# A NOTE ON THE SPECIFICATION OF WAGE RATES IN COST-PUSH MODELS OF FOOD PRICE DETERMINATION

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Since publication of Popkin's work on price determination by state of processing, cost-push models of "inflation" have provided the theoretical structure underlying much of the empirical analysis of food price behavior. The general premise of such models is that the price (usually a component of the Consumer Price Index) of a commodity can be expressed as the summation of that commodity's price in a less processed form, plus the cost of all resources expended in the physical transformation of the commodity to its current form. Then, if the costs of raw farm produce or other factors of production used by food processing firms increase, cost-push models predict that retail food prices will increase at some future date. It is argued that price increases at the retail level occur because market power of processing and retail firms permits them to "pass through" increased costs of production by increasing the prices of their output. Or, "because of their oligopolistic structure, these [food manufacturing] firms are able to select the prices at which they sell" (Lamm, p. 119). Similarly, Heien (p. 11) states that "an operationally more realistic theory is one where store managers apply a markup over costs for each product in order to arrive at a price." Finally, Lamm and Westcott (p. 188) propose a model in which "increases in resource prices are passed through to output markets."[1]

These quotations suggest empirical models of food price determination that would include components of the marketing bill as explanatory variables. Or, in other words, the models suggest that increases in factor costs, as measured by the marketing bill, will be incorporated into subsequent changes in retail prices. In this vein, both Lamm and Heien express the retail price of a specific food commodity as a function of its wholesale price and a nominal measure of labor costs. Their models also include the unemployment rate, presumably as a measure of excess capacity. Similarly, Lamm and Wescott express percentage changes in retail food prices as functions of percentage changes in the nominal values of various components of the marketing bill. However, their deletion of variables by pretest estimation does not provide a consistent final-form price equation for all food groups.

This paper addresses the theoretical and empirical issues raised by the use of nominal factor costs in the models of food price determination cited in the introduction. In particular, discussion of a theoretical model outlines how changes in wage rates *might* be related to subsequent changes in retail food prices and contrasts this specification to the causal relationships expressed in the cited empirical literature. After identifying the role of wages in a pricing model, the empirical specification of a wage variable as a causal factor is examined to determine what economic information that alternative specifications may provide. After a discussion of a specific cost-push model relating growth rate of wages to price increases, this representation of a wage-price causality is tested empirically. Since wages now constitute more than half of USDA's marketing bill—a measure of the value of factors used in the transformation of raw farm produce into finished food products—this particular issue has important implications for cost-push models of food price determination.

## Role of Wages in the Pricing Process

In a discussion of alternative models of the pricing process, Belongia and King note that any observed price change will be composed of a relative price change and a nominal price change. That is to say, part of the change in retail price will be a change in the relative price of food that is caused by shifts in market supply and demand conditions; the remainder of the observed price change will be a change in the nominal value of food as a result of a neutral inflation. One implication of this distinction between real and nominal values is that models of the pricing process include variables to represent each component of

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[1] Implicit in cost-push models is the assertion that firms with market power increase output prices after their costs of production have increased. This ability to "pass through" increased costs to consumers in the form of higher output prices is often cited as a cause of inflation. However, while market power may facilitate this type of pricing behavior, Baltan explains that it only creates a higher *level* of prices for monopolists, but does not explain why output prices may be constantly *rising*, consistent with a definition of inflation. Although Baltan's entire argument cannot be reproduced in a brief footnote, his point is that even monopolists face a downward-sloping demand curve, and that profits will fall if such a firm raises its price arbitrarily. Since decreasing profits will provide an incentive not to increase prices continuously, market power can only explain why firms with market power will charge a higher *level* of prices than firms in competitive industries. But the existence of market power cannot be a cause of inflation.

price changes. Although the cited empirical studies do not make such a distinction explicitly, it could be inferred from their model specifications that changes in wholesale prices are intended to represent the relative component of retail price changes, while increases in factor costs are included to represent changes in nominal values.

