WHY ARE PRICES SO RIGID?

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I. Introduction

The aggregate price level responds primarily to movements in standard unit cost. The impact of aggregate demand is significant but small and seems more closely related to such measures as inventories and unfilled orders than to the level of output. In other words, the observed price movements do not seem to follow the upward sloping supply curve of a competitive market. Apparently, price rigidity is much closer to the truth than price flexibility. This seems to be the conclusion that can be drawn after two decades of price equation estimation[1] and is confirmed by the more recent papers by de Menil (1974), Gordon (1975), and Sahling (1977). The findings of Maccini (1978) seem also to imply that unanticipated fluctuations in demand have only a modest impact on prices.

Faced with this large amount of evidence it may seem hard to avoid the conclusion that prices are essentially rigid. However, it is shown in this paper that, at least for the U.S. economy, another interpretation is possible, namely that the observed price rigidity can be explained within a competitive model when cyclical productivity variation is taken into account. Estimates from a previous paper by this author (Mork (1978a)) are used to demonstrate that, for any movement along the upward sloping marginal cost curve, the curve shifts in the opposite direction by almost exactly the same amount. Thid does not mean that

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[1]The articles of Nordhaus (1972) and Tobin (1972) give between them an excellent survey of the research up to that date.

price rigidity can be rejected, but it does offer an alternative explanation of what we seem to observe.

A few previous studies have included cyclical productivity in the price equation. Thus, Gordon (1971, 1975) uses actual over trend average labor productivity and gets a significant, although not very large coefficient in his 1971 paper; but the variable loses significance in the specification of his 1975 study. The present paper takes another route in that it uses an independent estimate of cyclical productivity and its shift effect on the marginal cost schedule. Thus, an explanation is also found to the weak impact of cyclical productivity in the price equation. Since the traditional price equations effectively have measured only the sum of the demand effect and the impact of cyclical productivity, the two separate effects have not been identified. This identification problem is solved in the present paper.

Finally, the observed demand effect as measured by unfilled orders or other variables of a similar character needs to be put in the right perspective within the competitive model. It is argued that this effect represents a reasonable extension of the competitive model in the sense that price movements in the very short run need not follow the regular short run supply curve.

The following section discusses the empirical framework of the study and presents estimates of various specifications of a price equation for this framework. Section III compares these findings with the previous estimates of cyclical productivity and discusses some of the implications of the findings. The observed demand effect is further discussed in section IV, and the conclusions are summarized in section V.

II. The Price Equation

Table 1 shows estimates of various specifications of a price equation for the nonfarm, non-primary-energy sector of the private U.S. economy. The purpose of presenting these estimates is not to produce still another competing price equation, but rather to show an equation estimated on the same data set as the cost function discussed in section III and to highlight some interesting results. Consequently, the specification is somewhat more simplistic than e.g. that of Gordon (1975); and no attempt has been made to improve the estimates by methods such as instrumental variable estimation, which have not been used elsewhere.

The nonfarm, non-primary-energy sector is defined as the business nonfarm sector plus the household sector minus coal mining and oil and gas exploration. The cost function to be discussed in the next section estimates the technology for the production of gross output in this sector in the sense that the inputs of intermediate goods from the farm sector and the primary energy sector are not subtracted off. The price index used in the price equation estimations corresponds to gross output in this sense and is thus slightly different from the private nonfarm GNP deflator.[2] In particular, it rose faster during the 1972-73 farm

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[2]The price index is defined as

$$P = \frac{GNP^N_{BNF} + GNP^N_H - GNP^N_E + X^N_E + X^N_A}{GNP^R_{BNF} + GNP^R_H - GNP^R_E + X^R_E + X^R_A} ,$$

where the superscripts N and R stand for nominal and real, respectively; X_i is intermediate deliveries from sector i; and the subscripts BNF, H, E, A stand for business nonfarm, households, energy, and farming (agriculture), respectively. This formulation is similar to de Menil (op. cit.).

price increase and even more so for the oil price jump in 1974. Furthermore, the gross character of this price index ensures the theoretical validity of the inclusion of indexes of farm and energy prices in the price equation. This seems a more satisfactory solution to the problem of food and energy prices than Gordon's construction of a non-food, non-energy price index.

