Sectoral wage growth and inflation

Ellen R. Rissman

Most mainstream macroeconomists believe that the price of forcing the unemployment rate permanently below the natural rate of unemployment for a prolonged period of time is ever-increasing inflation. If this overheating occurs, the conventional wisdom is that the inflation rate can be reduced to more acceptable levels only if one endures a difficult recessionary period during which the unemployment rate exceeds the natural rate. In the parlance of economists, there is a vertical long-run Phillips curve that limits the ability of policymakers to independently affect both the rate of inflation and the unemployment rate. In the short run, the Federal Reserve may be able to reduce the unemployment rate below the natural rate, but in the long run the economy would revert to producing at its equilibrium level. The only lasting legacy of the Fed's actions would be to raise the level of inflation.

The Federal Reserve has raised the federal funds target rate seven times since February 1994 in the hopes of keeping the economy from "overheating." In doing so, the Fed has been attempting to walk the fine line of the long-run Phillips curve. This is no easy feat. It is more akin to a walk in the dark with policymakers feeling their way than to a stroll down a well-marked street. The main obstacle is the measurement of the natural rate of unemployment itself. If we could know the natural rate with certainty, the Fed's course of action would be clear: If the unemployment rate fell below the natural rate, the Federal Reserve would conduct a more restrictive policy; if the unemployment rate rose above the natural rate, the Fed would conduct a more stimulative policy.

Unfortunately, the natural rate is not known and therefore must be estimated. There are as many different estimates of the natural rate as there are econometricians who estimate it. Furthermore, because these are just estimates, there is some uncertainty with respect to how confident we can be of these estimates. For example, a point estimate of the natural rate of 6 percent may easily have confidence intervals of ± 1 percent—an uncomfortably large spread if one is trying to implement policy.

To complicate matters further, the natural rate hypothesis is typically stated as a knife-edge phenomenon, that is, if unemployment is above the natural rate, the inflation rate would decline, while if unemployment falls below the natural rate, inflation would spiral out of control. In fact, both scenarios appear unlikely and simplistic. One can well imagine that as the unemployment rate slips below the natural rate, some industries, although not all, will experience difficulties in obtaining production inputs, including labor, at existing prices. As these shortages become more restrictive, input prices will be bid up and inflation will result. Only when these shortages

Ellen R. Rissman is an economist with the Federal Reserve Bank of Chicago.

become widespread at the existing price level will inflation result. The presence or absence of these shortages tells us a great deal about whether our assessment of the natural rate is accurate. If we believe the rate of unemployment is below the natural rate, then we should expect to see shortages and ensuing price pressures. If such shortages are absent, then our original assessment of the natural rate must be flawed. Absent such corroborating statistical evidence, we must reexamine our estimates of the natural rate.

It is tempting to argue that rising wages in specific sectors are a precursor to widespread inflation. However, an analysis requires more than simply identifying the industries in which nominal wage growth is accelerating. Wages can increase for reasons other than inflationary pressures. For example, as workers become more productive, their wages naturally rise. Wages respond to sector-specific as well as aggregate factors. Wages in one industry may be increasing relative to another because of changes in the composition of product demand unrelated to inflation.

Further complicating matters, even if some industries have high nominal wage growth unrelated to productivity growth, this does not necessarily foretell future inflation. According to economic theory, nominal wages adjusted for productivity should grow at the same rate as inflation in the long run. In the short run there may be deviations from this equilibrium relation, but the two tend to grow at the same rate over long periods. A recent article by Campbell and Rissman (1994) suggests that the direction of Granger-causality in aggregate wages is from inflation to wage growth and not the opposite. If this result holds true at the industry level, then high adjusted nominal wage growth need not have any implications for future inflation. Nominal wage growth may simply be "catching up" to past inflation.

In the remainder of this article, I attempt to document the relationship between a measure of aggregate inflation and unit labor costs in a number of one-digit industries. Specifically, I assess whether changes in nominal wage growth in one industry have any implications for future inflation. A positive finding would indicate that a more disaggregated approach would aid policymakers in further assessing estimates of the natural rate.

This article is divided into four sections. In the first section, I present a simple two-sector model of a profit-maximizing firm that employs two different types of labor. The implications for long-run equilibrium behavior are analyzed. The data are presented in the second section, with particular emphasis on the time-series properties. An empirical model of wage growth and inflation is developed in the third section. Conclusions and discussion of further research are found in the last section.

To summarize the results, the evidence suggests that the direction of causality for most industries is from prices to wages and not the reverse. Only in manufacturing and retail trade is there strong evidence for the hypothesis that wages Granger-cause inflation. The results for manufacturing depend upon the measurement of productivity employed in the analysis.

A simple model

Suppose that there are two different sectors (x and y), that each produce a single good using two types of labor (1 and 2).[1] Let the price of good i be denoted P_i, where $i = x, y$. Output in sector i is produced according to the production function $f^i(L_1^i, L_2^i)$, where L_j^i is employment of type j labor in industry i. The superscript i on the production function indicates the industry to which this technology applies. It is assumed that $f^i(L_1^i, L_2^i) = 0$ if $L_j^i = 0$ for any i, j, that is, both labor inputs are needed to produce any output; $\partial f^i/\partial L_j^i > 0$ and $\partial^2 f^i/\partial (L_j^i)^2 \leq 0$, that is, adding additional labor input increases output but at a decreasing rate. Furthermore, $\partial^2 f^i/\partial (L_1^i)^2 \, \partial^2 f^i/\partial (L_2^i)^2 - \partial^2 f^i/[\partial (L_1^i)\partial (L_2^i)] > 0$ states that the production function is concave in its inputs, guaranteeing a local maximum. The representative firm in each industry is assumed to take the wage rate for each type of labor as given, that is, the firm's actions do not affect the wage rate for either type of labor input. Similarly, the firm is assumed to be too small to influence the price of its output. Thus, the profit function of the representative firm is given by

$$\Pi_i = P_i f^i(L_1^i, L_2^i) - W_1^i L_1^i - W_2^i L_2^i,$$

where Π_i is the profit of the firm in sector i, and W_1^i and W_2^i are the wage rates paid respectively to type 1 and type 2 labor in industry i.

