The Econometrics of Price Determination

Conference

October 30-31, 1970
Washington, D. C.

Sponsored by / Board of Governors of the Federal Reserve System
and
Social Science Research Council
Preface

On October 30 and 31, 1970, in Washington, D.C. the Consultants Committee for Price Research of the Board of Governors of the Federal Reserve System and the Social Science Research Council's Committee on Economic Stability sponsored a conference on The Econometrics of Price Determination. The Conference was designed to encourage new research, to ascertain the price-wage properties of major econometric models, to hasten the completion of econometric studies under way, and to provide an interchange between Government agencies originating price data and econometricians using such data. The Conference was not aimed at policy, but rather was intended to deepen our understanding of the structural mechanisms that have made the U.S. economy so vulnerable to inflation.

Most of the scholars who were requested to present papers agreed to do so, and the papers, without exception, were of high quality. The lively discussion of the papers added importantly to the substance of the Conference.

Irving Kravis and Bert G. Hickman, the chairmen of the two sponsoring committees, took the initiative in calling for the Conference. Members of the Planning Committee for the Conference were: Otto Eckstein (chairman), R. A. Gordon, Lawrence R. Klein, Edwin Kuh, Louis Weiner, and Alexander J. Yeats. Mr. Yeats served as executive secretary of the Planning Committee and assumed administrative responsibilities for the Conference. When Mr. Yeats accepted an overseas assignment, Mr. Weiner graciously took over these functions and then supervised the completion of this volume.

The Planning Committee is grateful to the Board of Governors of the Federal Reserve System for its financial and administrative support of the Conference and to the Board's editorial staff, which expedited the production of this book.

Otto Eckstein
Editor

Cambridge, Massachusetts
December 1971
Recent Developments in Price Dynamics

William D. Nordhaus

This study surveys recent developments in price dynamics. The intention is to sort those theories that show promise for understanding the actual movement of prices and for leading to the formulation of models suitable for econometric testing and forecasting.

Section I focuses on classical dynamic theories. Section II then turns to the "new" microeconomics of inflation, with special emphasis on the role of uncertainty in price dynamics. Section III examines some recent econometric theories of inflation and attempts to give them a firm theoretical footing. Finally, Section IV surveys recent econometric studies of inflation and then applies the theoretical remarks to the specifications.

NOTE—The author of this paper is Associate Professor of Economics, Cowles Foundation for Research in Economics, Yale University.

The research for this study was supported by the National Science Foundation, the National Bureau of Economic Research, and the Federal Reserve. This paper is a condensation of that presented at The Econometrics of Price Determination Conference, Nordhaus [35]. Many helpful comments have been included, especially those of Franklin M. Fisher, Robert J. Gordon, Donald Nichols, and James Tobin. The views are entirely the responsibility of the author.
I. MICROECONOMIC FOUNDATIONS: CLASSICAL DYNAMICS

This section contains a review of the classical microeconomic foundations of price dynamics. The objective is to ascertain what of this literature, if any, is relevant for econometric studies of price and wage dynamics.

A. CLASSICAL DYNAMICS

The earliest formal mechanism of price adjustment was Walras’ \(\textit{tâtonnement}\). This mechanism assumed that a central clearinghouse, or auctioneer, found the set of market clearing prices. The algorithm that Walras assumed started with a set of prices randomly chosen. If these prices did not clear the market, a new set was tried with the new prices raised or lowered as excess demands became positive or negative. Recent studies have shown that such an algorithm will converge to the equilibrium prices under a restrictive set of conditions.\(^1\)

The crucial assumption behind the \(\textit{tâtonnement}\) system is that there is no trading until the equilibrium prices have been found. There are obviously very few markets where a central mechanism exists that guarantees that excess demands vanish before trading takes place. Some analysts have turned to a non-\(\textit{tâtonnement}\) process of price adjustment.\(^2\) In the non-\(\textit{tâtonnement}\) processes, prices adjust according to excess demand or supply at the going prices, but they do not adjust sufficiently to erase the excess demands. The non-\(\textit{tâtonnement}\) processes appear to be stable in a wider range of cases than the \(\textit{tâtonnement}\) process. There are, however, some difficulties in determining the quantities actually sold in periods of disequilibrium.

A particularly useful exposition of the non-\(\textit{tâtonnement}\) price adjustment mechanism was given by Arrow [3]. His treatment extends the static analysis of stability to the markets with increasing demands. The analysis is not, however, general equilibrium in the usual sense; he discusses price dynamics in a subset of the economy. The following discussion will attempt to show the implications of the Arrow analysis in an economy-wide framework.

Consider an economy with \((n+1)\) goods, with the \((n+1)\)st good being the \textit{numéraire} with fixed price. If we assume that Walras’ law holds, then we can just examine the first \(n\) goods and the \((n+1)\)st good will be residually determined. Let us also follow the convention of measuring factors as negative goods.

Excess demand functions (the difference between supply and demand) are linearized\(^3\) with \(p = \bar{p}\) yields:

\[
\begin{bmatrix}
X_1 \\
\vdots \\
X_n \\
\end{bmatrix} =
\begin{bmatrix}
D_1(\bar{p}) - S_1(\bar{p}) \\
\vdots \\
D_n(\bar{p}) - S_n(\bar{p}) \\
\end{bmatrix} +
\begin{bmatrix}
D_1^* - S_1^* \\
\vdots \\
D_n^* - S_n^* \\
\end{bmatrix}
\begin{bmatrix}
p_1 - \bar{p}_1 \\
\vdots \\
p_n - \bar{p}_n \\
\end{bmatrix} + O(p - \bar{p})
\]

\(= (D(\bar{p}) - S(\bar{p})) + [D'(\bar{p}) - S'(\bar{p})](p - \bar{p}) + O(p - \bar{p})\)

where \(D_i'\) (or \(S_i'\)) is the derivative of the \(i\)th demand.

---

\(^1\) See the excellent survey article by Negishi [33] for a discussion of the stability problem.

\(^2\) See Samuelson ([41], p. 263 ff.), Negishi [33], and Hahn [22].

\(^3\) Equation 1 can be derived as follows. Assume that consumers have \(n\) demand functions \(Y^i = D(p)\) and firms have \(n\) supply functions \(Y^i = S(p); Y^i, Y^i\), and \(p\) being output demanded, output supplied, and prices. Excess demand is defined as \(X = Y^i - Y^i = D(p) - S(p)\). We assume an equilibrium exists; that is, that there is a set of prices, \(\bar{p}\), such that \(D(\bar{p}) = S(\bar{p})\). Taking the first-order Taylor expansion around \(p = \bar{p}\) yields.
to give:

(1)  \[ X = Mp + a \]

where \( X, p, \) and \( a \) are \((nxl)\) vectors of excess demands, prices, and constants and \( M \) is an \((nxn)\) matrix of coefficients. Assuming a continuous price adjustment process, we have

(2)  \[ \dot{p} = KX \]

where \( \dot{p} \) is an \((nxl)\) vector of time derivatives, \( dp/dt \), and \( K \) is an \((nxn)\) positive, diagonal matrix of adjustment coefficients. Combining Equations 1 and 2 we have

(3)  \[ \dot{p} = KMP + Ka \]

Under some strict conditions, Equation 3 will be stable.\(^4\) The solution is \( \dot{p} = 0, X = 0, \) and therefore \( p = -M^{-1}a. \)

Thus, the first proposition is the following: the non-tâtonnement system is stable if goods are gross substitutes. Arrow next introduces the problem of adjustment when some demand or supply functions are constantly changing over time. Assume that demand and supply functions are each shifting over time and that the difference (that is, the rate of change of demand less the rate of change of supply at a given set of prices) is given by the vector \( e \). We can then rewrite our excess demand function as follows:

(4)  \[ X = Mp + a + et \]

where \( e \) is an \((nxl)\) vector of coefficients and \( t \) is time. But now we find a surprising result: \textit{with constantly changing demands, there will be shortages or surpluses that will not vanish}. To see this, simply differentiate Equation 4 with respect to time and substitute for \( \dot{p} \) from Equation 2, obtaining:

(5)  \[ X = MKX + a \]

Arrow shows that \( X \) tends to zero, so excess demands do not vanish but rather tend toward:

(6)  \[ X = \lim_{t \to \infty} X(t) = -K^{-1}M^{-1}e \]

Moreover, by substituting Equation 6 into 2 we see that

(7)  \[ \dot{p} = \lim_{t \to \infty} \dot{p}(t) = -M^{-1}e \]

In his work, Arrow assumed that all demands were rising over time (while supplies were stable) so that \( e \) was positive. In this case, it is clear that \( \dot{p} \) is positive and all prices are rising relative to the numétaire. In an economy-wide framework, however, we must be more careful in making assumptions about the sign of \( e \). If Walras’ law is to hold, all excess demands cannot be growing. In particular, \( X'p + X_{e+}p_{e+} = 0 \) by Walras’ law. If excess demand for the non-numénaire goods is rising, then excess demand for the numéaire good must be falling. It is easily seen that \( X \) is nonnegative if \( e \) is nonnegative. Thus, unless we are willing to assume that the excess demand for the numéaire good is falling over time, we must generally assume that \( e \) contains some negative elements.

