = \ln P_t - \ln P_{t-1}$ and is the rate of price inflation.

If we define $\pi_t^w = \Delta w_t - \Delta z_t$ as the rate of productivity-adjusted wage inflation, then equation 3 implies that the growth rates of price and wage inflation equal one another. In this simple world, the price inflation-wage inflation gap always equals zero.

Relaxing the assumption that firms are price-takers in labor and product markets can weaken the tight connection between wage and price inflation. In the case of monopoly or oligopoly, the output price no longer equals the competitive price. The monopolistic firm faces a downward-sloping demand curve for its product; that is, it is unable to sell all additional units of output it produces at the current price. When production is increased, the price of all units of output declines. The profit-maximizing monopolist must internalize this price effect in determining its optimal level of output and employment. In effect, because a degree of monopoly power is introduced, a wedge is introduced in the equilibrium condition of equation 2 so that the term on the right-hand side of the equation exceeds the wage rate. A similar wedge is introduced when the firm is the sole purchaser of a given labor service. In the case of a monopsonist, the firm faces an upward-sloping supply curve for labor; that is, it cannot hire additional labor input at the existing wage rate. Instead, if the firm increases the level of employment, the wage paid to all labor rises accordingly so that the marginal cost in fact exceeds the wage. The equilibrium condition of equation 2 no longer holds. Instead a wedge is introduced that causes the value of the marginal product of labor to exceed the wage.

Let $\mu$ be the markup, that is, the amount by which the output price, $P$, differs from the productivity-adjusted wage rate, $W/f'(L)$. The equilibrium condition then becomes

$$(4)\quad P\mu = W/f'(L),$$

where $\mu > 1$. The markup is determined by the degree of monopoly and monopsony power in the particular market. Furthermore, the markup can change over time. In an oligopolistic industry, price wars cause the markup to decrease. Decreasing the markup shifts the labor demand curve outwards. The increased demand for labor that results should be associated with a decline in the unemployment rate. Similarly, the monopsonist markup depends upon the number of close competitors for labor services. As the monopsonist's markup declines, the demand curve for labor services effectively shifts outward, again producing a decrease in the unemployment rate.

Other models of the labor market also suggest a wedge between the nominal wage rate and the value of the firm's marginal product of labor. For example, suppose that the firm incurs substantial hiring and firing costs when adjusting its labor input. Hiring costs can reflect such items as search and training costs. Firing costs can reflect problems with worker morale, legal fees, and higher unemployment insurance expenses. Costs such as these, that are incurred when the firm changes its level of employment, are referred to generally as adjustment costs. The profit-maximizing firm must assess how its current hiring and firing decisions affect its future production. By increasing its level of employment, the firm incurs not only the direct cost of wages, but also an additional adjustment cost that depends on the change in the level of employment. If the firm's level of employment is nearly optimal, then adjustment costs will be relatively small and the equilibrium condition of equation 2 holds reasonably well. However, adjustment costs can be substantial, with significant deviations from the equilibrium condition.

According to this model, the deviations are not completely random. Suppose, for example, that the firm finds it optimal to increase its labor force. It does not increase it to the new equilibrium level all at once, but gradually so as to avoid incurring large adjustment costs. During this period of adjustment, the value of the firm's marginal product of labor exceeds the wage rate with the gap declining over time. The model suggests that the productivity-adjusted wage-price gap should at some times be positive and at other times negative. Moreover, the gap should adjust slowly over time so that, for example, if it is positive today, it is likely to continue to be positive tomorrow; that is, the gap is positively serially correlated.

In the case in which adjustment costs are captured by $(c/2)(L_{t+1} - L_t)^2$, the equilibrium condition becomes

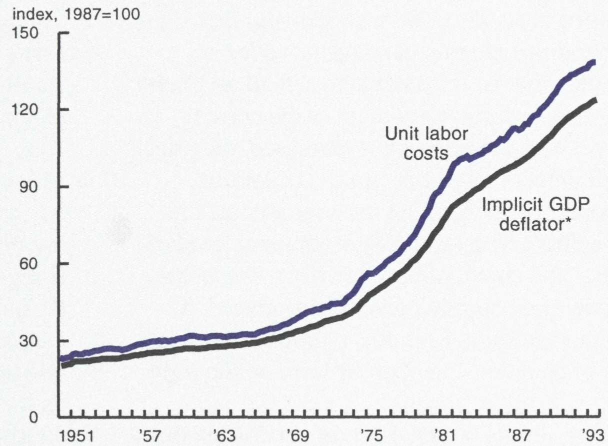
$$(5)\quad Pf'(L) = W + c(L_{t+1} - L_t) - c\beta(L_t - L_{t-1}),$$

where $\beta$ is the discount factor and $t$ indexes the time period. In the long run after the firm is at its optimal level of employment where $L_{t+1} = L_t = L_{t-1}$, the last two terms in equation 5 disappear so that the familiar marginal condition holds. In the short term, deviations will occur from the equilibrium described in equation 2.