The firm's problem is to select the amounts of L_1^i and L_2^i given P_i, W_1^i, and W_2^i so as to maximize profits. The firm's first-order conditions are given by

$$(1)\quad P_i f_j^i(L_1^i, L_2^i) = W_j^i,$$

where $f_j^i(L_1^i, L_2^i) = \partial f^i/\partial L_j^i$, the marginal product of type j labor in industry i, can be thought of as the extra output the firm in sector i would produce if it hired an additional unit of type j labor but held the amount of the other type of labor unchanged ($i = x, y$, and $j = 1, 2$). The profit-maximizing firm chooses inputs of labor, L_1^i and L_2^i, so as to equate the value of the marginal product of each type of labor to the wage rate for that labor input. If the value of the firm's marginal product of labor exceeds the wage rate for a particular type of labor, then the firm will not be profit-maximizing. This is because the firm could increase its revenues more than its costs by hiring additional labor. Conversely, if the value of the firm's marginal product of labor were less than the wage rate for that particular type of labor, then the firm could increase profits by reducing its employment of the labor input.

Until this point, the model has not addressed how labor is allocated across industries. The representative firm takes the wage rate as outside its control and hires all the labor input it requires at the existing wage. How wages and the allocation of labor across industries are determined depends upon assumptions concerning resource flows and supplies. To address these issues in a simple way, it is assumed that labor resources flow freely across industries. In fact, if a particular type of labor could earn more in one industry than in the other, labor would flow to the industry that pays the highest wage.[2] Thus, we would expect that in the long run, $W_j^1 = W_j^2 = W_j$ for all j. The first-order conditions imply that in equilibrium, the value of the marginal product of labor ($VMP_{L_j}^i$) must be equated across industries for both labor inputs.

Suppose that the wage rate paid to type 1 labor is higher in industry x than in industry y. Then from the first-order conditions, the value of the firm's marginal product of labor in industry x exceeds the marginal value product for the same type of labor in industry y, that is, $VMP_{L_1}^x \geq VMP_{L_1}^y$. Type 1 labor sees the wage differential and flows to industry x. In the process, wages are reduced there and the marginal value product is lowered. At the same time, the outflow of labor from industry y causes the wage rate and marginal value product to rise in that industry. This adjustment continues until the wage rate and the *VMP* are equilibrated across sectors. In equilibrium, $VMP_{L_1}^x = VMP_{L_1}^y = W_1$.

Of course, the average wage rate paid in a sector can differ across industries. For one thing, firms use labor inputs in different combinations. Those industries employing more professional workers, for example, will typically pay higher wages than those that require lower-skilled workers. However, in the long run, professionals (lower-skilled workers) should earn the same regardless of the industry in which they are employed.

In an economy populated by many small firms such as those described above, the price of output always equals the productivity-adjusted wage rate in equilibrium. Firms' profit-maximizing behavior constrains the price's growth rate as well as the growth rate of productivity-adjusted wages. To see this, take logarithms of equation 1 and subtract it from itself across adjacent time periods, t and $t-1$

$$(2)\quad \Delta w_j(t) - \Delta z_j^i(t) = \Delta p_i(t),$$

where $\Delta w_j(t) = \ln W_j(t) - \ln W_j(t-1)$ is the growth rate of nominal wages for type j labor; $\Delta z_j^i(t) = \ln[f_j^i(L_1^i(t), L_2^i(t))] - \ln[f_j^i(L_1^i(t-1), L_2^i(t-1))]$ is the growth rate of type j's marginal physical product of labor in industry i; and $\Delta p_i(t) = \ln P_i(t) - \ln P_i(t-1)$ is the growth rate of the price of output in industry i.

It can be shown that equation 2 can be aggregated so that

$$(3)\quad \Delta w_i(t) - \Delta z_i(t) = \Delta p_i(t),$$

where $\Delta w_i(t)$ is the growth rate of nominal wages in sector i, $\Delta z_i(t)$ is the growth rate of total factor productivity in sector i, and as before, $\Delta p_i(t)$ is the growth rate of prices in industry i. Market discipline ensures that, given industry productivity growth, the growth rate of nominal wages cannot deviate from the growth rate of output prices in equilibrium.

The model examined above overlooks some potentially interesting questions about labor market and product market behavior.

For example, firms and workers may not be price-takers as assumed above. Instead, they may be monopolists and monopsonists, exerting some degree of control over prices and wages respectively. Although this modifies the tight connection between productivity-adjusted wages and price growth described above, as long as the wage and price markups do not deviate from a constant mean for prolonged periods of time, productivity-adjusted wages and prices must move in tandem.

Second, the model expounded above does not take into consideration how the participants adjust to changing economic conditions. For example, suppose that the firm incurs substantial hiring and firing costs when adjusting its labor input. In the interests of profit-maximization, the 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 3 will hold reasonably well. However, adjustment costs can be substantial, with significant short-run deviations from the equilibrium occurring.

Similarly, workers may not be completely mobile. For example, suppose that an individual is currently employed in one industry but wages are higher for the same type of worker in another industry. The worker will not necessarily switch industries as this may require moving costs, both pecuniary and nonpecuniary. Only over time are workers likely to switch industries. Again, the equilibrium condition relating the growth of wages, productivity, and prices would hold only in the long run.

The data

The theory of the profit-maximizing firm presented above suggests that productivity-adjusted wages in an industry must grow at the same rate as the industry output price in the long run. However, the model is not particularly informative on the subject of short-term dynamics. Short-term deviations from equilibrium may occur, but economic theory suggests that there is a tendency for these variables to converge to their equilibrium relationship as described in equation 3.

In the analysis that follows, the price–wage–productivity linkages are examined in ten one-digit industries for the nonfarm non-government sector. These industries include construction (CON); mining (MIN); manufacturing (MFG); durable manufacturing (MFGD); nondurable manufacturing (MFGN); finance, insurance, and real estate (FIR); services (SRV); retail trade (RT); wholesale trade (WT); and transportation and public utilities (TPU). The agriculture and government sectors are omitted from the discussion because of the difficulty in imputing wages in the former and the noncompetitive nature of the latter.