It is important to note, however, that the rates of inflation on each market (and the aggregate as well) depend on the structure of demand and supply (the \( M \) matrix) and on the relative changes in demand and supply \( d \) functions (the \( e \) matrix). We know that the prices will be changing on all markets, that this change will tend toward some constant rate of change, and that the final rate will depend only on conditions of supply and demand—not on reaction speeds.
It is only in the exceptional case where $M^{-1}e$ is zero that there will be no inflation or deflation. Arrow has also shown that the propositions stated earlier also hold when some restricted forms of price expectations are added to the model.\(^5\)

There are many shortcomings to the simplified model analyzed here. Nevertheless, it does indicate that in a growing economy the average price level may have an over-all trend that is not one of stability. The model may also give insights into recent controversies about the natural level of utilization in an economy.

B. PHILLIPS CURVE CONTROVERSY REVIEWED: IS THE ECONOMIC SYSTEM NEUTRAL TO INFLATION?

The inadequacy of classical price dynamics has been indicated in certain controversies surrounding the trade-off between inflation and unemployment. The controversy, briefly stated, is whether there is a long-run trade-off between resource unemployment and inflation. In terms of the non-tâtonnement model presented earlier, the debate turns around the form of the price dynamics function contained in Equation 2. Some economists, notably Phelps and Friedman,\(^6\) have argued that the function should have a term incorporating the expected rate of change of prices: \(^7\)

\[ \hat{p} = KX + \lambda \hat{p} \]

where $\lambda$ is an $(m \times n)$ matrix. According to this school of thought (call it "accelerationist"), two conditions are met: (1) $\hat{p} \to \hat{p}$ as $t \to \infty$ and (2) $\lambda = I$. The first condition is quite straightforward: it simply assumes that expectations are, in the long run, correct. The second condition is more difficult to interpret. It says that the price adjustment mechanism responds fully to fully anticipated inflation. Both of these assumptions are part of the accelerationist hypothesis.\(^8\) Using the system of the previous section, assuming prices are correctly anticipated ($\hat{p}^* \to \hat{p}$), and recalling that $X = MKX + e$, we obtain

\[ X = -M^{-1} \cdot M^{-1} e \]

Putting this in Equation 8 yields:

\[ \hat{p} = - (I - \lambda)^{-1} M^{-1} e \]

Clearly as $\lambda \to I$, $\hat{p} \to \infty$; and since $X = M\hat{p} + e$, $X \to 0$ as $\hat{p} \to \infty$. If $\lambda = I$, $KX = 0$, which implies that $X = 0$. As long as $(I - \lambda)$ is nonsingular, Equation 9 will hold.

We can thus summarize the argument conveniently with the present model. When price dynamics can be summarized by a non-tâtonnement model, the question of whether there is a natural rate of unemployment, corresponding to clearing of all markets and no excess demands in any market in the long run ($X = 0$ in the system here), revolves around the price-clearing equations. If the adjustments in each market respond completely to the expected rate of change of prices (and $[I - \lambda]$ is thus singular), there will be only one level of output consistent with $X(t)$ in which $\hat{p}(t) \to \hat{p}^*$ and $X(t) \to X^*$ as $t \to \infty$. In these paths $X^*$ is independent of $\hat{p}$.

There is generally no statement about the behavior of the path $(\hat{p}(t), X(t))$ during any finite period. We are here using $\hat{p}$ to indicate the proportional rate of price change, or the time derivative of log $p$.

Friedman [17], Phelps [39e], and Phelps et al. [39].

\(^{\ast}\) A precise statement of the hypothesis of a "natural rate of unemployment" in the present model runs as follows: Consider alternative paths $(\hat{p}(t), X(t))$ in which $\hat{p}(t) \to \hat{p}^*$ and $X(t) \to X^*$ as $t \to \infty$. In these paths $X^*$ is independent of $\hat{p}$.

\(^{\star}\) Phelps (1936) and earlier works recognizes the necessity of both conditions for the accelerationist position. Friedman [17], on the other hand, appears to assume the first condition ($\hat{p} \to \hat{p}$) is sufficient. For a fuller discussion and a counterexample to Friedman's view, see Nordhaus [36].
with bounded rates of inflation—that where there are no excess demands or supplies.9

Thus, the question of whether there is a “natural rate of unemployment” (or whether the system is “inflation neutral”) revolves around whether the matrix in Equation 8 is such that \((I - \lambda)\) is singular. There are four points to be made about this. First, it is not a sufficient condition for inflation neutrality that price or inflation expectations be correct.10 As is easily seen in the system above, expectations can be perfect; yet if the adjustment mechanism is not singular, the system can have excess demands or supplies. Second, it is often supposed that complete adjustment in the labor market (that is, the labor market’s \(\lambda = 1\)) is sufficient for inflation neutrality. This is not generally true, but rather assumes that the rest of the economy is also inflation-neutral. Third, the theoretical argument that markets should display inflation neutrality rests mainly on the proposition that rational individuals should display inflation neutrality. This proposition does not generally follow, for markets do not usually conform to any collective rationality. Our knowledge of market behavior is not sufficient to know how markets react with respect to fully anticipated inflation.11 Fourth, there has by now been accumulated a great deal of empirical evidence about the actual response of markets, especially labor markets, in periods of rising prices. The evidence is overwhelmingly against the hypothesis that markets are inflation-neutral.12

9 Incidentally, there will be an equilibrium for the model where \(X = 0\), or \(P = -M^{-1}(\pi + \epsilon t)\), which implies that \(\hat{p} = -M^{-1}e\). In this case prices adjust immediately to wipe out excess demands.

10 See Footnote 8.

11 Whereas the argument cannot be generally made that markets are inflation-neutral, the analysis of the "new" microeconomics discussed in the next section does lead to that conclusion. The reason for this is that prices, and price adjustments, are set by individual firms that are, by assumption, inflation-neutral.

12 Much of the evidence is reviewed by Bodkin et al. [5]. See also Gordon [19] for an explicit test of the accelerationist position. To my knowledge, the only writer who finds evidence of inflation neutrality is Cagan [9] and [10]. Cagan’s work is of some interest because it covers a long period of time. Some evidence is reviewed in Section IV.

II. "NEW" MICROECONOMICS OF INFLATION

In the last couple of years a new wave of analysis of the microeconomic foundations of inflation theory has appeared. One of the leading writers in this new wave, E. S. Phelps, has given the following explanation for the outpouring of "non-Walrasian" economics:13

13 Phelps [38, p. 147]. The terminology in the discussion is somewhat confusing. We used the terms tâtonnement (and non-tâtonnement) in Section I to indicate that transactions did not (or did) take place at nonequilibrium prices.

Phelps appears to use the term “Walrasian economies” to mean those where agents are price adjusters, and “non-Walrasian economies” to mean quantity adjusters. This paper will conform to that distinction. It should be noted that the Walrasian case does not necessarily mean a tâtonnement process.

It is notorious that the conventional neoclassical theory of the supply decisions of the household and of the firm are inconsistent with Keynesian employment models and with the post-Keynesian economics of inflation. . . . It seems clear that macroeconomics needs a microeconomic foundation.

The stated purpose of the analysis can hardly be questioned.

The new microeconomics is based on two fundamental assumptions: (1) Economic agents are rational and—within the economic constraints of their environments—consumers behave as to maximize “lifetime expected utility” and firms “doggedly” maxi-
mize "net worth." 14 The most important environmental constraint considered is "that collating information about potential exchange opportunities is costly and can be performed in various ways." 15 Put differently, the "new" theory accepts the neoclassical analysis except the assumption of perfect and costless information structure. In one way or another, almost all recent developments put these two assumptions to work on the age-old problems of economic analysis: What are optimal prices, wages, employment, output, and so forth? Taken together, these contributions clear up many of the inconsistencies in current macroeconomic thinking.

We will first give a brief description of the effect of uncertainty on decisions, then turn to the implications of this for the microeconomics of inflation.

A. UNCERTAINTY AND PRICES

The Walrasian paradigm which is usually the starting point for most microeconomic reasoning assumes that products are homogeneous and that all economic agents have full information about both the quality and the price of relevant goods. Further work of Arrow and Debreu 16 has extended this analysis to markets characterized by uncertainty. It is extremely important to note, however, that in the Arrow-Debreu world there are (as in the Walrasian paradigm) no costs of obtaining information about characteristics of goods or about states of the world. It is clear that these assumptions are crucial for the validity of the general equilibrium model. Under conditions of uncertainty, markets are imperfect, reliable information is costly, and the economic agent has quite a different task. It is now possible that he will spend a good deal of his time engaged in searching for goods that suit his tastes, determining the cost and characteristics of products, and hedging himself against risks that he cannot market.

It is instructive to consider "information" as an additional commodity. Especially where goods are heterogeneous, indivisible, infrequently purchased, or immovable, it costs real resources to gather information about the different dimensions of a good. This information is an intermediate good since it does not yield satisfaction directly. There are several consequences of this added complication. Often, workers will decide to spend time searching for a better job ("unemployment"), goods will wait for potential customers ("inventories"), and in certain cases specialists in information ("brokers") will help facilitate transactions.

Some progress has been made recently on the problem of information. The simplest kind of model for integrating uncertainty into price theory starts with buyers (or sellers) uncertain about the price, $p$, of a commodity, $x$. They take a sample from a group of $n$ sellers and get offers ($p_1, \ldots, p_n$).