The wholesale price index for farm products is used as the price of inputs from the farm sector. The energy price index is a Divisia index based on the wholesale price indexes of coal and crude petroleum. The latter was adjusted to include imports from 1973. The price of natural gas was not included because this was not an economically meaningful price concept for an important part of the sampling period. The wage rate is compensation per man-hour adjusted for overtime and interindustry shifts. The stock of capital was computed by the perpetual inventory method. The series of unfilled orders was taken from Business Statistics 1975 and updated from recent issues of the Survey of Current Business. For a detailed discussion of data, sources, and empirical structure of the model, the reader is referred to Mork (1978a,b) and Flavin, Mork, and Pauls (1978).

One can distinguish between two different theoretical formulations of the price equation. Competitive behavior, implying full price flexibility in the form of marginal cost pricing, gives, for a Cobb-Douglas technology,[3]

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[3]As us well known, this specification is highly restrictive. It is used in this section because it conforms to the tradition of the price equation in that it has a log-linear functional form, which justifies estimation of linear equations in relative rates of change.

$$(1) \qquad \Delta \ln P = a_0 + a_L \Delta \ln w + a_A \Delta \ln p_A + a_E \Delta \ln p_E + a_Q \Delta \ln (Q/K) .$$

Here, a_L, a_A, a_E are variable cost shares;

$$a_Q = \alpha_K/(1 - \alpha_K) ,$$

where α_K is the long run cost share of capital; P is the price level index, Q is gross output, K is the stock of capital, and w, p_A, p_E are the wage rate, the farm price index, and the energy price index, respectively. Homogeneity in factor prices gives the restriction that a_L, a_A, and a_E sum to unity, which is imposed throughout.

Thus, the output-capital ratio plays the same role in competitive theory as the "demand variable" in the traditional price equation.[4] Since the cost share of capital in the data used here is around 1/3, the predicted value of a_Q for the Cobb-Douglas specification is around 1/2.

Although competitive theory suggests that the output-capital ratio belongs in the price equation, it is not commonly used in the literature. Other demand variables, such as inventories or unfilled orders, are usually preferred. This type of demand variable can also be added to the competitive price equation (1), with the following justification. For the very short run, it may not be possible or optimal to adjust output and variable factor input fully to a demand change, so that the firm is off its regular short run supply curve. This can either be interpreted as a short run disequilibrium, and a price adjustment mechanism of the form

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[4] This result does not depend on the Cobb-Douglas assumption.

$$\frac{\Delta P}{P} = f\left(\frac{D-S}{S}\right)$$

can be postulated. In this case, the rate of change of price will depend on the level of the demand variable. Or, it may be assumed that price follows the marginal cost curve of the very short run, which will differ from (1). In this case, the level of price will depend on the level of the demand variable, so that the latter can be added to (1) in first difference form.

The alternative formulation of the price equation rests on an assumption that prices essentially are rigid and can be described as a mark-up over standard unit cost, i.e.

$$\ln P = \ln M + \alpha_L \ln w + \alpha_A \ln p_A + \alpha_E \ln p_E + \alpha_K \ln p_K ,$$

where M is the mark-up, and the α's are long run cost shares. In a one-sector model, p_K will be proportional to P so that, suppressing the real rental price of capital, one can write

$$\Delta \ln P = a_L \Delta \ln w + a_A \Delta \ln p_A + a_E \Delta \ln p_E + \Delta \ln M ,$$

where the a's are defined as in (1). The mark-up may, however, depend on demand pressure. Then, M will be a function of some demand variable E, so that

(2) $$\Delta \ln P = a_0' + a_L \Delta \ln w + a_A \Delta \ln p_A + a_E \Delta \ln p_E + \gamma \Delta \ln E.$$

Note that there is no straightforward hypothesis as to the numerical value of γ. Just as for the competitive price equation, it may be argued that ln E should replace Δln E in (2). Both alternatives are tried empirically in this paper. Rather than entering the discussion of which demand variable is "best", I pick unfilled orders, normalized by division by the capital stock (UFK) as representative of the literature. It is used for the mark-up specification as well as for the equation implied by competitive theory.