While nominal wage information is available for each of these industries, productivity data are unfortunately available for only a subset including manufacturing and its durable and nondurable components. Let Z_i be productivity in industry i, with Z_i defined as

$$Z_i \equiv \frac{(Y_i/P_i)}{(L_i h_i)},$$

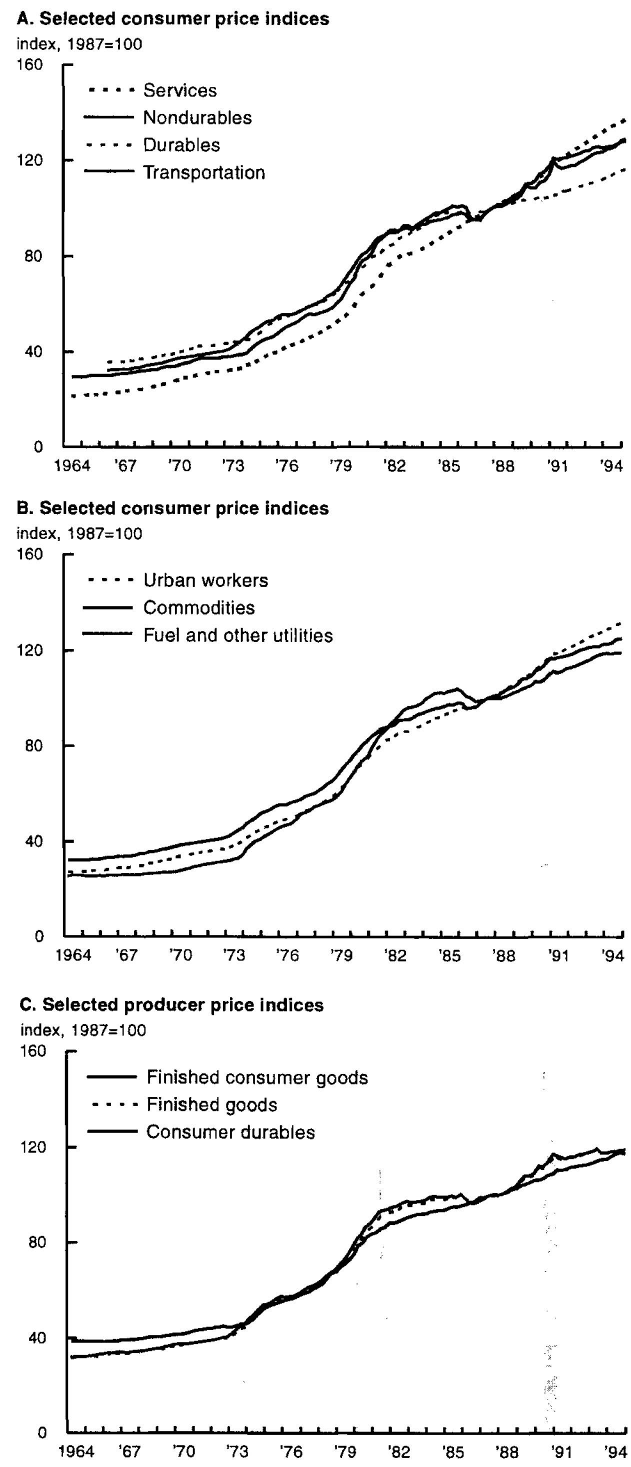
where Y_i is nominal output in that industry, P_i is an appropriate price index, L_i is the number of workers in the industry, and h_i is the average number of hours worked. Thus, productivity in any given industry is defined as real output per man-hour.

For the nominal output for each sector, I used national income in the relevant industry as reported quarterly by the Department of Commerce in its *National Income and Product Accounts*. Employment is reported for each of these sectors by the Bureau of Labor Statistics in its monthly publication, *Employment and Earnings*. Hours, also reported monthly, are measured by the Index of Average Weekly Hours for each of these sectors with the exception of retail and wholesale trade. It was assumed that for these two industries the relevant hours index is that for the combined trade sector. Nominal wages are given for the different sectors and are also reported monthly by the Bureau of Labor Statistics. All monthly data have been converted to quarterly averages for the period from 1964:Q1 to 1994:Q4.

The selection of an appropriate price index to use in constructing productivity is not a straightforward matter. There are a number of candidates from which to select. In the econometric work that follows, I examined ten different price indices, all of which have been

FIGURE 1

Selected price indices



Note: Shaded areas indicate recessions.
Source: U.S. Department of Labor.

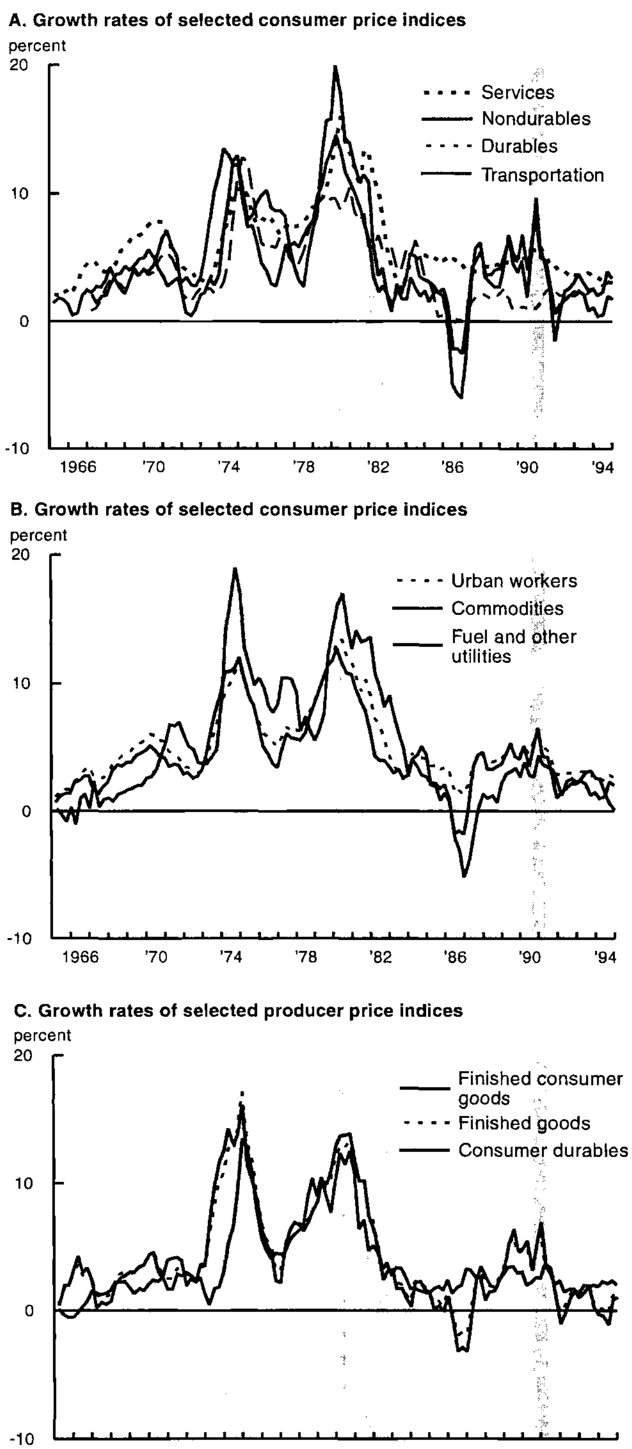
indexed to 1987=100. These include seven from the Consumer Price Index (CPI): commodities (CPICOM), durables (CPID), fuel and other utilities (CPIFOU), nondurables (CPIND), services (CPISRV), transportation (CPITRN), and urban workers (CPIU). In addition, I examined the Producer Price Index (PPI) for consumer durables (PPICD), finished consumer goods (PPICG), and finished goods (PPIFG). I then measured productivity for each of the industries using each of the possible ten different price indices, which yields 100(=10 x10) different productivity measures.