If the cost of an offer is $c$, then they will continue to sample until the expected decrease in price on the next offer is less than $c$. For example, if prices are normally distributed with mean $\mu$ and variance $\sigma^2$, then the minimum offer $p(n)$ at the $n$th observation is approximately 17

$$p(n) = m - \sigma \sqrt{2 \log n}$$

If the seller is looking for one item, then the minimum net cost, $p(n) + cn$, comes at approximately 15

14 These quotations are from Phelps ([39a], p. 3). Also see Phelps [38].

15 Alchian ([39a], p. 28).

16 Arrow [2] and Debreu [12].

17 Gumbel shows that the modal largest value for a sample of $n$ from a normal variable (N(0, 1)) is approximately $\sqrt{2 \ln(0.4n)} \approx -1 + 2 \ln n$. (See Gumbel [20], Section 4.23, pp. 136-40.) The approximation in the text is found in Alchian [39a].

18 Net price is $p^* = m - \sigma \sqrt{2 \log n} + cn$, so $\frac{dp^*}{da} = -\sigma \sqrt{2} (\log n)^{-\frac{3}{2}} \cdot n^{-\frac{1}{2}} + c = 0$. Thus the sample that minimizes cost is:

$$n^* \log n = 2\sigma^2/c^2$$
\[ n = \sqrt{\frac{2}{\sigma / c}} \]

Clearly, the amount of optimal search depends directly on the dispersion of prices prevalent in the market and inversely on the cost of search. As the numerical examples in Footnote 18 indicate, a considerable amount of search may be consistent with the uncertainty presently found in markets. A number of important phenomena can be explained by this simple search model. First, it is clear that under the usual conditions markets need not be perfect in the sense that there is perfect information and all prices are the same. If the costs of information-gathering are significant, a certain amount of product differentiation may be a long-run phenomenon. Secondly, one of the interpretations of the phenomenon of persistent unemployment in market economies is that this is simply a result of workers shopping around for better wages, or of employers refusing to lower wages in periods of declining demand because of the probability that they will lose workers and be unable to rehire them in more affluent periods without substantial search costs. Third, since price information is a scarce resource (in that it is costly to obtain and to store), there will be real costs to rapid changes in prices since change makes past price quotations obsolete and therefore worthless. Fourth, in economies that are in a constant state of flux (with movement in and out of the labor force, with fluctuations in aggregate demand, and with firms taking these parameters into account when they make their decisions), there will generally be unemployment of all factors and outputs for a significant amount of time.

Before we turn to the significance of these findings for price dynamics, let us note some of the unexplored or unexplained problems in these theories. The most important shortcoming is that, without exception, the theories have not succeeded in marrying supply and demand. Glancing back at Equation 10, we see that it gives optimal behavior when dispersion of prices and costs of search are given. But search costs, and certainly the amount of price dispersion, are crucial endogenous variables of the system. To be complete, the new microeconomics must explain these magnitudes as well.

It is perhaps in order to offer some suggestion on how the two sides of the market can be combined. Assuming there are large numbers of potential buyers and sellers for a good, it should be noted that the optimal search rule (1) is applicable for both sides of the market. That is, both buyers and sellers will generally have incentives to do some sampling. For reasons that are not always clear, it is customary in most markets for one of the two sides to post a price. If institutions are well arranged, one would suspect that the price setter is the one that

---

For \( n \) around 2 this is approximately the number in the text. Just to get a rough check, the optimal size of sample for different items (assuming $5 per sample) is something like: washing machines: 2; automobiles: 12; houses: 80. The coefficients of variation are from Stigler ([49], p. 4) for washing machines and automobiles. The figure for houses draws on unpublished regressions of Peter Mieszkowski.

19 See Stigler [47] and Phelps and Winter [39g].
20 See Holt [39c] and Alchian [39a].
21 See Alchian [39a].

22 See Alchian [39a], Gordon and Hynes [39b], and Nordhaus [36].
23 The following provide concrete examples. Both Stigler [47] and Alchian [39a] consider the optimal search and stopping rules when price dispersion is given. They fail to discuss the sources of price dispersion and why it is a permanent, as opposed to a transient, phenomenon. Similarly, Stigler [48] and Rees [40] apply the theory to the labor market and do not explain the dispersion in wage offers on the part of the firm. Holt, in many places, analyzes the optimal behavior of the individual worker in detail and in the aggregate, without looking into the firm's demand for labor (see Holt [39c]).

Several authors look at the decisions from the point of view of the firm alone—for example, Phelps and Winter [39g], Mortenson [39d], and Phelps [39e].
Figure 1/Density Function of Minimum Prices for Samples of Size 1, 2, 3, 5, and 10 from a Normal Distribution

Source.--Gumbel [20], p. 132.
does not do the searching 24 and that this arrangement might minimize aggregate search costs. (Search costs are \(c_{nx}\), where \(x\) is now the total number of transactions and \(c\) and \(n\) are the same as described earlier.)

The link between buyer and seller, in fact, would seem to be very close to the mechanism specified by Phelps and Winter [39g]. 25 What happens in markets with search is that the low-price sellers attract more customers than the high-price sellers. This can be shown in Figure 1. Let \(f(p)\) be the density function of existing prices and \(f(p,n)\) the minimum 26 of a sample of \(n\). The density function of sales, \(f(p,n)\), is closely related to \(f(p)\) by Equation 10: if \(n = 1\), then the density function of sales will be exactly the density function of prices. But as the size of the sample increases, first to 5, then to 10, the distribution becomes more and more concentrated toward lower-priced sales. If sales are repetitive and customers have memories, there will be cumulative movement toward low-priced firms, and high-priced firms will be driven out of business. In this model, then, we may make the following prediction about the equilibrium dispersion of prices. If customers have memories and there are no new entrants into the market, the equilibrium dispersion comes when the optimal number of searches is one.

In the present model, this implies that the dispersion of price is around two-thirds of the search cost for a price quotation. 27

It may also become stable with higher dispersion if customers have short memories, or are infrequent purchasers, or if there is a steady stream of uninformed buyers that come into the market. A good example of where high dispersion of prices can persist for a long time is the "tourist trap," where the terrain is unfamiliar, purchases are infrequent, and no substitutes are available. In the case of a stable system of prices with high dispersion, firms will be faced with a clearly defined, negatively sloped demand curve between price and flow of purchases. It is easily seen that sales prices will be approximately distributed with mean \(\{m - \sigma \sqrt{2} \log n\}\) and standard deviation \(\{\sigma(0.40 + \sigma \sqrt{0.6n^{-0.5}})\}\), where \(m\) and \(\sigma\) are the moments of the price distribution. 28 These distributions define the static demand curve in the stable limit. 29

B. UNCERTAINTY AND PRICE DYNAMICS

Several papers have applied, more or less directly, some of the ideas discussed earlier to derive theories of disequilibrium wage and price behavior. The new features of these dynamic theories are the following:

1. Even though firms or consumers behave rationally, they do not learn about possibilities instantaneously. As a result, parties have temporary monopoly power in markets.

2. Given the dynamics of adjustment, firms will have an optimal path over time for prices and wages, the path depending on initial conditions, prices, costs, and the usual factors.

3. In general, the optimal paths and comparative dynamics for price, output, and so forth behave very much like the usual textbook examples when modifications for existence of monopoly power are made.

24 Advertising is in some ways an exception to this rule, for it is an attempt to inform (or, more likely, to try to misinform) the broad mass of consumers about the terms of a given deal.

25 See subsection II-B.

26 We have adapted Gumbel's figure by graphing \((p - \bar{p})\), thus looking at the maximum rather than the minimum. By viewing Figure 1 in a mirror, the more intuitive distribution \((p - \bar{p})\) can be seen.

27 See Equation 10.

28 The mean is from Footnote 1. The standard deviation of the mean is an approximation from a figure in Gumbel ([20], p. 135).

29 After this paper was written, an excellent application of some of the concepts to consumer theory was published (Nelson [34]).
One of the most elegant treatments is that of Phelps and Winter [39g]. They utilize the basic competitive model with one major modification: They assume that, although the elasticity of demand for an individual firm is infinite in the long run, it is finite in the short run. Their economy is therefore a kind of Chamberlinian model, where each firm’s $dd$ curve is like the industry’s $DD$ curve—in fact it has the same elasticity instantaneously in the Phelps-Winter model—but in the long run, the firm’s $dd$ curve becomes perfectly horizontal at average industry price. The major simplifying assumption is that the fraction of the market possessed by a single firm is a first-order differential equation in the firm’s price and the industry price:

$$\dot{x}_i = H(p_i, \bar{p}) x_i$$

where $x_i$ is the $i$th firm’s share of the industry, $p_i$ is the $i$th firm’s price, and $\bar{p}$ is the average price in the industry. (The dots over variables represent time rates of change of those variables.) Also, $H(\bar{p}, \bar{p}) = 0.$

It is not clear how Phelps and Winter derive this basic behavior hypothesis. From our discussion in subsection II-A, it is clear that the qualitative properties of Equation 11 could be derived from the model of search under conditions of uncertainty discussed there. On the other hand, the quantitative properties of Equation 11 would depend on the number of searches. Thus, referring back to Figure 1, we know that whereas the bold line is the density function of prices, the thin lines are the density functions of sales. For example, if the number of searches is $n = 5$, then the “break-even price” ($\bar{p}$) (at which the firm just has its proportional share of customers) comes at about $\sigma/2$ below the mean. Below $\bar{p}$, the firms have more than their share of the market, while above $\bar{p}$, firms have less. Thus, the $H(\bar{p}, \bar{p}) = 0$ assumption of Phelps and Winter—meaning that a firm that sets prices at the industry average will lose no customers—does not square with the underlying search model except in the case where no search occurs. In fact, as we have indicated in subsection II-A, the Phelps-Winter assumption will hold asymptotically as (or rather if) the high-price firms get selected out of the population and price dispersion decreases. A second problem with the model is that the assumption of a first-order differential equation is not persuasive. By itself, the search model does not generate the first-order equation directly, for its customers have no memory; the firm’s share with a constant price differential is unchanging. To get a constant erosion of customers, it must be assumed that individuals have memory and do some sampling every period and go to the lowest-priced firm. Thus, if all customers sample and have memory, it is as if the size of sample increases over time, and the density function of sales moves further and further to the left. This would indeed drive out the high-priced firms, as Phelps-Winter assume.