This simple model does not directly address the issue of unemployment. However, it is reasonable to expect that periods of time during which firms are rapidly increasing their level of employment will coincide with periods of falling unemployment. Conversely, when firms lay off workers, the unemployment rate should rise. This observation suggests that while in the long term the rate of growth of productivity-adjusted wages equals the inflation rate, short-term deviations are correlated with the unemployment rate.

**FIGURE 1**

**Wage and price trends**




*Nominal nonfarm nongovernment gross domestic product divided by real nonfarm nongovernment gross domestic product.

Source: U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings*.

## The data

The theory of the profit-maximizing firm presented above suggests that there is a specific long-run relation between wage inflation and price inflation. Short-term deviations may occur, but there is a tendency for these variables to converge to their equilibrium relation expressed in equation 3. The analysis that follows includes data for the United States nonfarm business sector. Agriculture and government are omitted from the discussion because of the difficulty in imputing wages in the former sector and the noncompetitive nature of the latter. The price level variable, denoted as *PGDP*, is defined as the implicit gross domestic product (GDP) deflator for the nonfarm business sector. This has been constructed by dividing nominal GDP less government and farm output by the analogous real quantity. The unemployment rate, *UR*, is that of the civilian labor force. The Bureau of Labor Statistics measures unit labor costs for the nonfarm business sector, *ULC*, as $w * L/y$ where $y$ is real output, $L$ is labor hours, and $w$ is the nominal wage.[5] If production can be described by a Cobb-Douglas technology, the average and marginal productivity are identical. Unit labor costs therefore measure productivity-adjusted nominal wages.

The data cover the period beginning the first quarter of 1950 and ending the third quarter of 1993. The price level (*PGDP*) and productivity-adjusted nominal wages (*ULC*) are shown in figure 1. The two series follow each other quite closely, with price and wage growth accelerating through the late 1970s and slowing markedly in the 1980s. Growth rates of the two series ($\pi^p$ and $\pi^w$) are shown in figure 2. Again the time-series pattern between the two are quite similar. Both exhibit increasing growth over the 1960s with a significant decline in the 1980s. However, neither inflation nor productivity-adjusted nominal wage growth appears to revert to its mean. In fact, the most salient feature is the persistence of both inflation and productivity-adjusted wage growth. Inflation tends to increase at the same

**FIGURE 2**

**Growth rates of prices and wages**

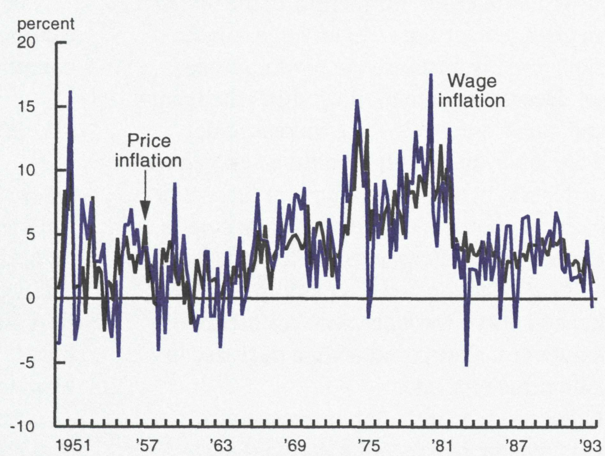
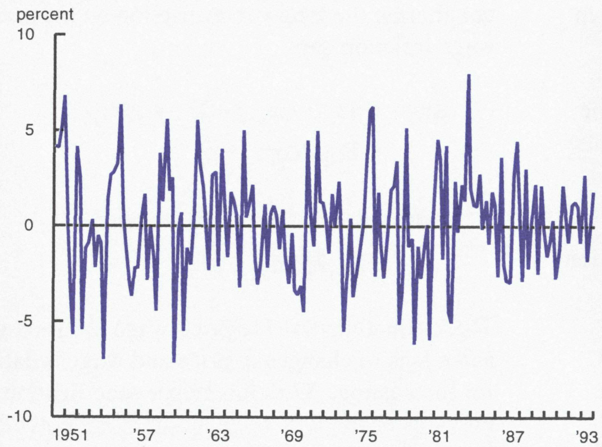


FIGURE 3

Price inflation less productivity-adjusted wage growth




*EC* should exhibit some positive serial correlation and revert to its mean over time; that is, it should be stationary. The evidence in figure 3 clearly supports this interpretation.