For wage rates to cause nominal price changes, several assumptions are necessary. Economic theory tells us that under perfectly competitive conditions, nominal wages equal the value of the marginal product of labor. Under these conditions, if nominal and real wages increase at the same rate, money wage growth reflects only gains in the per unit productivity of labor. Thus, an increase in nominal wages should not affect real labor costs nor the associated price of labor's output, because the marginal product of labor has increased, and the same quantity of output can be produced with fewer units of the labor input. Or, in terms of an isoquant mapping, the isoquant associated with a given level of output has moved closer to the origin, but the isocost line to which it is tangent is calculated with a higher per unit nominal cost of labor. However, if institutional arrangements or market imperfections prevent adjustments in the quantity of labor services that are used in production or that artifically increase nominal wages at a rate higher than that warranted by growth in labor productivity, money wages will increase faster than real wages. In this instance, if nominal wages increase at a faster rate than real wages, the real cost of labor services will increase.

However, even if real wages increase, additional assumptions not discussed by the studies cited are necessary to support a cost-push model of the pricing process. First, the models predict that an increase in factor costs will cause subsequent increases in output prices. But this implies that firms operate under (essentially) fixed-proportions technology, which limits or eliminates possibilities for substitution among inputs employed in the production process. Economic theory suggests that firms will use less of a factor if its relative price increases and the elasticity of substitution between it and another factor is not equal to zero. Then, if it is possible to use less of a relatively more expensive factor by replacing it with a relatively less expensive input, costs of production need not increase. And without increased real costs of production, there is no impetus for the output price increase predicted by cost-push models.

A similar argument if applied to possibilities for substitution among items in consumers' commodity bundles would suggest that if firms are to be successful in their attempt to increase real output prices, consumers must have limited opportunities for substitution among the goods they purchase. Or, another assumption implicit in cost-push models is that cross-price elasticities between outputs take values near zero. If these elasticity values are much different from zero, the implication is that an increase in a good's real price will lead to a decrease in the consumption of that good. And with possibilities for substitution among goods in a commodity bundle, firms will be limited in their ability to "pass through" increased costs to consumers in the form of higher output prices.

To test the validity of this explanation of the pricing process, it is necessary to express the relationships among nominal wages, real wages, and prices within a consistent theoretical model. The outline of such a model is presented below, with further details found in Moore's discussion of pricing behavior. Following Moore's notation, we have

$$(1) \quad \dot{w} = \dot{W} - \dot{p}$$

where the (•) over variables denotes "rate of change", w is the average real wage, W is the average nominal wage, and p is the price level. Under the assumption of "markup" pricing behavior that is constant in the short run, this equation implies that increases in nominal wages that exceed the increases in real wages will necessarily lead to increases in the price level. Since changes in real wages are unobservable, but dependent upon changes in labor productivity, we may rewrite (1) as

$$(2) \quad \dot{p} = \dot{W} - \dot{z}$$

where $\dot{z}$ is the average rate of growth of labor productivity. Under this relationship, if the contracting arrangement between employers and workers generates increases in nominal wages greater than the increases in labor productivity over the same time period, the price level will increase. The relationship in (2) will hold if it can be assumed that the markup pricing rule and, therefore, labor's share, are constant in the short run. To complete the model, we have assumed that the Federal Reserve responds to increases in nominal wages with an accommodating monetary expansion. This implies

$$(3) \quad \dot{M1} = \dot{W}$$

or that the narrowly defined money stock ($\dot{M1}$) will grow at a rate consistent with the observed growth in nominal wages. This monetary expansion by the Federal Reserve completes the first round of activity within the model.[2] Then, as

[2] The pricing models cited assume that wage increases cause price increases. Wage growth, under this specification, would initiate inflationary episodes that are subsequently ratified by expansionary monetary policy. That is, if the Federal Reserve conducts monetary policy according to the maintenance of some desired nominal interest rate, increased rates of inflation can signal a monetary expansion. Under the Fisher relation, $i = r + \Pi$ where i is the nominal interest rate, r is the real rate and $\Pi$ is the rate of inflation. Assuming that r is relatively constant, an increase in $\Pi$ increases i. But since higher i suggests tight money conditions, a policy to maintain i at some level would call for an increase in the money stock. This policy was pursued by the Federal Reserve until October 6, 1979.

workers find their gains from a nominal wage increase eroded by inflation, they will lobby for another wage increase, and the second round of wage-price increases will begin. Together, equations (2) and (3) represent a complete cycle of wage and price behavior.