Further assuming that the firm produces at constant marginal and average cost, and that $x_i(p)$ is the demand function for the $i$th firm’s product, the firm wishes to maximize
its net worth in Equation 12 subject to Equation 11.

\[ V = e^{\int_{P}^{\infty} (p-c) \chi \eta (p) dt} \]

Let us further simplify by setting \( H(p', \bar{p}) = k(\bar{p} - p') \), \( k > 0 \). Using standard techniques in optimal control, we can derive the following set of conditions for describing the firm's optimal price behavior (omitting subscripts):

\[ \dot{x} = k(\bar{p} - p) \]

\[ \dot{q} = q[r - k(\bar{p} - p) - (p - c) \eta] \]

\[ \dot{x} = 1 / [\eta' \eta' - c] + q k x = 0 \]

where \( q \) is the conjugate variable of \( x \) and is interpreted as the "shadow price of patronage." It is easily seen that if \( k \) is zero (the firm is a monopolist) the condition is simply that the bracketed term in Equation 15 holds; that is, the standard monopoly condition that the ratio of marginal cost to price be equal to one plus the inverse of the elasticity of demand, \( c/p = 1 + 1/\epsilon \), where \( \epsilon = \eta' \dot{x} / \eta = \) price elasticity of demand.

In final equilibrium, where the firm's share is constant, \( \dot{x} = \dot{q} = 0 \), so we know from Equations 13 through 15

\[ p = \bar{p} \]

\[ q = \eta (p - c) / r \]

\[ (p - c) / p = \left[ kp / \eta - \epsilon \right]^{-1} \]

These conditions tell us that the firm's price tends toward the average industry price and that at that price the firm's "monopoly power," \( (p - c) / p \), is less than it would be for a monopolist according to reaction speeds \( k \) and discount rates \( r \). Equation 18 is of great interest because it allows us to judge the importance of patronage in price decisions.\[ ^{33} \]

Moreover, Phelps and Winter derive a rather complicated rule for disequilibrium price behavior. From their description it appears that price moves toward the equilibrium \( (\bar{p}, \bar{x}) \) in Equations 16 through 18 in a mixed Walrasian, non-Walrasian mechanism (see their Equation 42):

\[ \dot{p} = a_{p}(p - \bar{p}) + a_{x}(x - \bar{x}) \]

\[ \dot{x} = \beta_{x}(p - \bar{p}) \]

The most important questions for Phelps and Winter, insofar as they are attempting to propose non-Walrasian adjustment mechanisms, is to show that firms adjust output rather than price when demand shifts. For this to be the case, \( \beta \), in Equation 19 must be large relative to \( a_{p} \) and \( a_{x} \). In this case, increases in demand would be met mainly by increases in output rather than increases in price.

A careful examination of the relevant sections of the Phelps-Winter paper (pp. 325–35) indicates that (aside from the usual static variables) the non-Walrasian case (where output rather than price responds) is important when interest rates are high, or when reaction speeds \( k \) are low. This result, although not completely spelled out, is of interest. It indicates that one can expect non-Walrasian behavior where conditions approximating monopoly conditions obtain, including the condition that price is significantly above marginal cost. Similarly, if profit margins are low, the Phelps-Winter model predicts the Walrasian model will give relatively good predictions. As noted in discussion of Equations 16 to 19, this case

\[ ^{33} \text{This is a major criticism of the Phelps-Winter model. As noted earlier, this result comes from a misspecification of the customer-flow dynamics in a search model. The correct specification would lead to a non-zero dispersion, the dispersion dependent on search costs and customers memories.} \]

\[ ^{34} \text{It is a common criticism in price theory that "marginalism" ignores the fact that short-run profit maximization leads to loss of customers and is thus inconsistent with long-run profit maximization. Equation 18 shows the extent of the modification that should be made to account for potential loss of customers.} \]
corresponds to conditions where competitive behavior obtains.

Another set of papers examines the problem of wage dynamics in heterogeneous labor markets. Using the basic framework set forth in the preceding section, this theory demonstrates that a worker will have a declining “acceptance wage” that depends basically on the worker’s perceptions of the market opportunities. The authors show that (for given expectations about the general trend of wages) there will be a trade-off between the unemployment rate and the rate of wage inflation like that postulated in the Phillips curve. In other words, the new microeconomics leads one to predict that for labor markets there will be a mixed Walrasian, non-Walrasian adjustment mechanism. Prices respond to excess demands or supplies in the general manner predicted by the Walrasian adjustment mechanism, but one has to pay close attention to the move-

55 Holt [39c], Mortensen [39d], and Phelps [39f].

III. OPTIMAL PRICING IN THE LONG AND SHORT RUN

In recent years, significant progress has been made in understanding the empirical behavior of prices. It is slightly troubling, however, that the theoretical foundation of these studies bears little relation to standard price theory. The authors rely more heavily on questionnaires or behavioral studies of business behavior than on the traditional body of economic thought. The main reason for this is probably that while there is an elegant theory of equilibrium price behavior, there is no well-developed theory of price dynamics. A second problem with existing empirical studies is that they lean heavily on mark-up theories of pricing. These theories have been attacked by some as antithetical to profit-maximizing behavior, whereas others have argued that mark-up pricing is not at variance with optimizing behavior.

In this section we shall set down very briefly a “neoclassical” theory of price bei-

56 Two behavioral studies are widely cited: Hitch and Hall [24] and Kaplan et al. [26]. Other studies are by D. C. Hague, I. F. Pierce, and A. C. Cook.

57 Machlup [31] and [32].

58 See Simon [43] and [44], Eckstein [14], and Williamson [52]. The relation between cost functions and profit-maximizing prices has been discussed by de Menil [13]. The idea that mark-up pricing is consistent with profit maximization is treated briefly in Bodkin et al. [5].
behavior. The theory will be helpful both in interpreting the theories commonly cited in applied price theory and also in interpreting the econometric results reported in the next section.

A. NEOCLASSICAL PRICE BEHAVIOR

This section derives a model of long-run, or equilibrium pricing. We will assume that the representative firm has a technology as represented by a production function. There are no lags in the production process, so that orders, production, and demand are all known immediately and can respond instantaneously to changes in the independent variables. To simplify the analysis, assume the firm uses capital (K), labor (L), and materials (M) as inputs. Homogeneous physical output (X) is then given by

\[ X = F(K, L, M) \]

L is measured in manhours, M in physical units, and K in capital services. To start with, we examine a representative firm producing the output. The firm faces a well-defined demand curve.

The firm’s criterion in setting price is that the expected value of discounted profits be maximized, where \( \phi \) is a discount rate. Using “hats” (\( \hat{\cdot} \)) to represent expected values, this criterion is:

\[ \max \left\{ p \right\} U = \int_0^T \left\{ \hat{p} \hat{X} - \hat{C} \right\} e^{-\phi t} dt \]

where \( C \) is cost. At this stage of the analysis, we will assume there are no temporal dependencies, so Equation 21 reduces to instantaneous maximization of the profit flow, \( \Pi \), at every point of time. The criterion is thus:

\[ \max \left\{ X \right\} \Pi = pX - C \]

The solution to the problem will reduce to the familiar condition that marginal revenue equals marginal cost. The new twist is that given the production and demand functions we can calculate the profit-maximizing price explicitly. Because of these assumptions, we call the optimal price behavior “neoclassical.” To get the flavor of the analysis, we will show explicitly how optimal price is derived in the Cobb-Douglas case. If production is given by a Cobb-Douglas production function, with Hicks-neutral technological change occurring at rate \( h \), we have:

\[ X = cK^{a_1}L^{a_2}M^{a_3}e^{ht} \]

we further assume that demand is log-linear in price \( (p) \) and income \( (Y) \):

\[ X = Bp^{a_1}Y^{a_2} \]

We can form our profit function:

\[ \Pi = CX^{1-a_2} - \lambda L - qK - vM \]

where \( C = cB^{1-a_2}Y^{a_2} \). Maximizing with respect to all inputs we have

\[ \begin{align*}
\frac{\partial \Pi}{\partial K} &= a_1 \left( 1 - \frac{1}{b_1} \right) pX - q = 0 \\
\frac{\partial \Pi}{\partial L} &= a_2 \left( 1 - \frac{1}{b_2} \right) pX - w = 0 \\
\frac{\partial \Pi}{\partial M} &= a_3 \left( 1 - \frac{1}{b_3} \right) pX - m = 0
\end{align*} \]