Finally, the civilian unemployment rate is shown in figure 4. Although there does appear to be an increase in the unemployment rate over the 1970s and early 1980s with a subsequent decline, formal tests of whether there is a "normal" long-run level of unemployment to which it reverts are inconclusive.

Table 1 reports summary statistics for inflation ($\pi^p$), productivity-adjusted nominal wage growth ($\pi^w$), the disequilibrium term (*EC*), and civilian unemployment (*UR*). All growth rates are expressed in annual percentage terms and are calculated as the log first difference in the variable.

The table clearly shows the increase in inflation from 2.8 percent in the 1950s to 6.7 percent in the 1970s with a decline in the 1980s to 4.5 percent. Similar behavior holds true for productivity-adjusted wage growth. In the 1950s, wage growth averaged 2.8 percent, increasing over the 1970s to 6.8 percent and declining in the 1980s to 4.1 percent. Although the two series are similar in magnitude, wage growth is much more volatile. As expected, the disequilibrium term *EC* shows no tendency to rise or fall over time. Finally, the unemployment rate shows a slight upward trend through the 1960s, increasing dramatically in the 1970s and 1980s.

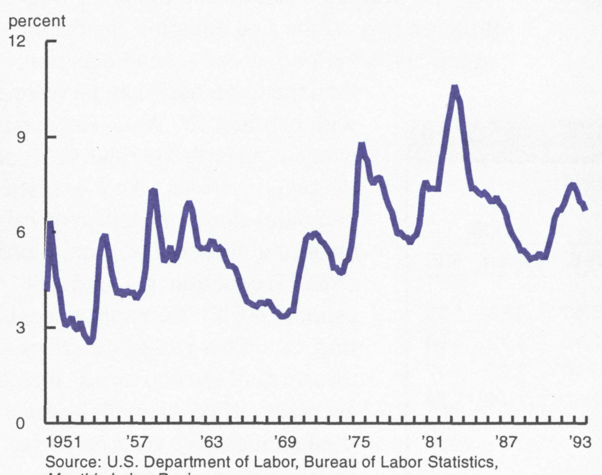
The crude descriptions of the variables' time-series behavior suggests that empirical models of wage and price dynamics should incorporate the following behaviors. First, inflation has no long-term "normal" level, and shocks to inflation appear to be persistent. In other words, disturbances to inflation tend to be permanent. In addition, although inflation and wage growth both exhibit some persistence, with no

time that wage growth is rising. Although simple correlations do not imply causality, the similarity in time-series behavior between inflation and wage growth suggests that there may be some superficial justification for the contention that lower wage growth should lead to lower inflation rates.

The difference between inflation and productivity-adjusted nominal wage growth ($EC = \pi^p - \pi^w$) reflects deviations away from long-run equilibrium. The disequilibrium term, *EC*, is shown in figure 3. According to the theory of the firm discussed above, this term should be zero in the long run. In terms of its time-series behavior, this suggests that

FIGURE 4

The civilian unemployment rate




Source: U.S. Department of Labor, Bureau of Labor Statistics, *Monthly Labor Review*.

tendency to revert to a mean rate of growth, there does appear to be a stable long-term relation between the two series, with disturbances to one apparently affecting the other in much the same way. Finally, we interpret abnormally high or low levels of unemployment as being transitory, so that there is some stable "normal" unemployment rate, regardless of its current value.