## TESTING THE CAUSALITY

Equations (2) and (3) suggest a specific causal ordering among changes in the rates of growth of wages, labor productivity, prices, and the money stock. Verification of econometric causality is of interest for at least two reasons. First, the discussion of the role of wages in the model demonstrated that studies using nominal wage variables that are unadjusted for changes in labor productivity do not provide information about whether costs of production are actually increased by wage growth. Thus, existing reports of a significant relationship between nominal wage growth and food prices are based on incorrect specifications of the model. Second, as Pierce, and Granger and Newbold have argued, failure to remove autocorrelation from economic time series prior to estimation will produce artificially small and incorrect parameter variances that will inflate the t-ratios associated with the regression coefficients. Because these t-values are used to test for the existence of a significant relationship between wage growth and price increases, failure to account for autocorrelation in the error structure can produce a t-statistic that suggests a significant causal relationship, when in fact none exists. This possibility is especially likely if the model is estimated with data that are expressed in levels. Thus, a secondary reason for testing the model is that existing reports of a significant coefficient for a wage variable in a price equation may have been the product of what Granger and Newbold call a "spurious regression."

To test the causal orderings of the model, procedures developed by Granger and by Sims can be employed. To begin, we use Granger's definition of causality, which states that "$Y_t$ is causing $X_t$ if we are better able to predict $X_t$ using all available information than if the information apart from $Y_t$ had been used" (p. 428). Or, in other words, X is caused by Y if and only if X is predicted better by using past values of Y, as opposed to omitting those values of Y from the available information set. In practice, the test is essentially a joint F-test on the significance of future values of Y in predicting X. Sims, and Feige and Pearce discuss causality tests in greater detail.

Before model estimation, these tests require that the data be filtered to remove autocorrelation from the error structure or, equivalently, to reduce the series to white noise processes. Filtering was accomplished by fitting ARMA models to the data. Since the residuals of such processes will be white noise, the residuals from the estimated models were used in the tests for econometric causality.

To construct the F-tests[3] on the significance of future values of $Y_t$ in explaining $X_t$, we must estimate four equations for both of the causal relationships that are suggested by the theoretical model in equations (2) and (3). Using our $\dot{p} = (\dot{W} - \dot{z})$ causal relation as an example, we must estimate the following equations:

$$(4)\quad \dot{P} = f([\dot{W} - \dot{z}]_{t-i}, T, D_k);\ i = 0 - 24,\ k = 1 - 11$$

$$(5)\quad \dot{P} = f([\dot{W} - \dot{z}]_{t+j}, [\dot{W} - \dot{z}]_{t-i}, T, D_k);\ j = 1 - 12;\ i = 0 - 24,\ k = 1 - 11$$

$$(6)\quad [\dot{W} - \dot{z}] = f(\dot{P}_{t-i}, T, D_k);\ i = 0 - 24,\ k = 1 - 11$$

$$(7)\quad [\dot{W} - \dot{z}] = f(\dot{P}_{t+j}, \dot{P}_{t-i}, T, D_k);\ j = 1 - 12;\ i = 0 - 24,\ k = 1 - 11$$

where T is a linear time trend and $D_k$ are monthly zero/one variables. From equations (4) and (5), we get an F test on the significance of the (t+j) coefficients in explaining P. Equations (6) and (7) give an F test for the (t+j) coefficients in explaining $[\dot{W} - \dot{z}]$. If neither F test is significant, we can conclude that no causal relationship exists between the two variables. If both tests are significant, we can state that the variables are related by a feedback or bidirectional causal mechanism. If only one F is significant, we can con-