Thus

\[ X = Ce^{ht} \left( \frac{ka_1}{q} \right)^{a_1} \left( \frac{ka_2}{w} \right)^{a_2} \left( \frac{ka_3}{v} \right)^{a_3} \]

where \( k = p^{1-a_1}B \left( 1 - \frac{1}{b_1} \right) Y^{a_2} \). Putting Equation 24 into 26:

\[ Bp^{a_1}Y^{a_2} = Ce^{ht} \left( \frac{a_1}{q} \right)^{a_1} \left( \frac{a_2}{w} \right)^{a_2} \left( \frac{a_3}{v} \right)^{a_3} k^{a_4 + a_5 + a_6} \]

Setting \( m = a_1 + a_2 + a_3 \), the degree of homogeneity of the production function,

\[ p^{1-a_1 + (1 - b_1) m} = Ce^{ht} \left( \frac{a_1}{q} \right)^{a_1} \left( \frac{a_2}{w} \right)^{a_2} \left( \frac{a_3}{v} \right)^{a_3} B^{m-1}Y^{a_2(m-1)} \left( 1 - \frac{1}{b_1} \right)^m \]
Finally set \( \theta = [b_1 + (1 - b_1)m]^{-1} \), so

\[
(27) \quad p = (B^{n-1}c_o)^{-1}e^{-\lambda_Y} \left( \frac{w}{q} \right) = \left( \frac{a_i}{w} \right)^{-a_q} \left( \frac{a_i}{Y} \right)^{-a_q} Y^{-b_1 + a_1 - \alpha_1} \left( 1 - \frac{1}{b_1} \right)^{-w}.
\]

Equation 27 gives the basic, long-run rule for the profit-maximizing price. We can simplify greatly for purposes of discussion by assuming constant returns to scale \((m = 1)\). In this case, we get \( \theta = 1 \) and

\[
(28) \quad p = C e^{-\lambda_Y} w^m v^n,
\]

where
\[
C' = \left( 1 - \frac{1}{b_1} \right)^{-1} a_i^{-a_q} a_i^{-a_q} a_i^{-a_q} C_v.
\]

The optimal price is closely related to average and marginal cost; in fact, it equals these when \( b_1 = \infty \), the competitive case. Under noncompetitive conditions, the ratio of price to marginal cost equals \((1 - 1/b_1)\), the usual rule under static conditions. Three important points should be made about the optimal price. The first is the effect of factor prices on price. As Equation 28 shows, the logarithm of price is a log-linear function of factor prices. Thus a rise of 1 per cent in the wage rate leads to a rise of \( a_i \) per cent in the optimal price. The second point is that the cost of capital is an important component of the optimal price. It is slightly surprising that cost of capital has been omitted from statistical estimates of price behavior. The third point is that productivity does not explicitly appear in the equations. (More precisely, it appears through the time trend.) The omission of productivity is a result of the assumption that technological change proceeds smoothly at an exponential rate and does not vary over the business cycle.

Table 1 gives the form of the optimal price equation for other assumptions about the form of the production function. For

<table>
<thead>
<tr>
<th>TABLE 1 / Neoclassical Price Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production function</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Fixed proportions</td>
</tr>
<tr>
<td>Nonconstant returns to scale</td>
</tr>
<tr>
<td>Cobb-Douglas</td>
</tr>
<tr>
<td>Nonconstant returns to scale</td>
</tr>
<tr>
<td>Constant elasticity of substitution</td>
</tr>
<tr>
<td>Nonconstant returns to scale</td>
</tr>
</tbody>
</table>

**Note:** The degree of homogeneity of the production function is \( m, \delta = [b_1 + (1 - b_1)m]^{-1} \) and \( C \) is a constant. All parameters (except \( \rho \)) are nonnegative.
derivations and results for different demand functions, see Nordhaus [35].

B. IS MARK-UP PRICING OPTIMAL?

An interesting application of the model is to examine the relation of the optimal price to the well-known “mark-up pricing” model. According to Eckstein, the target-return pricing formula is the following:

\[ p = \frac{\hat{\pi} K}{X} + \frac{L_v}{X} + \frac{M_v}{X} \]

where \( \hat{\pi} \) is the target rate of return and bars over variables are standard levels of operation. We can compare Equation 29 to 27 by linearizing Equation 27

\[ p = c_e + c_q q + c_w w + c_y y \]

\[ \hat{\pi} = \frac{K}{X} \]

A common rationalization of target-return pricing or other mark-up pricing equations is that they provide a good rule-of-thumb to follow in an uncertain world. A good rule-of-thumb is presumably one that is approximately optimal, such as a linearization of an optimal decision rule. If the target-return pricing is to be an approximation to the optimal pricing rule, we should find that the coefficients in the two equations, 29 and 30, are equal; that is, we should find that:

\[ c_1 = \frac{\hat{\pi} K}{q \bar{X}} \]

\[ c_2 = \frac{L}{X} \]

\[ c_3 = \frac{M}{X} \]

Some manipulation shows that:

\[ c_1 = \frac{K}{X} \left( \frac{q}{1 - (1 - b_i)(1 - m) + m} \right) = \frac{K}{X} c_i^* \]

\[ c_2 = \frac{L}{X} \left( \frac{1}{1 - (1 - b_i)(1 - m) + m} \right) = \frac{L}{X} c_i^* \]

\[ c_3 = \frac{M}{X} \left( \frac{1}{1 - (1 - b_i)(1 - m) + m} \right) = \frac{M}{X} c_i^* \]

Thus, target-return pricing is a good rule-of-thumb (in the sense defined here) when \( \hat{\pi} = c_i^* \) and when \( c_i^* = c_i^* = 1 \).

The condition that \( c_i^* = c_i^* = 1 \) is straightforward. It says that the only time when the target-return pricing formula gives optimal behavior is when there is perfect competition \((b_i = \infty)\) and when there are constant returns to scale \((m = 1)\). Otherwise, the \( c_i^* \) and \( c_i^* \) will be greater than unity. There should be no surprise in this: monopoly power means that some monopoly profits are squeezed out of rewards of all factors, not just from the rewards to capital. Factors are paid their marginal revenue product, not their value of marginal product.

The condition that \( c_i^* = q/((1 - b_i)(1 - m)) \) is more difficult to interpret. Recall that \( q \) is the service cost of capital. Ignoring capital gains and taxation, this is \((\delta + i) p_c\), where \( \delta \) is the depreciation rate, \( i \)
the interest rate, and $p_c$ the price of capital goods. The optimal price includes enough to cover both interest and depreciation on the capital equipment. Thus, \( \hat{\alpha} = \delta + i \). Slightly more will be recovered if there is imperfect competition or nonconstant returns.

In summary, the optimal pricing rule does not coincide with the target-return pricing rule except under competitive conditions. But this theory is especially designed for pricing in noncompetitive markets! To the extent that the model used here is an accurate reflection of the underlying conditions of demand and production, the result implies that target pricing is not a good rule-of-thumb except under competitive conditions. A better rule-of-thumb would be to follow the optimal price rule in Equation 28 or the linearized rule in Equation 30 with proper coefficients.

C. TAX SHIFTING

Although our neoclassical price equation looks much like the familiar mark-up equation, it should be noted that behavior toward profits taxes is quite different in the two worlds. It is sometimes argued that a full-cost mark-up price would include any profits tax (such as the corporation profits tax). In the neoclassical model, the profits tax is irrelevant to pricing decisions except insofar as it affects the cost of capital, \( q \). In general, there will be an effect on the cost of capital, so some shifting of the corporation tax should be expected.\(^{42}\)

More precisely, in well-behaved capital markets, the cost of capital is \( q = (\delta + i)p_c \) \( (1 - k)(1 - uz)/(1 - u) \), where \( q \) is cost of capital services, \( p_c \) = the price of capital goods, \( \delta \) = depreciation rate, \( i \) = discount rate, \( k \) = rate of investment tax credit, \( z \) = present value of the depreciation deduction, and \( u \) = corporate profits tax rate.\(^{43}\) For \( \delta = .1, i = .12 \), and the double-declining balance method of depreciation \( z = .651 \). We can then calculate the cost of capital and the effect of the corporation income tax on price as follows (for \( a = \frac{1}{4} \)):

<table>
<thead>
<tr>
<th>Tax rate (( u ))</th>
<th>Cost of capital (( q ))</th>
<th>Price (( = 1.0 ) when ( u = 0 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.220</td>
<td>1.00</td>
</tr>
<tr>
<td>0.25</td>
<td>0.248</td>
<td>1.03</td>
</tr>
<tr>
<td>0.50</td>
<td>0.297</td>
<td>1.08</td>
</tr>
</tbody>
</table>

This calculation implies that for every 10-percentage-point rise in the corporation tax rate, there is a 2 per cent rise in price.

D. SHORT-RUN PRICING

The model developed in subsection B is a long-run theory of price determination. How can this be translated into a short-run model? On the one hand, it might be argued that a distributed lag adjustment model would be appropriate to take into account the fact that adjustment to long-run desired levels is impeded by uncertainty, administrative delays, and long-run contracts. On the other hand, market structure and price administration might lead to short-run pricing decisions that are inconsistent with long-run profit maximization. In this section we note some of the arguments that have been made concerning the deviation of short-run from long-run behavior. The remarks are organized around the three problems of uncertainty, market structure, and costs of adjustments.

1. It is sometimes argued that uncertainty about the form of demand or cost functions causes stickiness in the price mechanism.\(^{44}\)

\(^{41}\) We are now being inconsistent by defining \( p_c K \) as the value of capital, whereas in the target-return formula \( K \) is book value of capital. The two are reconciled if we set \( p_c = 1 \) by convention from now on.