## Forecasting

A forecasting framework that accounts for these features of the data and the long-run restriction on wage and price inflation is the error corrections model. Engle and Granger (1987) discuss the econometric restrictions which this model imposes. In the simplest form of this model, the changes in wage and price inflation are linear functions of the price-wage inflation gap plus a random error term:

$$(6)\quad \Delta\pi^p_t = \alpha^1(\pi^p_{t-1} - \pi^w_{t-1}) + \varepsilon^1_t$$
$$\Delta\pi^w_t = \alpha^2(\pi^p_{t-1} - \pi^w_{t-1}) + \varepsilon^2_t.$$

The error terms, $\varepsilon^1_t$ and $\varepsilon^2_t$, are normally distributed and have zero mean. They are possibly correlated with each other, but they are independent over time. In the short run, changes in price and wage inflation respond to the price-wage inflation gap. If the system were left undisturbed, these adjustments would eliminate the gap in the long run. Because the error terms constantly disturb the system, however, the gap never closes to zero. Rather, it fluctuates around it.

The system's short-run dynamics are very simple. If $a^1 < 0$ and $a^2 > 0$, then price inflation decreases and wage inflation increases to eliminate the price-wage inflation gap. In this case, only the current price-wage inflation gap is useful for constructing inflation forecasts.

Including lagged changes in price and wage inflation on the right-hand side of model 6 enriches the system's short-run dynamics without altering the long-run restriction on the price-wage inflation gap:

$$(7)\quad \Delta\pi^p_t = \alpha^1(\pi^p_{t-1} - \pi^w_{t-1}) + \Sigma^k_{j=1}\gamma^1_j\Delta\pi^p_{t-j} + \Sigma^k_{j=1}\lambda^1_j\Delta\pi^w_{t-j} + \varepsilon^1_t$$

$$\Delta\pi^w_t = \alpha^2(\pi^p_{t-1} - \pi^w_{t-1}) + \Sigma^k_{j=1}\gamma^2_j\Delta\pi^p_{t-j} + \Sigma^k_{j=1}\lambda^2_j\Delta\pi^w_{t-j} + \varepsilon^2_t.$$

These equations use the price-wage inflation gap and $k$ lags of changes in price and wage inflation for forecasting. With this richer specification, previous changes in wage inflation are potentially useful for forecasting price inflation. The model's parameters are not known, but they can be estimated using ordinary least squares.

Whether wage inflation is useful for forecasting price inflation depends upon the model's parameters. If either $\alpha^1 \neq 0$ or $\lambda^1_j \neq 0$ for some $j$, then data on wage inflation help forecast price inflation. If this is not true, then forecasts using only price inflation data are adequate. Therefore, a test of the null hypothesis,

$$(8)\quad H_0 \begin{cases} \alpha^1 = 0 \\ \lambda^1_1 = 0 \\ \vdots \\ \lambda^1_k = 0, \end{cases}$$

will indicate whether wage inflation can help forecast price inflation.

It is simple to test hypothesis 8 by estimating the first equation of model 7 and estimating an analogous equation eliminating lagged changes in wage inflation and the price-wage inflation gap. If the first equation fits the data significantly better than the second equation, then the hypothesis can be rejected with confidence. An $F$-test can be used to quantify the relative fit of the two equations. An $F$-statistic compares the estimated standard error of $\varepsilon^1_t$ from the original (unrestricted) equation, $\sigma_{1u}$, and that estimated from the restricted equation, $\sigma_{1r}$. These standard errors are measures of the equations' forecast accuracy. If $\sigma_{1u}$ is much larger than $\sigma_{1r}$ then including data on wage inflation produces much more

**TABLE 1**

**Summary statistics, 1950:Q1 – 1993:Q3**

| | $\pi^p$ | | $\pi^w$ | | EC | | UR | |
|---|---|---|---|---|---|---|---|---|
| **Decade** | **Mean** | **S.E.** | **Mean** | **S.E.** | **Mean** | **S.E.** | **Mean** | **S.E.** |
| 1950s | 2.80 | 2.90 | 2.82 | 4.15 | –0.02 | 3.50 | 4.51 | 1.28 |
| 1960s | 2.53 | 1.85 | 2.61 | 3.27 | –0.08 | 2.50 | 4.78 | 1.08 |
| 1970s | 6.70 | 2.74 | 6.78 | 4.20 | –0.09 | 3.10 | 6.22 | 1.17 |
| 1980-93 | 4.54 | 2.48 | 4.09 | 3.74 | 0.45 | 2.65 | 7.11 | 1.39 |

Note: S.E. indicates the standard error.

accurate forecasts. In this case, the $F$-statistic will be large, providing evidence against the hypothesis that wage inflation does not help forecast price inflation. To decide whether the $F$-statistic is large enough to warrant rejecting the null hypothesis, it can be compared to the critical values of its distribution when hypothesis 8 is true. If the $F$-statistic exceeds one of the conventional critical values, then the null hypothesis can be rejected with confidence.