[3] The F statistic takes the form

$$F = (SSE_p - SSE_f)/(f - p)/SSE_f/n - f$$

where

$SSE_p$ = sum of squares error for the regression, using only past and present right-hand-side variables

$SSE_f$ = sum of squares error for the regression, also employing future values of the right-hand-side variable

f = number of parameters estimated in the model, using future values

p = number of parameters estimated in the model, using only past and present values

n = number of observations

Note that the use of distributed lag model and the addition of dummy variables and a trend term reduced the number of usable observations and degrees of freedom.

clude that the causality is unidirectional, running only from one variable to the other. The procedure will be repeated for both of the theoretical model's causal relationships in an attempt to verify the sequence of events hypothesized by equations (2) and (3).

Many studies using this procedure with quarterly data have used 4 positive and 8 negative lag periods (e.g., Sims; Lamm and Wescott). Consistent with this practice and the use of monthly data, the tests reported here employ 12 positive and 24 negative lags.[4] However, Feige and Pearce have shown test results to be sensitive to the selection of lag length. In recognition of this potential problem, the tests are repeated also for lag structures of varying lengths.

### Data Description

Descriptive statistics for the data used in the causality tests are provided in Table 1. Price variables include the Consumer Price Indices for: all food (CPIF); meat, poultry, and fish (CPIMPF); processed fruits and vegetables (CPIPRFV); cereal and bakery products (CPICB); nonalcoholic beverages (CPIBEV); and dairy products (CPID). The nominal wage variable (W) is the average wage rate for all production workers in the manufacturing sector. The measure of labor productivity is an index of productivity for workers in the food processing industry. The narrowly defined money stock (M1) is the monetary measure used in equation (3).[5] The sample includes 216 monthly observations, from January, 1960, through December, 1977. Consistent with the theoretical model of equations (2) and (3), data were expressed in percentage changes prior to the estimation of the ARMA models.

**TABLE 1.** Descriptive Statistics for Data Used in the Causality Tests, Expressed in Log-Difference Form

| Variable | Mean[a] | Variance |
|---|---|---|
| CPIF | 0.379 | 0.534 |
| CPIMPF | 0.342 | 3.556 |
| CPICB | 0.367 | 0.662 |
| CPID | 0.322 | 0.528 |
| CPIPRFV | 0.344 | 0.763 |
| CPIBEV | 0.601 | 1.741 |
| M1 | 0.399 | 2.286 |
| W | 0.449 | 0.157 |
| z | 0.276 | 0.891 |
| W - z | 0.173 | 1.083 |

[a] n = 216

## RESULTS

Table 2 presents results of the causality tests described earlier. With the exception of the nonalcoholic beverage (CPIBEV) commodity group, the results provide no support for the basic hypothesis that a growth rate of nominal wages in excess of the growth rate of labor productivity causes increases in retail food prices. Only the calculated F value of 2.92 for the nonalcoholic beverage group exceeds the $\alpha = 0.5$ critical value of 1.82 for (12,150) degrees of freedom. A significant causal relationship between real wage growth and dairy prices is suggested at the $\alpha = 0.10$ level of significance. However, in no instance was a change in a food group price index found to cause changes in real wages. Also, money growth and changes in nominal wages were found to be unrelated processes in the sense of econometric causality. The results were invariant with respect to changes in the number of positive and negative lag terms in the regression models. Finally, analyses of the ARMA model residuals under the Fisher Kappa and Kolmogorov-Smirnov tests for white noise suggest the data were filtered properly prior to the estimation of the causality tests.