\(^{42}\) I am indebted to Robert J. Gordon for pointing out an error in an early draft of this section.

\(^{43}\) See Hall and Jorgenson [21] for further discussion of this model of the cost of capital.

\(^{44}\) This argument is made by Cagan [8]. Also see Stigler [47].
We should consider separately the case of uncertainty about the level of the functions and uncertainty about the parameters.\(^{45}\)

First, consider the case where random disturbances enter the demand and production functions. Assuming that the parameters of the functions are known, it is easily seen that the multiplicative disturbances magnify price flexibility rather than reduce it.\(^ {46}\)

If there is uncertainty about the parameters, the conclusion is quite different. If firms are risk-neutral, they will move to the certainty equivalent optimal price and there will be no reduction in flexibility. It is clearly more reasonable to assume that firms are risk-averse. In this case, the more price is changed, the greater the risk. Firms will thus generally move more slowly to an optimal price under risk conditions than they would under conditions of certainty.\(^ {47}\)

2. The second qualification on short-run, instantaneous price adjustment is that firms do not adjust price because of oligopolistic interdependencies. Most writers\(^ {48}\) feel that the stickiness of price is chiefly due to fear of "rocking the boat." One model of the process is the "kinky demand curve," showing how short-run price movements may have a certain inflexibility.\(^ {49}\)

Recent evidence on price flexibility by Stigler and Kindahl\(^ {50}\) casts serious doubt on the standard notions about price inflexibility. Recall that the "stickiness" usually works downward, according to this theory, while prices should retain their upward flexibility. In contrast to this theory, Stigler and Kindahl find that by examining transactions prices (rather than list prices) there is substantial downward flexibility of price even during contractions. On the other hand, there does seem to be evidence that competitive industries are more likely to behave as predicted by standard price theory than noncompetitive industries.\(^ {50}\) The evidence, however, is that the inflexibility in prices is associated with all forms of noncompetitive markets, rather than only those markets with oligopoly of small numbers.\(^ {51}\)

The test of the effect of different forms of noncompetitive market structure on price inflexibility given by Stigler and Kindahl relies on cross-sectional analysis. As an attempt to determine whether market structures affect price flexibility directly, observations on the price of primary aluminum were obtained for the years 1909-66. The interest in looking at the primary aluminum industry over this period is that there was an exogenous change in the market structure of aluminum after World War II when the Federal Government sold aluminum plants to two new companies, thus changing a monopoly into a "tripoly." If the inflexibility of price

\(^{45}\) This distinction was correctly made by Franklin M. Fisher in his discussion (pp. 113–15). The present section was modified to include the second kind of uncertainty.

\(^{46}\) If we multiply Equation 23 by \(U_1\) and Equation 24 by \(U_1, U_1, U_1\) being random disturbances, it is easily seen that the profit-maximizing price is \(p = p^* U_1(U_1)^{0.5}\), where \(p^*\) is the optimal price under certainty. Clearly the price with multiplicative uncertainty has greater variance.

\(^{47}\) For a discussion of the problem of decisionmaking with uncertainty about the parameters of structural relations, see Brainard [6].

\(^{48}\) See Eckstein [14].

\(^{49}\) The original kinky demand curve was in Sweezy [51], with criticism by Stigler [46]. Also see Cohen and Cyert [11], Chapter 12.

\(^{50}\) The following table gives the percentage of prices behaving according to theory. "According to theory" is interpreted as prices that rise more than 5 per cent in booms and fall more than 5 per cent in recessions.

<table>
<thead>
<tr>
<th>Concentration ratio</th>
<th>Fraction behaving (in per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–25</td>
<td>90</td>
</tr>
<tr>
<td>25–50</td>
<td>60</td>
</tr>
<tr>
<td>50–75</td>
<td>45</td>
</tr>
<tr>
<td>75–100</td>
<td>57</td>
</tr>
</tbody>
</table>

Source.—Stigler and Kindahl ([50], p. 61, Footnote 5 and p. 63, Footnote 8).

\(^{51}\) It is clear that the rocking the boat or kinky demand curve reasoning holds only for industries with more than one seller.
is due to oligopolists’ fear of rocking the boat, there should have been a noticeable increase in price inflexibility after World War II. Table 2 gives estimates of the average and standard deviation of price change for components of the total period. For all sample periods, the frequency and dispersion of price change fell considerably over the 60-year span. The most important change in flexibility came between the first and second periods (divided by 1929), rather than between the second and third (divided by World War II). The conclusion would seem to be that events surrounding the depression of the 1930’s were more important in leading to price inflexibility than those surrounding the change in market structure. This conclusion reinforces the evaluation by Stigler and Kindahl mentioned earlier.

3. The final source of stickiness in price is cost of price adjustment. There are several possible sources of stickiness. First, there may be some physical cost of price changes: This would include certain costs of drawing up prices, printing new books, informing personnel, and so forth. This might be important for goods, especially low-

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean (per cent)</th>
<th>Standard deviation (per cent)</th>
<th>Frequency (per cent of periods)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1909-29</td>
<td>.00017</td>
<td>.0464</td>
<td>71</td>
</tr>
<tr>
<td>1929-41</td>
<td>.0032</td>
<td>.0146</td>
<td>9</td>
</tr>
<tr>
<td>1948-66</td>
<td>.0021</td>
<td>.0140</td>
<td>20</td>
</tr>
<tr>
<td>Deflationary years only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1909-29</td>
<td>.022</td>
<td>.0179</td>
<td>74</td>
</tr>
<tr>
<td>1929-41</td>
<td>.011</td>
<td>.0266</td>
<td>25</td>
</tr>
<tr>
<td>1948-66</td>
<td>.0059</td>
<td>.0176</td>
<td>13</td>
</tr>
<tr>
<td>Stable years only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1909-29</td>
<td>.0006</td>
<td>.0238</td>
<td>52</td>
</tr>
<tr>
<td>1929-41</td>
<td>.00046</td>
<td>.00454</td>
<td>4</td>
</tr>
<tr>
<td>1948-66</td>
<td>.000145</td>
<td>.01136</td>
<td>12</td>
</tr>
<tr>
<td>Inflationary years only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1909-29</td>
<td>.032</td>
<td>.0656</td>
<td>90</td>
</tr>
<tr>
<td>1929-41</td>
<td>.0073</td>
<td>.0147</td>
<td>35</td>
</tr>
</tbody>
</table>

Note.—Deflationary (inflationary) years are those where the December-to-December price fell (rose) by more than 5 per cent. I am indebted to Robert Neugebauer for performing these calculations.

1 Number of months in which price changes occurred divided by total number of months.

priced items, where changing prices often would be annoying, but it could hardly be significant for larger goods where the ratio of price to sales cost is high. Second, there might be a reaction from the demand side to changes in price: Customers might change product from pique. This case is explicitly analyzed in the Phelps-Winter model of subsection II-B. Finally, since knowledge about prices is scarce, there is an incentive not to change price because of the obsolescence of knowledge that would occur. In any of these cases, the price would change only when actual and desired prices differ by some finite amount. Eckstein 32 uses this as an argument for stickiness: “Under noncompetitive conditions, deviation from list price occurs only when the market conditions differ from normal by more than some threshold amount.”

As noted earlier, a more significant source of inflexibility in the short run is the fact that buyers like to have prices stable as a service. Cagan writes: 33

Most buyers would like to have assured supplies at stable prices to ease the problems of financing and scheduling production over time. One of the valued services of a supplier is his ability to take care of regular customers and maintain a “fair” price at all times. . . . It is well known that commercial banks ration credit during periods of “tight money” to accommodate loyal customers who patronize the bank during other periods as well.

In light of our estimates of the search costs in Section II, this explanation seems to be reasonable. It implies that suppliers

32 Eckstein ([14], p. 270).
33 Cagan ([8], p. 10). In light of results of Stigler and Kindahl [50], it might be questioned whether the stability of list prices (when transaction prices are changing) is really a significant service. Moreover, Kane and Malkiel [25] argue that for banks price inflexibility is a peculiarity of the banking product, so this example should be used with caution.
bear the risk of fluctuations by keeping their prices stable over business cycles. There is one puzzle in the institutional arrangement, however, for to the extent that firms hold prices constant in anticipation of future price declines, they are speculating and assuming the risks of price changes. One would expect that (except for labor markets) consumers, for whom the goods are a small part of their "portfolio," would prefer to bear the risk rather than to compensate the firm to bear it.

IV. RECENT EMPIRICAL STUDIES OF PRICE BEHAVIOR

Price behavior has only recently been the object of detailed econometric investigation.\(^{54}\) Unfortunately, it is not clear that the studies have proved fruitful. As Fromm and Taubman write about their simulations of the Brookings Model, "An examination of the complete model solutions for 1961–62 reveals that the wages and prices sector is one of the larger contributors of errors in the aggregate results."\(^{55}\)

This section reviews recent important studies of the behavior of prices, with attention confined to studies of U.S. prices. In addition, when several sectors are studied, attention is confined to manufacturing.