**TABLE 2**

***F*-tests, bivariate error corrections model**

| Dependent variable | Excluded data | Test statistic | Degrees of freedom | | Lags |
|---|---|---|---|---|---|
| $\Delta\pi^p$ | $\pi^w$ | 0.55 | 5 | 140 | 4 |
| $\Delta\pi^p$ | $\pi^w$ | 0.79 | 7 | 136 | 6 |
| $\Delta\pi^p$ | $\pi^w$ | 0.88 | 9 | 132 | 8 |
| $\Delta\pi^w$ | $\pi^p$ | 5.99*** | 5 | 140 | 4 |
| $\Delta\pi^w$ | $\pi^p$ | 3.59*** | 7 | 136 | 6 |
| $\Delta\pi^w$ | $\pi^p$ | 3.30*** | 9 | 132 | 8 |

***$p < .01$

Table 2 presents $F$-statistics that test the null hypothesis 8 and those testing the converse hypothesis for the second equation of model 7, that price inflation does not help forecast wage inflation:

$$(9)\ H_0 \begin{cases} \alpha^2 = 0 \\ \gamma_1^2 = 0 \\ \vdots \\ \gamma_k^2 = 0. \end{cases}$$

The $F$-statistics were calculated using 4, 6, and 8 lags of price and wage inflation changes as regressors in both the restricted and unrestricted equations. The reported statistics use the entire data sample for estimation. Removing the Korean War period (1950-1953) does not significantly alter the results.

For price inflation and wage inflation to move together in the long run, either $\alpha^1 \neq 0$ or $\alpha^2 \neq 0$. Otherwise, neither variable would respond to the price-wage inflation gap. In the bivariate model, this implies that one of hypotheses 8 and 9 is false. Separately applying $F$-tests to the price and wage inflation equations of 7 could possibly generate the nonsensical result that neither hypothesis 8 nor 9 can be rejected. This did not occur in practice.

The results of the tests are clear, and they contradict the view that wage inflation is a good short-run predictor of price inflation. With every lag length examined, the $F$-test provides no evidence against hypothesis 8, that wage inflation is *not* helpful for forecasting price inflation. In contrast, the $F$-tests universally reject hypothesis 9, that price inflation is not a useful predictor of wage inflation. The estimated error corrections model suggests that wage inflation responds to price inflation and to the price-wage inflation gap, but that price inflation has a life of its own.

These results illustrate the pitfalls of extrapolating from the long run to the short run. In the estimated version of the error corrections model, wage inflation and price inflation move together. This says nothing about how they adjust in the short run. They move together because wages adjust to close the price-wage inflation gap, not because price inflation responds to wage inflation.

One advantage of the simple bivariate error corrections model is its parsimony. However, the model focuses on the price-wage inflation gap, when there may be other important short-run determinants of price and wage inflation. One obvious candidate for such a determinant is the unemployment rate. By tightening and loosening the labor market, changes in the unemployment rate can have short-run effects on wage inflation. To the extent that firms' prices reflect changes in their labor costs, the unemployment rate can also cause short-run movements in price inflation. To incorporate these effects into the error corrections model, one can include lags of the unemployment rate in the wage and price inflation equations. Augmenting those equations with an unemployment equation completes the trivariate error corrections model:

$$(10)\ \Delta\pi_t^p = \alpha^1(\pi_{t-1}^p - \pi_{t-1}^w) + \Sigma_{j=1}^k \gamma_j^1 \Delta\pi_{t-j}^p + \Sigma_{j=1}^k \lambda_j^1 \Delta\pi_{t-j}^w + \Sigma_{j=1}^k \delta_j^1 u_{t-j} + \varepsilon_t^1$$

$$\Delta\pi_t^w = \alpha^2(\pi_{t-1}^p - \pi_{t-1}^w) + \Sigma_{j=1}^k \gamma_j^2 \Delta\pi_{t-j}^p + \Sigma_{j=1}^k \lambda_j^2 \Delta\pi_{t-j}^w + \Sigma_{j=1}^k \delta_j^2 u_{t-j} + \varepsilon_t^2$$

$$u_t = \alpha^3(\pi_{t-1}^p - \pi_{t-1}^w) + \Sigma_{j=1}^k \gamma_j^3 \Delta\pi_{t-j}^p + \Sigma_{j=1}^k \lambda_j^3 \Delta\pi_{t-j}^w + \Sigma_{j=1}^k \delta_j^3 u_{t-j} + \varepsilon_t^3.$$

The error term in the unemployment equation, $\varepsilon_t^3$, is identically and independently normally distributed over time. It is possibly correlated with $\varepsilon_t^1$ and $\varepsilon_t^2$.