Some price indices are clearly more appropriate for constructing measures of industry productivity in specific sectors than others. For example, a price index measuring service prices is probably not a good deflator of manufacturing output. Services output should not be deflated by a price index for durable goods for a similar reason. However, I report results for all of the productivity measures constructed to assess how important the price index is in the analysis.

The price indices are shown in figures 1A–C, and their growth rates are shown in figures 2A–C. Growth rates are calculated as four-quarter log differences. There are several points to make concerning the time-series pattern exhibited. All of these price series show quite similar behavior. All have been trending upward, with a slowdown in the growth rate occurring in the early 1980s. There is of course some difference in the growth rate across sectors. Since 1987, service prices have grown most rapidly. Durables prices have grown more slowly, as has

FIGURE 2

Selected price index growth rates



Note: Growth rates are calculated as four-quarter log differences. Shaded areas indicate recessions.
Source: U.S. Department of Labor.

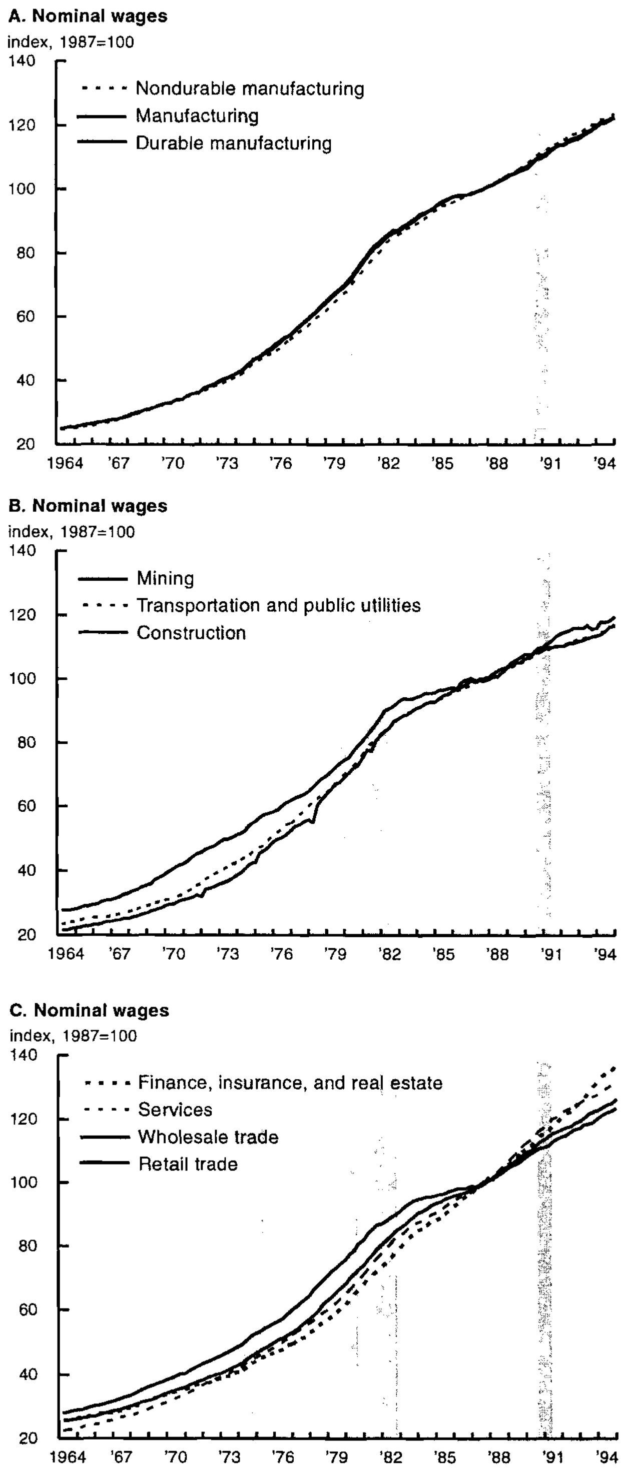
the CPI index for fuel and other utilities. From figure 2 it is clear that price inflation accelerated through the 1970s and slowed markedly in the early 1980s. This characterization of rising then falling inflation is true for all of the series examined. It is also worth noting that inflation is highly persistent, in that high inflation today usually means high inflation tomorrow.

As shown in figures 3A–C, nominal wages across the various industries exhibit behavior over the same period that is quite similar to that of prices. Corresponding growth rates for the wage series are shown in figure 4.[3] Growth rates are calculated as four-quarter log differences. Again, the time-series behavior of the different wage series is quite similar across industries. As with prices, wages seem to be trending upward, and a kink occurs in the series in the early 1980s that corresponds to a decrease in the growth rate of wages. This decline in nominal wage growth is exhibited quite clearly in figure 4. Prior to the early 1980s, wage growth was trending upward. At some point in the early 1980s, wage growth fell abruptly and has shown little acceleration or deceleration since. As with prices, nominal wage growth is highly persistent.

The model described in the previous section suggests that the gap between productivity-adjusted wage growth and inflation $(GAP_i(t) \equiv \Delta w_i(t) - \Delta z_i(t) - \Delta p_i(t))$ reflects deviations away from long-run equilibrium, where $\Delta z_i(t) = \Delta \ln Z_i(t)$. In terms of its time-series properties, theory suggests that the gap should exhibit some positive serial correlation and should revert to its mean over time.