The price equation is estimated by ordinary least squares in relative rates of change, corrected for serial correlation with the Cochrane-Orcutt iterative technique.[5]

Since the factor prices perform very well without lags in the sense that the coefficients are close to the average cost shares, no lags are introduced for them. For the demand variables one would hardly expect long lags a priori because they are thought to reflect short run movements. There is a claim in the literature, though (cf. Gordon (1975)), that long lags improve the performance of the demand variables for some unknown reason. In conformity with this, lags of up to eight quarters are tried out. The results are presented for the specifications that give the highest t-ratios for ln(UFK) and Δln(UFK). For the specification with Δln(Q/K) alone, the results with the highest and lowest t-ratios are shown.

The equations were estimated on quarterly data for 1949:2-75:4. Table 1 shows the parameter estimates with standard errors in parentheses and length of lags (including the contemporaneous observations) in brackets. All lags are restricted to lie along third degree polynomials.

Three findings stand out. First, the output-capital ratio fails

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[5] This is an approximate correction for the moving average introduced by taking first differences. This indicates that estimation in level form and correcting for serial correlation is more logical. The first difference form is used here because it is much simpler when the rate of change of price is specified as a function of the level of unfilled orders.

Table 1. Price Equation Estimations

Dependent variable: $\Delta \ln P$

Eq. No.	Const.	$\Delta \ln w$	$\Delta \ln p_A$	$\Delta \ln p_E$	$\Delta \ln (Q/K)$	$\Delta \ln (UFK)$	$\ln (UFK)$	R^2	DW	ρ	SER
1	-0.0053 (0.0005)	0.864 (0.019)	0.063 (0.015)	0.073 (0.013)	0.017 (0.041) [1]			0.98	2.13	-0.33 (0.09)	0.0063
2	-0.0053 (0.0005)	0.862 (0.019)	0.066 (0.015)	0.073 (0.013)	-0.095 (0.094) [8]			0.98	2.14	-0.34 (0.09)	0.0063
3	-0.0057 (0.0005)	0.887 (0.019)	0.056 (0.015)	0.056 (0.013)		0.032 (0.010) [1]		0.98	2.18	-0.32 (0.09)	0.0060
4	-0.0057 (0.0006)	0.871 (0.019)	0.058 (0.016)	0.071 (0.013)			0.0019 (0.0028) [8]	0.98	2.17	-0.34 (0.09)	0.0062
5	-0.0057 (0.0005)	0.887 (0.019)	0.058 (0.015)	0.056 (0.013)	-0.159 (0.072) [4]	0.032 (0.010) [1]		0.98	2.18	-0.32 (0.09)	0.0060
6	-0.0059 (0.0006)	0.882 (0.020)	0.061 (0.015)	0.057 (0.013)	-0.184 (0.078) [4]		0.0021 (0.0024) [8]	0.98	2.21	-0.36 (0.09)	0.0061

completely to yield a significant positive coefficient. The estimated coefficient is negative for all specifications except equation 1 and larger negatively than twice its standard error in equations 5 and 6. It increases in absolute size and significance when used together with another demand variable, which seems to suggest a misspecification when the other demand variable is excluded. It should also be noted that equation 1 is the only specification of all those that were tried that gave a positive value of this coefficient. It might have been expected that the estimated coefficient is lower than its hypothesized value because of price rigidity. It is much more of a puzzle why it is so much lower as to get the wrong sign. The next section will propose a solution to this puzzle.

The second result is the poor performance of UFK in level form. Its coefficint is largest when the lag is long, but it is not significantly different from zero. This is consistent with Gordon's results.

Thirdly, the rate of change of UFK performs reasonably well as a demand variable. This would have to be expected in the light of the literature. The coefficients are somewhat lower than Gordon's 0.068, but still quite sizeable. Furthermore, lags fail to improve the performance of this variable. This is a contradiction of Gordon's results and conforms much better with the idea that demand pressure is a short run phenomenon.