Including unemployment as a short-run determinant of inflation alters the dichotomy found with the simpler bivariate model. Although wage inflation does not significantly enter the price equation, the unemployment rate does. On the other hand, including unemployment in the wage equation reduces the importance of price inflation. The unemployment rate significantly enters the wage equation, but lagged price inflation does not. This suggests that the unemployment rate plays a key short-run role in maintaining the long-run restriction on the price-wage inflation gap.

**TABLE 3**

***F*-tests, trivariate error corrections model**

| Dependent variable | Excluded data | Test statistic | Degrees of freedom | | Lags |
|---|---|---|---|---|---|
| $\Delta\pi^p$ | $\pi^w$ | 2.49** | 5 | 136 | 4 |
| $\Delta\pi^p$ | $\pi^w$ | 1.51 | 7 | 130 | 6 |
| $\Delta\pi^p$ | $\pi^w$ | 1.36 | 9 | 124 | 8 |
| $\Delta\pi^w$ | $\pi^p$ | 0.98 | 5 | 136 | 4 |
| $\Delta\pi^w$ | $\pi^p$ | 0.83 | 7 | 130 | 6 |
| $\Delta\pi^w$ | $\pi^p$ | 1.00 | 9 | 124 | 8 |

**$p < .05$

Table 3 presents the *F*-statistics that test the null hypotheses 8 and 9 using the trivariate error corrections model 10. Because unemployment can react to the price-wage gap, and price and wage inflation can react to unemployment, it is no longer necessary for either hypothesis 8 or 9 to be incorrect. The test fails to reject hypothesis 8 for all three lag specifications. When $k = 4$, the hypothesis that wage inflation does not help forecast price inflation is rejected at the .05 level. With the other two lag specifications, the test statistic falls below all conventional critical values. Adding unemployment to the analysis reduces the forecast power of price-inflation and the price-wage inflation gap.

If price and wage inflation do not help forecast one another, then at least one of them must be influenced in the short run by the unemployment rate. Table 4 reports *F*-tests of the hypotheses that the unemployment rate does not influence price or wage inflation in the short run. The null hypothesis for the first test is

$$(11)\quad H_0 \begin{cases} \delta_1^l = 0 \\ \vdots \\ \delta_k^l = 0. \end{cases}$$

When $l = 1$, this restriction omits the unemployment rate from the price equation. If $l = 2$, the unemployment rate is dropped from the wage equation. The test statistics indicate that the unemployment rate is an important short-run determinant of price and wage inflation. Unemployment enters the wage equation significantly with all three lag specifications. Unlike in the bivariate model, wage inflation does not respond directly to the gap. Rather, the unemployment rate first responds. Then wage inflation reacts to the change in unemployment via a Phillips curve type mechanism. Consideration of the unemployment rate also casts doubt on the proposition that the price level is independent of labor market phenomena. With four and six lags, the unemployment rate significantly enters the price equation.

Both the bivariate and trivariate systems of hypothesis 8 and model 10 can be used to generate forecasts of inflation. The results are shown in table 5. No exclusionary restrictions have been incorporated. The equations have been estimated over the period beginning in 1956:Q3 and ending in 1993:Q3 so that the Korean War period is excluded. In addition, the estimation was done using 4, 6, and 8 lags

**TABLE 4**

***F*-tests, trivariate error corrections model**

| Dependent variable | Excluded data | Test statistic | Degrees of freedom | | Lags |
|---|---|---|---|---|---|
| $\Delta\pi^p$ | $u$ | 3.08** | 5 | 136 | 4 |
| $\Delta\pi^p$ | $u$ | 1.98* | 7 | 130 | 6 |
| $\Delta\pi^p$ | $u$ | 1.64 | 9 | 124 | 8 |
| $\Delta\pi^w$ | $u$ | 4.59*** | 5 | 136 | 4 |
| $\Delta\pi^w$ | $u$ | 3.73*** | 7 | 130 | 6 |
| $\Delta\pi^w$ | $u$ | 2.80*** | 9 | 124 | 8 |