FIGURE 3

Nominal wage indices by industry



Note: Shaded areas indicate recessions.
Source: U.S. Department of Labor.

The disequilibrium term is shown for the ten industry categories in figure 5A–C. Productivity has been constructed using the CPI for urban workers. Inflation is also measured as the growth rate of that index. I have normalized the gap in each industry by subtracting the industry mean and dividing by the industry standard error. The evidence in figure 5 clearly supports the time-series interpretation.

Do wages cause prices?

In developing an econometric specification of the joint behavior of productivity-adjusted wages and prices, one needs to account for the long-run restriction that productivity-adjusted wages and prices move in tandem. The error corrections model is one such framework.[4] The advantage of using such a framework is that it imposes the long-run restriction that the gap between productivity-adjusted nominal wage growth and inflation disappears in the long run, while at the same time the framework permits the short-term dynamics to be estimated from the data.

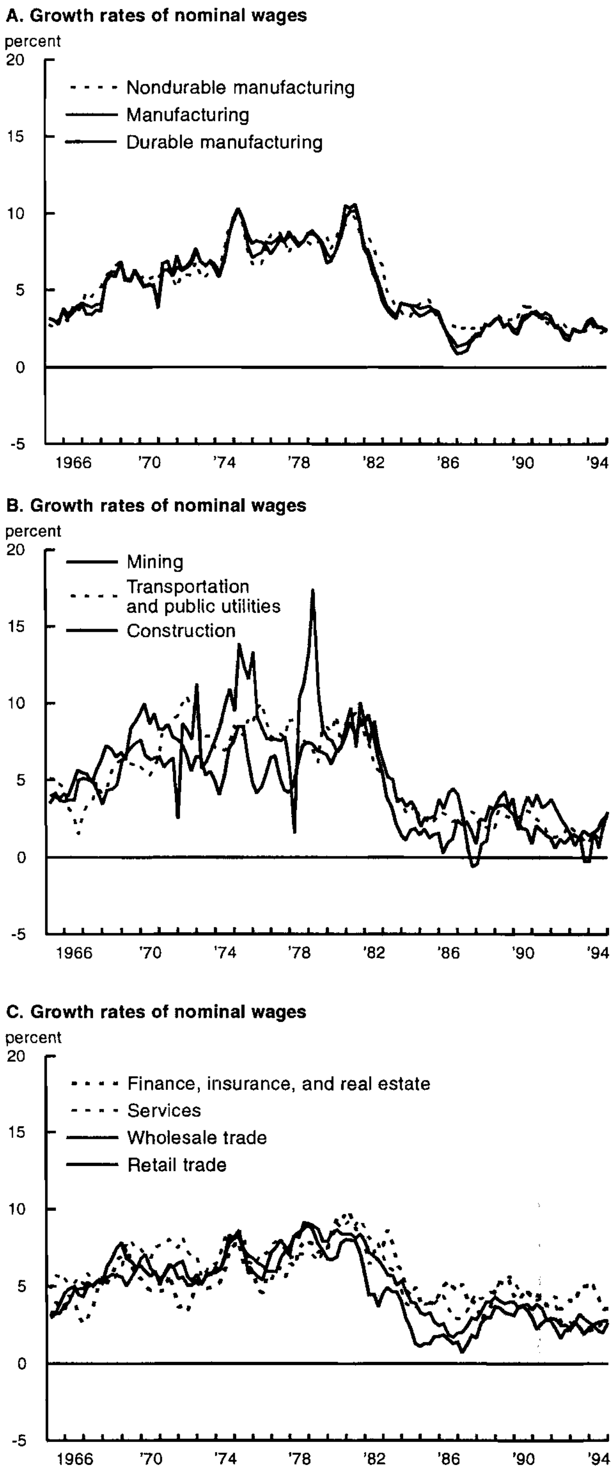
At its simplest, let $\omega_{i,t} \equiv \Delta w_{i,t} - \Delta z_{i,t}$ be the growth rate of productivity-adjusted nominal wages at time t. Furthermore, let $\rho_t = \Delta p_t$ be the inflation rate at time t. The error corrections model is then

$$(4)\quad \Delta\rho_t = \alpha^1[\omega_{i,t-1} - \rho_{t-1}] + \varepsilon^1_t$$
$$\Delta\omega_{i,t} = \alpha^2[\omega_{i,t-1} - \rho_{t-1}] + \varepsilon^2_{i,t},$$

where ε^1_t and $\varepsilon^2_{i,t}$ are random error terms assumed to be normally distributed with zero mean. These error terms may be correlated with each other but are independent over time. This

FIGURE 4

Nominal wage growth by industry



Note: Growth rates are calculated as four-quarter log differences. Shaded areas indicate recessions.
Source: U.S. Department of Labor.

model is quite clear in its implications for short-run and long-run behavior. The gap affects short-term behavior, which in turn affects the gap. If there were no further disturbances, these short-term adjustments would eliminate the gap in the long run. However, because the error terms change each period, the gap is never eliminated completely; rather, it fluctuates around zero. If $\alpha^1 \leq 0$ and $\alpha^2 \geq 0$, then the gap is closed by price inflation decreasing and wage inflation increasing. Alternatively, if $\alpha^1 \geq 0$ and $\alpha^2 \leq 0$, the gap is closed by increasing inflation and decreasing wage growth.