These results hold several implications for the specification and estimation of models representing the process of food price determination. While the theoretical discussion explained the lack of any clear relationship between nominal factor costs and output prices, the failure to find a significant causal relationship between real wage growth and price increases for five out of six commodity groups would suggest that cost-push pricing models are subject to more serious specification errors. In particular, the results challenge the implied or direct assertions of price determination under fixed proportions technology, imperfect input and output markets, and

[4] A reviewer was concerned about the potential for multicollinearity among the lag periods; however, if the choice of filter is appropriate, all regressors will be orthogonal.

[5] It should be noted that the wage rate and productivity index are aggregate measures not specific to the production of individual food commodities. For example, the productivity index is based on *all* workers in the food processing industry, but is used in the estimation of real wage growth for workers in particular commodity subsectors of the food industry. A similar aggregation problem exists for the wage variable. If these more general measures differ substantially from actual values for individual commodity subsectors, it is possible that the estimated results are influenced by the data chosen to represent wages and labor productivity.

**TABLE 2.** F-Tests on Causal Relationships

| | Model | Calculated F |
|---|---|---|
| (1) | $\dot{CPIF} = f(\dot{W} - \dot{z})$ | 1.17 |
| | $(\dot{W} - \dot{z}) = f(\dot{CPIF})$ | 0.94 |
| (2) | $\dot{CPIMPF} = f(\dot{W} - \dot{z})$ | 1.15 |
| | $(\dot{W} - \dot{z}) = f(\dot{CPIMPF})$ | 1.12 |
| (3) | $\dot{CPICB} = f(\dot{W} - \dot{z})$ | 0.87 |
| | $(\dot{W} - \dot{z}) = f(\dot{CPICB})$ | 0.82 |
| (4) | $\dot{CPID} = f(\dot{W} - \dot{z})$ | 1.77 |
| | $(\dot{W} - \dot{z}) = f(\dot{CPID})$ | 0.82 |
| (5) | $\dot{CPIBEV} = f(\dot{W} - \dot{z})$ | 2.92* |
| | $(\dot{W} - \dot{z}) = f(\dot{CPIBEV})$ | 1.37 |
| (6) | $\dot{CPIPRFV} = f(\dot{W} - \dot{z})$ | 1.59 |
| | $(\dot{W} - \dot{z}) = f(\dot{CPIPRFV})$ | 1.63 |
| (7) | $(\dot{M1}) = f(\dot{W})$ | 0.51 |
| | $(\dot{W}) = f(\dot{M1})$ | 1.09 |

* Indicates significance at the $\alpha = 0.5$ level. The calculated F values are to be compared with a critical value of $F_{12,150} = 1.82$.

zero-valued cross-price elasticities. Although a test for equality between mean rates of growth for nominal and real wages suggests that nominal wages did increase at a faster rate over the sample period, these potential increases in the real cost of production apparently were not "passed through" to consumers at the retail level. This result would suggest either that firms do not determine price by a markup process, or that the market imperfections and production technology assumed by the cited empirical literature are not representative of actual economic behavior.

## CONCLUSIONS

This paper has isolated several specific issues that are central to discussion of food price determination. Although models reported in the empirical literature attribute changes in retail prices to changes in nominal factor costs, development of a theoretical model indicated that it is not appropriate to use nominal costs without adjusting for increases in factor productivity. Without recognizing increases in the marginal product of labor over time (which is equivalent to moving the isoquant for any given level of output closer to the origin), we do not know if in fact the per-unit cost of labor services was changed by a nominal wage increase. If nominal wages and labor productivity grow at the same rate, a larger nominal wage bill for firms in the food industry need not increase their costs, and without increased costs of production, the model does not provide a reason why output prices should increase. Little support was found for a model of price increases based on wage growth. A causal relationship between price increases and increases in nominal wages in excess of the growth rate of labor productivity was found only for the nonalcoholic beverage commodity group. Also, no relationship was found to exist between nominal wage growth and the rate of growth of the money stock. The implication of these results is that the assumptions about firm behavior and market structure implicit in cost-push models may not be accurate representations of the actual pricing process.

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