*$p < .10$
**$p < .05$
***$p < .01$

**TABLE 5**

**Inflation and wage growth forecasts, bivariate and trivariate models**

| | | Bivariate model | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 lags | | 6 lags | | 8 lags | |
| Year | Quarter | $\Delta\pi^p$ | $\Delta\pi^w$ | $\Delta\pi^p$ | $\Delta\pi^w$ | $\Delta\pi^p$ | $\Delta\pi^w$ |
| 1994 | 2 | 0.0044 | 0.0055 | 0.0132 | 0.0166 | 0.0168 | 0.0166 |
| 1994 | 4 | 0.0040 | 0.0045 | 0.0153 | 0.0193 | 0.0163 | 0.0140 |
| 1995 | 2 | 0.0035 | 0.0032 | 0.0156 | 0.0148 | 0.0142 | 0.0167 |
| 1995 | 4 | 0.0035 | 0.0035 | 0.0146 | 0.0144 | 0.0157 | 0.0169 |
| 1996 | 2 | 0.0036 | 0.0035 | 0.0145 | 0.0143 | 0.0154 | 0.0159 |
| 1996 | 4 | 0.0036 | 0.0036 | 0.0144 | 0.0140 | 0.0150 | 0.0163 |
| | | Trivariate model | | | | | |
| 1994 | 2 | 0.0002 | −0.0098 | 0.0071 | 0.0030 | 0.0166 | 0.0195 |
| 1994 | 4 | −0.0030 | −0.0057 | 0.0075 | 0.0146 | 0.0175 | 0.0103 |
| 1995 | 2 | −0.0037 | −0.0017 | 0.0115 | 0.0158 | 0.0150 | 0.0158 |
| 1995 | 4 | −0.0033 | −0.0030 | 0.0142 | 0.0164 | 0.0147 | 0.0152 |
| 1996 | 2 | −0.0030 | −0.0042 | 0.0143 | 0.0145 | 0.0137 | 0.0138 |
| 1996 | 4 | −0.0031 | −0.0046 | 0.0132 | 0.0103 | 0.0136 | 0.0123 |

of the data. The forecast period begins in 1993:Q4 and ends in 1996:Q4. No standard errors have been estimated so that care must be taken in interpreting the results.

To summarize the results, inflation forecasts are sensitive to the lag length used in the estimation as well as the model employed. Because the uncertainty surrounding these forecasts was not computed, these are only meant to be crude guideposts. Forecasts of price and wage growth increase with lag length in both the bivariate and trivariate models. Using only four lags of data, the inflation forecasts are unreasonably low. This reflects a great weight given to the wage deflation at the end of 1993. Forecasts constructed using 6 and 8 lags assign this deflation a smaller weight. Adding the unemployment rate to the system slightly changes the forecasts. In the case of six lags, wage growth and inflation are lower at the beginning of the forecast period when unemployment is incorporated in the analysis. The converse appears to be the case when eight lags of data are used in the estimation.

## Conclusions

The short-run forecasting exercise illustrates an important point: It is dangerous to extrapolate short-run behavior from long-run restrictions. Although it is tempting to use information about nominal wage growth to infer the future path of prices, it is not valid to do so. The error corrections models estimated here are consistent with the long-run restriction that price and wage inflation equal each other. However, wage inflation is not a good short-run predictor of price inflation. In a simple bivariate analysis, price inflation appears to have a life of its own. 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 inflation.

Including unemployment as a short-run determinant of inflation alters the results of the simpler bivariate model. The unemployment rate significantly enters both the price and wage equations. Price inflation no longer appears to have a life of its own, but is influenced by labor market phenomena. The empirical results cast doubt on the simple wage-price spiral view of inflation. Unlike the bivariate model, price inflation does not enter the wage equation once unemployment is incorporated. This suggests that the unemployment rate plays a key short-run role in maintaining the long-run restriction on the price-wage inflation gap. The exact nature of this role is not yet clear, but a Phillips curve type of relation seems to appear in the sense that lagged unemployment is an important predictor of nominal wage and price growth.