In the error corrections model of equation 4, only the most recent wage–price gap is useful for constructing forecasts of wage and price inflation. A less restrictive error corrections model that permits more complex short-term dynamics while leaving the long-run restriction on the wage–price gap intact is

$$(5)\ \Delta p_t = \alpha^1[\omega_{i,t-1} - p_{t-1}] + \Sigma_{j=1}^{k} \gamma_j^1 \Delta p_{t-j} + \Sigma_{j=1}^{k} \lambda_{ij}^1 \Delta \omega_{i,t-j} + \varepsilon_{i,t}^1$$

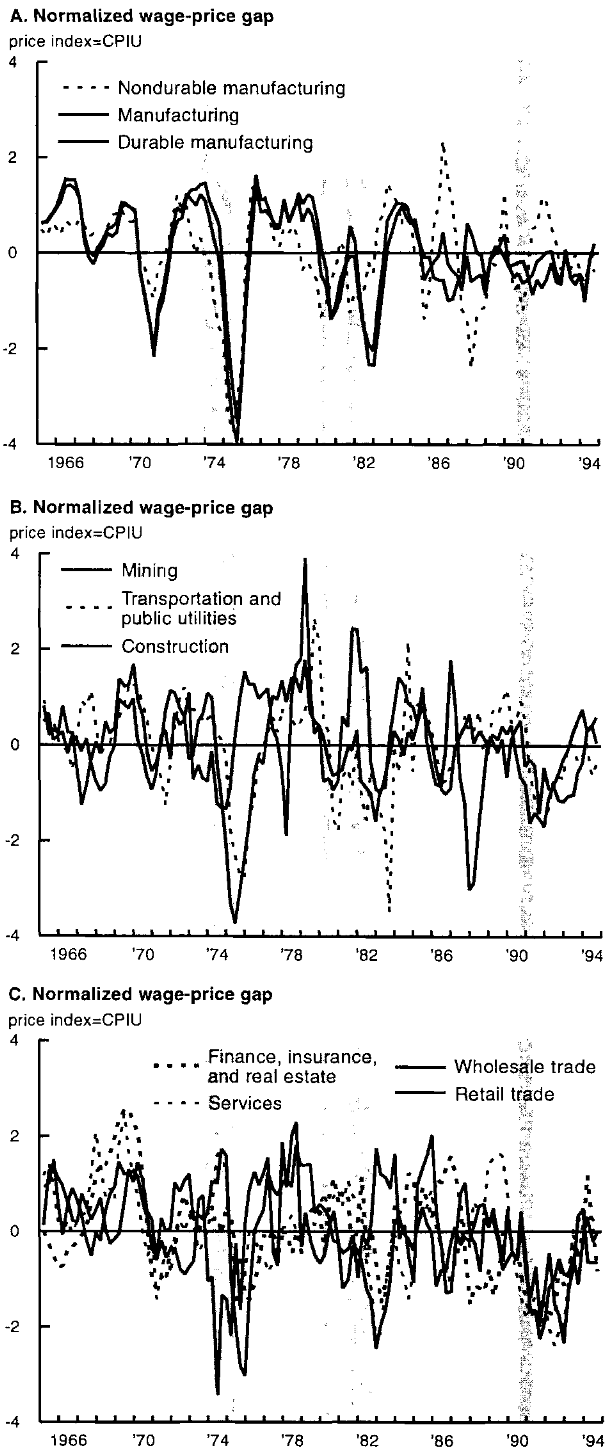
$$\Delta \omega_{i,t} = \alpha^2[\omega_{i,t-1} - p_{t-1}] + \Sigma_{j=1}^{k} \gamma_j^2 \Delta p_{t-j} + \Sigma_{j=1}^{k} \lambda_{ij}^2 \Delta \omega_{i,t-j} + \varepsilon_{i,t}^2.$$

In this system of equations, the wage–price gap and k lags of changes in price and wage growth are incorporated into forecasts. The parameters of the model (namely, α^s, γ_j^s, and λ_{ij}^s, where $s = 1, 2; j = 1, \ldots, k$) can be estimated by ordinary least squares for each $i = 1, \ldots, I$.

Whether wage growth is useful for forecasting price inflation depends upon the estimated parameters and their variance–covariance matrix. If either $\alpha^1 \neq 0$ or $\lambda_{ij}^1 \neq 0$ for some j, then

FIGURE 5

Productivity-adjusted wage–price gap



Note: Shaded areas indicate recessions.
Source: Constructed by the author as described in the text.

wage inflation in industry i helps forecast price inflation. If this is not true, then knowing wage growth in a particular industry does not add any additional information to inflation forecasts.

A test of the null hypothesis that wage inflation in industry i does not help forecast price inflation can be stated as

$$(6)\quad H_0 \begin{cases} \alpha^i = 0 \\ \lambda^i_{i1} = 0 \\ \vdots \\ \lambda^i_{ik} = 0. \end{cases}$$

A simple F-test can be used to test this hypothesis. Two equations are estimated. The first one estimates equation 5 without any constraints. The second equation reestimates equation 5 imposing the constraints of the hypothesis by eliminating lagged changes in adjusted wage growth and the gap from the equation. If the first equation fits the data better than the second, then the hypothesis is rejected.

Fit in this case is measured using an F-test that compares the estimated standard error of $\varepsilon^i_{t,t}$ from the original unconstrained equation, σ^i_{iu}, to that estimated from the restricted equation, σ^i_{ir}. The smaller the standard error, the more accurate the equation forecasts. If σ^i_{iu} is much smaller than σ^i_{ir}, then including data on wage inflation produces more accurate inflation forecasts. In this case the F-statistic will be large, providing evidence against the hypothesis that industry wage inflation does not help forecast price inflation. Unfortunately, test statistics can be large for another reason: random variation. Some of the time we may obtain large test statistics even though the

TABLE 1

Causality tests from wages to prices and from prices to wages

Price index	CON		MIN		MFG	
	W→P	P→W	W→P	P→W	W→P	P→W
Commodities	0.90	2.72***	1.19	1.45	2.59***	1.47
Fuel and other	0.64	2.45**	1.04	1.62	1.18**	1.13
Services	0.82	2.20**	1.07	1.74*	2.15**	1.33
Transportation	0.58	2.60***	1.07	1.82*	2.34**	1.33
Consumer durables	1.43	2.76***	1.13	1.54	3.17***	1.55
Finished consumer goods	1.06	2.63***	1.14	1.35	3.16***	1.36
Finished goods	1.09	2.61***	1.15	1.43	3.01***	1.32
Urban workers	0.87	2.59***	1.14	1.59	2.59***	1.49
Durables	1.03	2.49***	1.10	1.44	2.16**	1.21
Nondurables	0.67	3.30***	1.22	1.30	2.38**	1.42