III. Cyclical Productivity and Marginal Cost Pricing

Although the above results seem to be in clear conflict with the hypothesis of marginal cost pricing, it will now be shown that the two can in fact be reconciled when cyclical productivity fluctuations are taken into account. I have previously reported estimates of this component of labor productivity (Mork 1978a), showing that it moves roughly proportionately to the output-capital ratio. The estimates are obtained from a short run cost function for the goods and service sector defined above.[6] It is defined as

$$C = f(p)\ K(Q/K)^{\beta+(\theta/2)\ln(Q/K)}\ e^{T(p,Q,K,t)} \tag{3}$$

where

$$f(p) = \sum_i \sum_j b_{ij} p_i^{\frac{1}{2}} p_j^{\frac{1}{2}}, \quad i,j = L,A,E;\ b_{ij} = b_{ji}$$

$$T(p,Q,K,t) = (\tau + \tau_Q \ln(Q/K) + \sum_i \tau_i \ln p_i)t, \quad i = L,A,E,\ \sum_i \tau_i = 0.$$

Cyclical variation in labor productivity is estimated by defining the price of labor measured in efficiency units as

$$p_L = w(Q/K)^{-h}, \tag{4}$$

where h is a parameter to be estimated. Identification of this parameter requires the joint estimation of the "revenue-cost" equation

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[6] In Mork (1978a), a non-homothetic translog functional form is used. A revised version of this model is used here, which has a generalized Leontief functional form and is homothetic. The generalized Leontief funciton is preferred because it gives a better fit for factor demand, cf. Mork (1978b). Homotheticity is imposed because it is believed that non-homotheticity mainly is an aggregation phenomenon that does not affect pricing behavior. Thus, if industry technologies are homothetic in variable factors, the effect of variable factor price changes on the price level is determined by average rather than marginal cost shares. Then, the estimated aggregate cost function should reflect this in the form of the constraint that average and marginal cost shares are equal, i.e. it should be homothetic.

$$PQ/C = \partial \ln C/\partial \ln Q + u \tag{5}$$

and the system of factor demand equations. When marginal cost pricing is not assumed for the short run, the expectation of u conditional upon contemporaneous information is non-constant and non-zero, and it is potentially correlated with contemporaneous instruments. However, it can be shown (cf. Mork (1978a)) that u is well behaved when its distribution is defined conditionally on information available at the time the physical capacity was planned. With this justification, it is claimed that the estimated system gives a consistent estimate of cyclical productivity when estimated with instruments that are lagged eight quarters. The thus estimated parameters of the cost function are presented in table 2.

From (3), marginal cost is derived as

$$\begin{aligned} \ln MC &= \ln\left(\left.\frac{\partial C}{\partial Q}\right|_{p_L}\right) = \ln\left(\left.\frac{\partial \ln C}{\partial \ln Q}\right|_{p_L}\right) + \ln C - \ln Q \\ &= \ln\left(\beta + \theta \ln(Q/K) + \tau_Q t\right) + \ln C - \ln Q \end{aligned} \tag{6}$$

It is now possible to quantify the short run effects on marginal cost of a change in the level of output. First, there will be a movement along the marginal cost curve. This is measured by the elasticity

$$\left.\frac{\partial \ln MC}{\partial \ln Q}\right|_{p_L} = \frac{\theta}{\beta + \theta \ln(Q/K) + \tau_Q t} + \beta + \theta \ln(Q/K) + \tau_Q t - 1.$$

Table 2

Parameter Estimates

Homothetic Cost Function

Elements of the matrix $||b_{ij}||$

	A	E	L
A	0.0123 (0.0117)	0.0	0.0457 (0.0116)
E		0.0275 (0.0004)	0.0
L			0.5752 (0.0121)

h: 1.0360 (0.1269)	β: 1.4864 (0.0081)	θ: 0.4252 (0.1792)	τ: -0.00515 (0.00014)

Biased technical change parameters

τ_A: -0.00006 (0.00012)	τ_E: -0.00028 (0.00002)	τ_L: -0.00022 (0.00011)
	τ_Q: -0.00023 (0.00021)	