The following studies are reviewed: \(^{56}\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors and sources</th>
<th>Sectors studied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>Edwin Kuh [29]</td>
<td>Corporate</td>
</tr>
<tr>
<td>1965</td>
<td>Charles Schultze and Joseph Tryon [42]</td>
<td>Durable and Nondurable Manufacturing;(^{57}) Wholesale and Retail Trade; Regulated Industries; Contract Construction; Other</td>
</tr>
<tr>
<td>1968</td>
<td>Gary Fromm and Paul Taubman [18]</td>
<td>Durable and Nondurable Manufacturing;(^{57}) Wholesale and Retail Trade; Regulated Industries; Contract Construction; Other</td>
</tr>
<tr>
<td>1966</td>
<td>George Perry [37]</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>1967</td>
<td>Lawrence Klein [27] and Michael Evans [16]</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>1968</td>
<td>Robert Solow [45]</td>
<td>Private Nonfarm Deflator (^{57})</td>
</tr>
<tr>
<td>1968</td>
<td>Otto Eckstein and Gary Fromm [15]</td>
<td>All Manufacturing,(^{57}) also Durable and Nondurable Manufacturing</td>
</tr>
<tr>
<td>1970</td>
<td>Robert J. Gordon [19]</td>
<td>Private Nonfarm Economy (^{57})</td>
</tr>
</tbody>
</table>

---

\(^{54}\) I am indebted to Peter Reuter for assistance in preparation of this section.  
\(^{55}\) Fromm and Taubman ([18], p. 11).  
\(^{56}\) It was decided to restrict the survey to the published literature. For this reason the excellent material by George de Menil, prepared for the FR–MIT–Penn Model, has been omitted. (See, for example, de Menil [13].) The work of de Menil is of particular significance because he uses a theoretical approach to deriving optimal price. The work of Bodkin [4] was inadvertently overlooked.  
\(^{57}\) See the results discussed in this paper.
A. GENERAL FORM OF EQUATIONS

There is quite general agreement about the structure of price equation to be used, although the exact reasoning and variables differ. The theoretical structure behind these equations is best laid out in Schultz and Tryon. There are three important assumptions:

1. Prices are set as a mark-up over "standard" or "normal" costs. (Most studies make this assumption without discussion.) In general, the implication is that price changes occur with speed and certainty when long-run costs change, but are slower when short-run costs change. Most authors assume that changes in wages are considered by producers to be permanent, and therefore these enter immediately into "normal" costs. Short-run fluctuations in productivity, on the other hand, do not enter fully since they are usually transient phenomena. To smooth out short-run fluctuations in productivity, most authors take 12-quarter moving averages in calculating normal productivity.

For statistical purposes most authors use unit average labor cost (total compensation/total real output) to measure labor cost. The long debate between the full-cost pricing proponents and the marginalists—who would insert marginal labor cost—is seldom mentioned. Sometimes there is a discussion of unit material cost and, rarely, unit capital cost.

2. The second general hypothesis concerns the effect of deviations of actual from normal unit costs. Most authors postulate that these temporary changes in cost will affect prices less than permanent changes.

For the most part temporary changes prove statistically insignificant.

3. Finally, it is generally felt that the mark-up over cost is influenced by the level of output relative to capacity, leading the authors to introduce additively several variables representing demand pressure. There might also be an interaction effect, so that demand pressures would affect the mark-up over cost through the coefficients on labor, capital, and materials costs.

Table 3 provides a general picture of the kind of equations that are customarily run. As this table shows, every equation in one form or another uses labor costs, either cost per manhour or cost per unit product. And almost invariably, labor costs are highly significant. Moreover, about half of the equations contain a significant term in either costs of materials or costs of farm products. The second striking feature of Table 3 is that, on the demand side, there is very little uniformity, with equations using capacity utilization, inventory/sales ratios, and ratios of new orders or unfilled orders to sales. This seeming inability to find a significant (and consistent!) impact of demand is surprising.60

As can be seen, with the exception of the Brookings Model and the Klein-Evans equation, there are no entries from the well-known, large-scale econometric models. Many models do not explicitly include price equations but rather let prices be determined residually. This category includes Klein's early models, the Klein-Goldberger Model and the Suits-Michigan Model. The Wharton Model uses the "Klein" price equation listed in Table 3. To date, published versions of the FR-MIT-Penn Model have not included price equations. Clearly, this sector has been troublesome.

59 The discussion in subsections A through C omits the "monetarist" version of Andersen and Carlson. The monetarist model is so different that it is discussed separately in subsection D.

59 The assumptions mentioned here are not fully subscribed to by all authors. Deviations are noted in the following discussion.

60 The problem of finding a significant impact of demand on prices contrasts sharply with labor markets, where excess supply makes the most important contribution.
### TABLE 3 / Overview of Price Equations

<table>
<thead>
<tr>
<th>Author</th>
<th>Dependent variable</th>
<th>Cost</th>
<th>Labor cost</th>
<th>Materials costs</th>
<th>Demand</th>
<th>Capacity utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Short-run</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuh, 1959</td>
<td>$p_{w}^{m}$</td>
<td>.305 $w_{-1}^{*}$</td>
<td>(7.1)</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- .227 $(X/MH)^{*}$</td>
<td>(4.3)</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Schultze-Tryon (Brookings), 1965</td>
<td>$p_{w}^{m}$</td>
<td>.371 $(ULC - ULC)^{n}$</td>
<td>(2.9)</td>
<td>+1.845 $ULC^N$</td>
<td>(43.9)</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
<td>+1.490 $ULC^N$</td>
<td>(20.7)</td>
<td>+.279 $p_{w}^{m}$</td>
<td>...</td>
</tr>
<tr>
<td>Fromm-Taubman (Brookings), 1968</td>
<td>$p_{w}^{m}$</td>
<td>.8155 $(ULC - ULC)^{n}$</td>
<td>...</td>
<td>+1.1060 $ULC^N$</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
<td>+1.3190 $ULC^N$</td>
<td>...</td>
<td>+.1033 $p_{w}^{m}$</td>
<td>...</td>
</tr>
<tr>
<td>Perry, 1966</td>
<td>$\Delta p_{w}^{m}/p_{w}^{m}$</td>
<td>.466 $\Delta_{w}^{m}/m_{w}^{m}$</td>
<td>(2.39)</td>
<td>...</td>
<td>...</td>
<td>$- .610 \Delta CUP + .149 CUP$</td>
</tr>
<tr>
<td>Klein Evans, 1967</td>
<td>$p_{w}^{m}$</td>
<td>.542 $ULC^N$</td>
<td>(6.1)</td>
<td>...</td>
<td>...</td>
<td>$246 CUP$</td>
</tr>
<tr>
<td>Solow, 1968</td>
<td>$\Delta p_{w}^{m}/p_{w}^{m}$</td>
<td>.2145 $\Delta ULC^{n}$</td>
<td>(5.6)</td>
<td>...</td>
<td>...</td>
<td>$0.005 CU_{-1}^{r}$</td>
</tr>
<tr>
<td>Eckstein-Fromm, 1968</td>
<td>$p_{w}^{m}$</td>
<td>...</td>
<td>.179 $ULC$</td>
<td>(3.8)</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Gordon, 1970</td>
<td>$\Delta p_{w}^{m}/p_{w}^{m}$</td>
<td>.1939 $\Delta ULC^{n}$</td>
<td>(5.0)</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Andersen-Carlson, 1970</td>
<td>$(\Delta p_{w}^{m}/GNP_{-1})^{*}$</td>
<td>...</td>
<td>.7581 $\Delta ULC^{n}$</td>
<td>(15.1)</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Note.—The $t$ statistics are in parentheses.

* = $t$ statistics conditional on price expectations parameter.

† = Sources do not generally note whether $R^2$ is corrected for degrees of freedom.

n = Not given.

Key to Table 3. The regression selected in each case is the one that has the lowest standard error of estimate. The variables used are as follows:

Dependent variables:

- $p_{w}^{m}$ = Price deflator for corporate output
- $p_{w}^{m-d}$ = Deflator or wholesale price index for durable manufacturing
- $p_{w}^{m-n}$ = Deflator or wholesale price index for non-durable manufacturing
- $p_{w}^{m-f}$ = Private nonfarm deflator
- $p_{w}^{m-G}$ = GNP deflator

Labor costs:

- $w_{-1}^{*}$ (Kuh) = Average hourly earnings in the corporate sector
- $(X/MH)^{*}$ (Kuh) = Output per manhour in the corporate sector
- $ULC_{w}$ (Schultze-Tryon) = Compensation of employees/gross product originating
- $ULC_{w}$ (Schultze-Tryon) = Compensation per manhour: $\Sigma_{-1}^{1/2} \frac{output}{manhour}$
- $ULC_{w}$ (Fromm-Taubman) = Compensation per manhour/real gross product originating
- $ULC_{w}$ (Fromm-Taubman) = Compensation per manhour: $\Sigma_{-1}^{1/2} \frac{real\ output}{manhour}$
- $w_{a}^{m}$ (Perry) = Wage rate of straight-time hourly earnings
- $ULC_{w}$ (Klein) = Unit labor cost
- $ULC_{w}$ (Solow) = Private wage bill/real private nonfarm output
- $ULC_{w}$ (Eckstein-Fromm) = $w_{a}^{m}*a, b$ regression coefficients
- $ULC_{w}$ (Gordon) = Compensation in private nonfarm economy/private nonfarm output (adjusted by Gordon)
- $ULC_{w}$ (Gordon) = $2A(ULC_{w})_{-1}$, Almon weights

### B. SPECIFIC VARIABLES: COST

Next let us turn to specific cost variables used in the price equations.