Price index	MFGD		MFGN		TPU	
	W→P	P→W	W→P	P→W	W→P	P→W
Commodities	3.10***	2.51***	1.83*	1.24	1.48	1.88*
Fuel and other	1.49	2.08**	0.86	1.37	1.27	2.53***
Services	2.60***	2.27**	1.39	1.40	1.00	1.62
Transportation	2.84***	2.86***	1.45	0.79	1.41	2.05**
Consumer durables	3.84***	2.39**	1.82*	1.20	1.31	2.34**
Finished consumer goods	4.04***	2.04**	2.17**	0.89	1.50	1.98**
Finished goods	3.89***	2.06**	2.00**	0.93	1.50	2.16**
Urban workers	3.12***	2.53***	1.70*	1.35	1.32	1.91*
Durables	2.64***	1.83*	1.03	2.08**	1.09	1.77*
Nondurables	3.22***	2.46**	1.48	0.96	1.47	1.72*

Price index	RT		WT		SRV		FIR	
	W→P	P→W	W→P	P→W	W→P	P→W	W→P	P→W
Commodities	2.92***	2.02**	0.73	2.12**	1.06	1.10	1.58	1.30
Fuel and other	1.28	1.98**	0.81	2.63***	0.90	2.22**	1.76*	1.73*
Services	1.81*	1.54	0.50	2.51***	0.54	1.50	1.45	1.35
Transportation	2.56***	1.39	1.01	2.00**	0.77	1.45	1.39	2.15**
Consumer durables	5.00***	2.13**	1.52	2.30**	2.48	2.81***	0.98	1.92*
Finished consumer goods	3.21***	1.72*	1.30	2.30**	2.59	1.07	1.47	1.56
Finished goods	3.20***	1.97**	1.08	2.43**	2.29	1.18	1.38	1.62
Urban workers	2.31**	1.99**	0.61	2.59**	0.77	1.11	1.49	1.30
Durables	2.70***	2.04**	0.70	2.01**	0.80	1.62	0.85	1.98**
Nondurables	2.13**	1.97	0.66	2.46**	1.14	1.25	1.76*	2.04**

Note: Numbers are *F*-statistics. The equations were estimated using 8 lags. The notation W→P indicates a test of the hypothesis in equation 6 while P→W indicates a test of the hypothesis in equation 7. See page 19 for definitions of industry abbreviations.
*Significant at .10 level.
**Significant at .05 level.
***Significant at .01 level.

hypothesis is true. Recognizing this, one can compare the test statistic to some standard critical value in order to determine whether the former is big enough to warrant rejecting the null hypothesis with some degree of confidence.

Table 1 presents *F*-statistics that test the null hypothesis of equation 6 and those testing the converse hypothesis for the second equation of the model of equation 5, that price inflation does not help forecast industry productivity-adjusted wage growth. This second hypothesis is stated as

$$(7)\quad H_0 \begin{cases} \alpha^2 = 0 \\ \gamma^2_{i1} = 0 \\ \vdots \\ \gamma^2_{ik} = 0 . \end{cases}$$

Although I used 4, 8, and 12 lags of changes in price and wage growth as regressors in both the restricted and unrestricted equations, for the sake of brevity I report only the results for 8 lags.[5] The entire data sample from 1964 through 1994 was used for the estimation. Growth rates are calculated as the four-quarter log differences. Since the maximum lag length is 12, this leaves us with 106 observations for most of the models estimated. Because the durables and nondurables price indices are available for a shorter time span, regression estimates using these variables to construct productivity measures have only 98 observations. Inflation was measured as the four-quarter log differences in the CPI index for urban workers.

As noted above, the error corrections model imposes the long-run restriction that productivity-adjusted wage growth and prices move together in the long run. Therefore, it cannot be the case that both $\alpha^1 = 0$ and $\alpha^2 = 0$. Otherwise, neither variable would respond to the wage–price gap. Thus, it is impossible for the hypotheses in both equations 6 and 7 to be true simultaneously, even though separately testing these hypotheses can in principle lead to the result that both hypotheses cannot be rejected. In practice, this was an issue for some of the price indices used in constructing productivity in mining; nondurable manufacturing; services; and finance, insurance, and real estate.

Causality from wages to prices and from prices to wages varies depending upon the industry. In general, the direction of causation in construction was from prices to wages, with no evidence that construction wages help predict prices. This held true for all the different price indices used to construct productivity measurements. In mining, the number of lags used was critical for causality inference from prices to wages. For none of the lags or price indices did mining wages Granger-cause inflation. Exclusion tests suggest that a lag length of 12 quarters is appropriate. Results regarding the hypothesis in equation 7 are mixed depending upon the price index. However, they generally support the idea that prices Granger-cause wages in mining.

Results are somewhat different for manufacturing. In that industry, wages clearly show causality running from wages to prices rather than vice versa for most price indices. However, manufacturing's durable and nondurable components behave differently. The durable component typically shows joint causality, that is, prices cause wages and wages cause prices, although results on prices causing wages depend upon the lag length, with longer lags not as clear on statistical inference. Nondurable manufacturing exhibits some evidence suggesting that nominal productivity-adjusted wage growth causes inflation. In general, while the hypothesis of equation 6 cannot be rejected at conventional confidence levels using 8 lags of data, it can be rejected using other lag lengths. Evidence as to whether price inflation causes wage inflation is mixed for this sector, varying both with lag length and price index.

For transportation and public utilities, the hypothesis that wages do not Granger-cause prices is accepted for all price indices when 8 lags of the data are included. However, when only 4 lags are employed, the hypothesis is typically accepted, with the notable exception of the transportation price index. Prices clearly Granger-cause wages in this industry. Retail trade shows direction of causality going both ways, that is, from wages to prices and from prices to wages. The evidence for causality from wages to prices is much stronger than that for the opposite direction, since the former holds true at essentially all lag lengths. The latter seems to be true for only the intermediate length of 8 quarters. Wholesale trade is somewhat different, with a lag length of 12 quarters supporting the idea that wages cause prices, while the results for shorter lag lengths suggest the opposite. The data show fairly clearly that prices Granger-cause wages for most lag lengths and price indices.

The results of the hypothesis of equation 6 depend considerably on the price index employed to construct services productivity. When nominal income is deflated by the various PPI measures, wages strongly Granger-cause prices. However, this result does not hold for the various CPI measures. Inflation does not consistently Granger-cause wage growth in services. The results of tests of hypothesis 7 depend upon the lag length as well as the price index. It is interesting to note that the price index for services shows Granger-causality when the lag length is 4 but not longer. For finance, insurance, and real estate, the direction of causality does not run from wages to prices. There is, however, mixed evidence that prices cause wages in this sector.