The value of this expression varies slightly over the sample but is mostly around 0.8. Secondly, the change in output will cause a downward shift in the marginal cost curve because it affects the cyclical component of labor productivity. This can be expressed as the product

$$\left(\frac{\partial \ln MC}{\partial \ln p_L}\right)\left(\frac{\partial \ln p_L}{\partial \ln Q}\bigg|_w\right) = \left(\frac{\partial \ln C}{\partial \ln p_L}\right)\left(\frac{\partial \ln p_L}{\partial \ln Q}\bigg|_w\right) = -S_L h ,$$

where S_L is the share of labor in variable cost. With S_L varying between 0.8 and 0.9, and h equal to 1.04, the value of this expression is around -0.9. Thus, the net effect of an output change on short run marginal cost is measured by the elasticity

$$\frac{\partial \ln MC}{\partial \ln Q}\bigg|_w = \frac{\partial \ln MC}{\partial \ln Q}\bigg|_{p_L} + \left(\frac{\partial \ln MC}{\partial \ln p_L}\right)\left(\frac{\partial \ln p_L}{\partial \ln Q}\bigg|_w\right) \tag{7}$$

whose mean value over the sample is -0.1. This is remarkably close to the results of section II.

More important than the negative sign, which may be due to sampling variation,[7] is the fact that the net effect is very close to zero. This solves the puzzle of why prices appear to be rigid. Given the observed cyclical flucatuation in productivity, marginal cost just does not move procyclically. Cyclical productivity may be hard to

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[7]Obviously, computation of exact standard errors for (7) over the sample is very complicated. For the 1972:2 observation, for which ln(Q/K) = t = 0 by normalization, the asymptotic standard error of (7) can be computed as 0.163 if S_L is treated as non-stochastic. The value of (7) of the same observation is -0.138. This justifies the conjecture that (7) is not significantly different from zero.

explain,[8] but once it is accepted as an observed fact, the rest follows easily.

This finding also offers an answer to the question of why it is so difficult to detect a significant coefficient for cyclical productivity in the price equation. Since both demand and productivity fluctuate cyclically, the separate effects of the two are not identified within the price equation. When different cyclical variables are used, perfect collinearity is avoided, but the identification problem cannot really be resolved within a single equation.

Although this identification problem appears to be solved by the present findings, a new and more fundamental one is created. For U.S. observations it just so happens that the hypothesis of marginal cost pricing, given the observed fluctuation in productivity, predicts the same type of price behavior over the cycle as the hypothesis of price rigidity. This is an identification problem in the sense that the two hypotheses of price rigidity and price flexibility are observationally equivalent.[9]

The presence of this identification problem means of course that neither hypothesis can be rejected. There is nothing in the data that con convince a person who believes in price rigidity that he or she is wrong. The various underpinnings of the Keynesian assumption of

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[8]Hall (1977) hints at an explanation base d on the incentive to better matches between jobs and workers provided by a tight labor market.

[9]Although not related to simultaneity, this belongs to the general class of identification problems as discussed by Koopmans and Reiersøl (1950).

rigid prices, like the oligopoly theories reveiwed by Modigliani (1958), are not disturbed. On the other hand, one may equally well believe in fully flexible prices. The findings of this paper do, however, have one substantive implication: even though prices may in fact be flexible, they do not have the procyclical movements that the neoclassical model is usually thought to predict. And this has further implications of a clearly Keynesian flavor. If an unexpected increase in nominal demand does not cause the price level to rise, it must have real consequences. An upward sloping supply curve may exist in the labor market and thus indirectly cause prices to move, but the short run supply curve in the goods market proper is esentially flat.

There is one important caveat to this conclusion, namely that it rests upon an empirical estimate of cyclical productivity for the aggregate U.S. economy. For this case it just so happens that the two effects of output fluctuations outweigh each other. Whether this holds for other countries or for sectors of the U.S. economy is an unexplored empirical issue. For the sector studied, however, the result seems quite robust.[10]

IV. The Demand Effect

It remains to determine whether the "demand effect" of the

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[10]With a somewhat heuristic argument, it may be noted that the two hypotheses can be distinguished empirically almost everywhere, but that the observations for the aggregate U.S. economy lie within (or sufficiently close to) the set of measure zero for which cyclical productivity exactly offsets movements along the marginal cost curve. This is similar to a situation where the order condition for identification is satisfied in a simultaneous system but the rank condition is not because some parameter is found empirically to be zero.

price equations, as measured by UFK or its rate of change, remains valid within a model with marginal cost pricing and correction for cyclical productivity. The estimates of table 1 suggest that this is so, and the issue will now be further explored with the flexible form of marginal cost defined in (6). This can be done by estimation of the equations

(8) $$\Delta \ln P_t - \Delta \ln SRMC_t = \sum_{\tau} \beta_t \Delta \ln UFK_{t-\tau}$$

(9) $$\Delta \ln P_t - \Delta \ln SRMC_t = \sum_{\tau} \alpha_{\tau} \ln UFK_{t-\tau} \quad ,$$

where $SRMC_t$ are fitted values defined as in (6)[11]. OLS estimates of the sums of the lag coefficients, corrected for serial correlation, are shown in table 3.