This finding implies lessons for policymakers. First, any argument that lower infla-

**TABLE 5**

**Inflation and wage growth forecasts, bivariate and trivariate models**

| | | Bivariate model | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 lags | | 6 lags | | 8 lags | |
| Year | Quarter | $\Delta\pi^p$ | $\Delta\pi^w$ | $\Delta\pi^p$ | $\Delta\pi^w$ | $\Delta\pi^p$ | $\Delta\pi^w$ |
| 1994 | 2 | 0.0044 | 0.0055 | 0.0132 | 0.0166 | 0.0168 | 0.0166 |
| 1994 | 4 | 0.0040 | 0.0045 | 0.0153 | 0.0193 | 0.0163 | 0.0140 |
| 1995 | 2 | 0.0035 | 0.0032 | 0.0156 | 0.0148 | 0.0142 | 0.0167 |
| 1995 | 4 | 0.0035 | 0.0035 | 0.0146 | 0.0144 | 0.0157 | 0.0169 |
| 1996 | 2 | 0.0036 | 0.0035 | 0.0145 | 0.0143 | 0.0154 | 0.0159 |
| 1996 | 4 | 0.0036 | 0.0036 | 0.0144 | 0.0140 | 0.0150 | 0.0163 |
| | | Trivariate model | | | | | |
| 1994 | 2 | 0.0002 | −0.0098 | 0.0071 | 0.0030 | 0.0166 | 0.0195 |
| 1994 | 4 | −0.0030 | −0.0057 | 0.0075 | 0.0146 | 0.0175 | 0.0103 |
| 1995 | 2 | −0.0037 | −0.0017 | 0.0115 | 0.0158 | 0.0150 | 0.0158 |
| 1995 | 4 | −0.0033 | −0.0030 | 0.0142 | 0.0164 | 0.0147 | 0.0152 |
| 1996 | 2 | −0.0030 | −0.0042 | 0.0143 | 0.0145 | 0.0137 | 0.0138 |
| 1996 | 4 | −0.0031 | −0.0046 | 0.0132 | 0.0103 | 0.0136 | 0.0123 |

of the data. The forecast period begins in 1993:Q4 and ends in 1996:Q4. No standard errors have been estimated so that care must be taken in interpreting the results.

To summarize the results, inflation forecasts are sensitive to the lag length used in the estimation as well as the model employed. Because the uncertainty surrounding these forecasts was not computed, these are only meant to be crude guideposts. Forecasts of price and wage growth increase with lag length in both the bivariate and trivariate models. Using only four lags of data, the inflation forecasts are unreasonably low. This reflects a great weight given to the wage deflation at the end of 1993. Forecasts constructed using 6 and 8 lags assign this deflation a smaller weight. Adding the unemployment rate to the system slightly changes the forecasts. In the case of six lags, wage growth and inflation are lower at the beginning of the forecast period when unemployment is incorporated in the analysis. The converse appears to be the case when eight lags of data are used in the estimation.

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The short-run forecasting exercise illustrates an important point: It is dangerous to extrapolate short-run behavior from long-run restrictions. Although it is tempting to use information about nominal wage growth to infer the future path of prices, it is not valid to do so. The error corrections models estimated here are consistent with the long-run restriction that price and wage inflation equal each other. However, wage inflation is not a good short-run predictor of price inflation. In a simple bivariate analysis, price inflation appears to have a life of its own. 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 inflation.

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This finding implies lessons for policymakers. First, any argument that lower inflation is likely since wage growth is slow is not supported by the data. Rather, the bivariate model suggests that price growth does not respond to wage growth. Second, wage and price growth projections depend on the variables included in the model. If one wishes to forecast future wage and price growth, the unemployment rate is a useful guide.

## FOOTNOTES

[1]See Okun (1981), p. 3.

[2]See Gordon (1982, 1985, 1988) and Stockton and Glassman (1987) for examples of the expectations-augmented Phillips curve.

[3]Several researchers, including Sachs (1980) and Neumark and Leonard (1991) have experimented with alternative expectations formulations and incorporated more complicated models of wage and price dynamics.

[4]For an assessment of cost-push versus demand-pull inflation, see Barth and Bennett (1975).

[5]The data used to construct the implicit price deflator for the nonfarm business sector come from the *National Income and Product Accounts* published by the U.S. Department of Commerce. Data on the unemployment rate can be found in the *Monthly Labor Review*, and unit labor costs can be found in *Employment and Earnings*, both published by the U. S. Department of Labor, Bureau of Labor Statistics.

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