Alternate manufacturing productivity measures

The results discussed above are based on productivity measures that have been constructed from national income data by industry. For manufacturing, an alternative source for productivity is available. The Bureau of Labor Statistics (BLS) reports quarterly productivity indices for manufacturing and its durable and nondurable components separately. The correlation between the BLS productivity measures and the various constructed productivity measures is quite high. For example, the correlation between BLS manufacturing productivity and productivity constructed using the CPI index for durables is .96. For durable manufacturing, the correlation is .93 for productivity constructed from the same price index. Nondurable manufacturing exhibits a correlation of .95 with productivity constructed using the CPI index for nondurables.

However, it is the growth rate of productivity that is important for constructing estimates of the wage–price gap and for estimating the error corrections model. For manufacturing as a whole, the growth rates of the constructed productivity measures tend to lead productivity growth as measured by the BLS. For durable manufacturing, the results depend on the price index employed in the construction of productivity measures. For example, when national income in nondurables is deflated by the CPI index for commodities, the constructed growth rate tends to lead that reported by the BLS. However, using the CPI index for durables changes the result, with BLS productivity growth tending to lead constructed productivity growth. Results in nondurables also hinge on the measure of constructed productivity.

I reestimated the error corrections model using the BLS productivity measures for manufacturing, durable manufacturing, and nondurable manufacturing. Granger-causality tests for 4, 8, and 12 lags of the data show that the null hypothesis that wages do not enter the inflation equation cannot be rejected at standard confidence levels. Similarly, tests of whether prices enter the wage inflation equation cannot be rejected at standard confidence levels.

Clearly, the measurement of productivity is important in the analysis. The two measures presented here differ in the measure of real output used to construct the index. The BLS adjusts annual data based on the *National Income and Product Accounts* to form a quarterly series. The form of the adjustment comes from the Federal Reserve Board's index of manufacturing production. Thus, the quarterly pattern is imputed from another source. This appears to be the main cause of discrepancy between the two measures.

Summary

There are various ways to construct productivity measures. In the evidence presented above, national income by industry was deflated by a number of price indices to construct productivity measures. The causality results are quite robust across the various price indices employed. Judging from the similar time series exhibited amongst these price indices, such a result is to be expected. In most of the industries examined, the direction of causality runs from prices to wages rather than wages to prices. Only in manufacturing and retail trade does productivity-adjusted wage growth appear to help forecast inflation.

This finding has a variety of implications. First, if one is attempting to find corroborating evidence that the unemployment rate is below or above the natural rate, observing wage growth in a variety of sectors is apt to be misleading. High wage growth today may simply be a natural response to high past inflation and in most industries does not presage impending inflation. Manufacturing and retail trade are the anomalies in that the wage–price gap appears to be narrowed not only by movements in prices but by movements in wages as well. In short, high productivity-adjusted wage growth in these sectors helps predict future inflation.

It has frequently been argued that the way in which our gross domestic product has been produced has shifted away from goods production towards service production. However, the statistics that are collected to gauge the health of our economy disproportionately represent the now smaller goods-producing sector. Is our perception of the economy's performance somehow skewed by the narrow focus of these measures? The above empirical work suggests that for the purposes of forecasting inflation, it is not necessary to have data on wages in a wide variety of industries, as wages in these sectors do not Granger-cause inflation. Only in manufacturing and retail trade is any value added to our forecasts of inflation.

These results hinge heavily on the measurement of productivity. Only in manufacturing can statistics be found to independently test the hypothesis that wages Granger-cause inflation. The results based upon BLS productivity measures do not support the hypothesis that wages Granger-cause inflation. The extent to which this is due to the imputation of quarterly patterns in the measurement of real manufacturing output is a question for further study.

NOTES

[1]In the discussion that follows, the introduction of two distinct types of labor is not essential. However, it is included to motivate an understanding of why wages differ across industries.

[2]Of course, if workers were performing hazardous work in one industry relative to another, then they would need to receive a compensating wage differential to make them indifferent to the hazard.

[3]I have indexed wages to equal 100 in 1987 for ease of comparison.

[4]See Engle and Granger (1987) for a full discussion of the error corrections model.

[5]Results for 12 lags in the specification are qualitatively the same except as noted. Tests of the hypothesis that lags of greater than length k enter with a zero coefficient suggest that 8 to 12 lags is a proper specification.

REFERENCES

Barth, James R., and James T. Bennett, "Cost–push versus demand–pull inflation," *Journal of Money, Credit, and Banking*, Vol. 7, No. 3, August 1975, pp. 391-397.

Campbell, Jeffrey R., and Ellen R. Rissman, "Long-run labor market dynamics and short-run inflation," Federal Reserve Bank of Chicago, *Economic Perspectives*, Vol. 18, No. 2, March/April 1994, pp. 15–27.

Engle, Robert F., and Clive W. J. Granger, "Co-integration and error correction: Representation, estimation, and testing," *Econometrica*, Vol. 55, No. 2, March 1987, pp. 251–276.

Friedman, Milton, "The role of monetary policy," *American Economic Review*, Vol. 58, No. 1, March 1968, pp. 1–17.

Gordon, Robert J., "The role of wages in the inflation process," *American Economic Review*, Vol. 78, No. 2, May 1988, pp. 276–283.

______________, "Understanding inflation in the 1980s," *Brookings Papers on Economic Activity*, Vol. 85, No. 1, 1985, pp. 263–299.

______________, "Price inflation and policy ineffectiveness in the United States, 1890–1980," *Journal of Political Economy*, Vol. 90, No. 6, December 1982, pp. 1087–1117.

______________, "Can the inflation of the 1970s be explained?" *Brookings Papers on Economic Activity*, Vol. 77, No. 1, 1977, pp. 253–277.

Mehra, Yash P., "Unit labor costs and the price level," Federal Reserve Bank of Richmond, *Economic Quarterly*, Vol. 79, No. 4, Fall 1993, pp. 35–51.

Perry, George L., "Inflation in theory and practice," *Brookings Papers on Economic Activity*, Vol. 80, No. 1, 1980, pp. 207–241.

______________, "Slowing the wage–price spiral: The macroeconomic view," in *Curing Chronic Inflation*, Arthur M. Okun and George L. Perry (eds.), Washington: Brookings Institution, 1978, pp. 269–291.

U.S. Department of Commerce, Bureau of Economic Analysis, *National Income and Product Accounts*, electronic database, Washington, DC, March 1995.