As in the price equation, the coefficients of UFK in level form fail to be significantly different from zero for all lag specifications. For the first difference form, the lowest standard error is obtained without any lag. The highest coefficient and the highest t-ratio is obtained for an eight quarter lag.[12] The long lag is, however,

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[11] In doing this, fitted rather than actual values of C were used. Also, even though the equations of the cost function estimation were corrected for serial correlation, no lagged residuals are included for computation of the fitted values. It may seem unsatisfactory to use fitted values of SRMC rather than estimating the effect of unfilled orders jointly with the other variables of the cost function. The complexity of the functional form does, however, make this very difficult.

[12] The lag coefficients are not constrained to lie along polynomials. When a third degree polinomial is used, this coefficient drops to 0.025 with the same standard error. The coefficients of the other specifications are not changed substantially.

Table 3

Sum of lag coefficients for equations (8) and (9)

	No lag	4 quarters	6 quarters	8 quarters
Δ ln UFK	0.019 (0.009)	0.016 (0.011)	0.007 (0.013)	0.033 (0.014)
ln UFK	0.0012 (0.0017)	0.0019 (0.0019)	0.0030 (0.0019)	0.0026 (0.0019)

unreasonable if unfilled orders are a proxy for demand movements in the very short run. Thus for the OLS Estimates, the specification without lag seems most attractive.

Instrumental variable estimation was also tried, for which rates of change of government expenditure, money supply, and capital stock were used as instruments for the contemporaneous values of $\Delta \ln$ UFK.[13] The changes in the results were slight, except for the specification without lag, for which the coefficient switched sign to -0.008. Although the standard error rose to 0.014, so that the difference can be said to be insignificant, this is somewhat disturbing. Nevertheless, the prior belief in short or no lags together with the tight OLS estimate for the no lag specification, leads to the cautious conclusion that this estimate is to be preferred.

V. Conclusions

With this, the final puzzling piece of the price equation falls into place. The weak, but significant coefficient of a demand variable other than output has (with some reservations) been shown to be a reasonable extension of a competitive model of aggregate pricing behavior. The extension consists of allowing for price movements off the estimated marginal cost curve in the very short run in addition to movements along and shifts in the same curve.

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[13] This was done for ln UFK in level forms also, with the instruments in level form as well, but without substantive changes.

The competitive model itself has been shown to be observationally equivalent to a model with rigid prices for the aggregate U.S. economy when cyclical productivity is taken into account. If the competitive model is believed *a priori*, this explains why the aggregate price level appears to be rigid. By the same token, it offers an explanation for the puzzling weak effect of cyclical productivity in the price equations in the literature. The explanation is that the effect of cyclical productivity and the demand effect as measured by output are not identified as separate effects within the price equation. They are, however, identified and estimated within the larger model of the present paper.

The following method was used to obtain these results. Previous estimates of short run cost and cyclical productivity were used to determine the slope of the marginal cost schedule, the cyclical shifts in the same caused by productivity fluctuations, and hence the net cyclical fluctuation in marginal cost. It was demonstrated that the result corresponds almost exactly to the findings of the price equation. It was also shown that the same findings are implied by the hypothesis of price rigidity, so that the Keynesian and the competitive models of price behavior cannot be distinguished empirically.

Thus, even though the lack of cyclical movement in the price level (relative to the wage level) can be explained by the competitive model, price rigidity in the Keynesian sense cannot be rejected. More important, however, is the positive implication that the aggregate supply curve is flat for a given wage rate. It means that important aspects of the Keynesian model will remain valid even if the approach itself should prove erroneous.

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