1. **Labor costs.** As we have noted, every equation (except the monetarist) includes some form of labor costs. All but Perry use unit labor costs, but the lag structure varies widely among different equations. It is customary to define unit labor cost as $ULC = (Comp/X)$ = (Total compensation of labor/Real output). This can be further defined as $ULC = (Comp/MH)(MH/X)$, where
### TABLE 3 (Continued)

<table>
<thead>
<tr>
<th>Demand</th>
<th>Ratio of—</th>
<th>Other</th>
<th>Estimate period</th>
<th>Durbin-Watson</th>
<th>Standard error of estimate</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>“Demand ratchets”</td>
<td>1949.1-1958.1</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>(-.096 \left[ \frac{L}{X} \right]_{-1} \times ) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>1948.2-1960.4</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>(-.098 \left[ \frac{L}{X} \right]_{-1} \times ) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>1948.2-1960.4</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>(-.247 \left[ \frac{L}{X} \right]_{-1} \times ) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>1948.1-1960.4</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>(-.2945 \left[ \frac{L}{X} \right]_{-1} \times ) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>1948.1-1960.4</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>( \phantom{.2945} \left[ \frac{L}{X} \right]_{-1} \times ) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>1947.1-1960.4</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>( .643 \text{ Korean war} + \ldots \right. \right. \sum \text{ p, } \ldots (\text{7.1}) \text{ dummy} ) &amp;</td>
<td></td>
<td>1948.1-1960.4</td>
<td>.60</td>
<td>.0098</td>
<td>.982</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( +.4271 \text{ p, } \ldots \right. \right. \sum \text{ p, } \ldots (\text{16.0}) \text{ dummy} ) &amp;</td>
<td></td>
<td>1947.1-1966.4</td>
<td>n</td>
<td>n</td>
<td>.9088</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( .162 \left( \frac{C}{X} \right)_{-1} ) &amp;</td>
<td></td>
<td>1954.2-1965.4</td>
<td>1.64</td>
<td>.0022</td>
<td>.995</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( .1518 \Delta(O/S) ) &amp;</td>
<td></td>
<td>1951.1-1969.4</td>
<td>.93</td>
<td>.0053</td>
<td>.899</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( .0881 \Delta \sigma ) &amp;</td>
<td></td>
<td>1955.1-1969.4</td>
<td>1.41</td>
<td>1.07</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( \Delta \Psi ) &amp;</td>
<td></td>
<td>1955.1-1969.4</td>
<td>1.41</td>
<td>1.07</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>( \Delta \Psi ) &amp;</td>
<td></td>
<td>1955.1-1969.4</td>
<td>1.41</td>
<td>1.07</td>
<td>.87</td>
<td></td>
</tr>
</tbody>
</table>

Materials costs:
- \( p^e \) = Farm deflator (several different versions used)
- \( p^r \) = Raw materials price index
- \( p^{ar} \) = Faith Halfer Ando's raw materials price index

Capacity utilization:
- \( CD = (\text{Perry}) \text{ FR index of manufacturing production/Commerce Department} \)
- \( CU = \text{Wharton index of capacity utilization} \)
- \( CDP = \left[ \text{GNP}_{pp} - \text{GNP}_{p, p} \right] = \left[ \text{GNP}^P - \text{GNP}_r \right] \)

Other variables:
- \( I/X \) = Ratio of inventories to output originating
- \( (F/X) \) = Trend or 12-quarter moving average of \( (I/X) \)
- \( (O/S) \) = Unfilled orders/sales
- \( \tau^e \) = (Sawyer) \( \theta \sum \left( 1 - \theta \right)^i \Delta \psi^e \), where \( \psi^e \) is annual rate of change of \( p^e \). Series starts in 1929.
- \( \sigma^e \) = (Gordon) Total employment rate
- \( \text{GNP}^P \) = Gross national product, constant dollars
- \( \text{GNP}^P \) = Potential output (Council of Economic Advisers), constant dollars
- \( \Delta \psi^e \) = \( \Delta \Psi - \psi^e \)

\[ \Delta \Psi = \sum_{i=1}^{\infty} \left( \frac{h_i \Delta \sigma}{\sigma} - 4 \right) \left( 1 + 1 \right)^{(i-1)} \]

\( MH \) = manhours. Great care is not always taken to make sure that the labor cost refers to the same sector as the price index, but this can be rationalized as a shortcoming of the data. Many authors do not include productivity explicitly (that is, \( MH/X \) is omitted), and this can perhaps be understood as implicitly assuming productivity is growing smoothly.

In any case, we can calculate the estimated effect of \( ULC \) on prices explicitly for most of the regressions, and these are pre-
sented in Table 4. Given that the unit labor cost is the only uniformly present variable, it is hard to rationalize the range of long-run elasticities (0.3744 to 1.845). The most likely culprit is omission of correlated variables, such as prices of raw materials or capital costs. It is comforting to note that the two lowest elasticities (Solow and Perry) both include a measure of the prices of raw materials. An examination of the lag structures on unit labor costs in different equations shows that very little consensus on lag structures has been reached by the surveys. Several authors assume that reactions to wage changes are instantaneous. A general argument has been made for at least some delay in reaction to costs. Moreover, the evidence is reasonably strong that some delay in reaction to changes in unit labor costs does exist (see Gordon's estimates), but it is not clear that this delay holds for wages as well as productivity. It would therefore seem better to include some lag in compensation.

The lag structure on average productivity hardly seems better. Some authors use a 12-quarter average to determine "normal" productivity. There is no reason to expect a rectangular distribution and, again, Gordon's results would tend to argue against it.

One might ask how the results surveyed here fit in with the theoretical results discussed in earlier sections. For purposes of concreteness, we will assume that production is by a Cobb-Douglas production function with constant returns to scale. In this case, for individual firms, the coefficient on unit labor costs should be approximately

---

62 It should be mentioned that, due to the hesitancy of authors (or editors?) to report all the summary statistics, it is exceedingly difficult to compare different equations. As can be seen in Table 2, standard errors, means of variables, and elasticities are virtually never mentioned. Other embarrassing statistics, like Durbin-Watson statistics, also are often ignored.

63 If materials prices and the cost of capital have unit coefficient in a regression of rates of change on the rate of change of the wage rate, then the coefficient on the wage rate in the price equation should be $1/m$, where $m$ is the degree of homogeneity of the production function.

---

**TABLE 4 / Elasticities of Price with Respect to**

<table>
<thead>
<tr>
<th>Author</th>
<th>Unit labor costs</th>
<th>A priori coefficients a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate</td>
<td>Long-run</td>
</tr>
<tr>
<td>Kuh (p^m)</td>
<td>[.227...-.305] b,e</td>
<td>[.227...-.305] b,e</td>
</tr>
<tr>
<td>Schulze-Tryon (p^m)</td>
<td>[.492...1.845] c</td>
<td>1.845 b</td>
</tr>
<tr>
<td></td>
<td>1.450 b</td>
<td>.40</td>
</tr>
<tr>
<td>Fromm-Taubman (p^m)</td>
<td>[.839...1.1068] b,e</td>
<td>1.1068 b</td>
</tr>
<tr>
<td></td>
<td>1.3109 b</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>.466</td>
<td>.466</td>
</tr>
<tr>
<td>Perry (p^m)</td>
<td>.2145</td>
<td>.3744</td>
</tr>
<tr>
<td>Klein (p^m)</td>
<td>[.542] b</td>
<td>[.375] b</td>
</tr>
<tr>
<td></td>
<td>.179</td>
<td>.989</td>
</tr>
<tr>
<td>Solow (p^m)</td>
<td>.1939</td>
<td>.9470</td>
</tr>
<tr>
<td>Eckstein-Fromm (p^m)</td>
<td>.73</td>
<td>.73</td>
</tr>
<tr>
<td>Gordon (p^m)</td>
<td>.39</td>
<td>.39</td>
</tr>
<tr>
<td>Andersen-Carlson (p^m)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a A priori coefficients are from the tabulation on p. 39.
b Number is coefficient. Since no mean of dependent variable is given, elasticity cannot be calculated.

c Higher figure is related to increase in wages; lower figure is for decrease in productivity.

d Since $p = 1.0$ for 1954, the coefficient is approximately the elasticity. No mean of dependent variable is given.
equal to (wage bill/total sales). For a sector (such as manufacturing) the "total sales" should refer to sales outside the sector. It is not easy to get an estimate of the relevant total sales figure to go in the denominator. Under highly simplified assumptions, however, it is approximated that the elasticities of labor, capital, and materials are as follows: 65

<table>
<thead>
<tr>
<th>Sector</th>
<th>Share (in per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labor</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
</tr>
<tr>
<td>Nondurable</td>
<td>.24</td>
</tr>
<tr>
<td>Durable</td>
<td>.40</td>
</tr>
<tr>
<td>Total</td>
<td>.45</td>
</tr>
<tr>
<td>Private nonfarm</td>
<td>.61</td>
</tr>
<tr>
<td>GNP</td>
<td>.73</td>
</tr>
</tbody>
</table>

65 The figures for GNP are from the national income accounts, whereas those for manufacturing for 1958 are from Input-Output Tables, Survey of Current Business (Sept. 1965). The other estimates are made as follows: The share of labor, capital, and imports as a fraction of national income are the numbers given for GNP. To get the figures for other sectors, it is assumed that the proportion of sales of sector i going to sector j is proportional to total sales of sector j. The prediction by this method is 0.48 for manufacturing, which compares with the total of 0.42 for manufacturing from input-output tables.

The estimates are not firm, but they do give a rough idea of what one should expect from econometric estimates of long-run elasticities. The comparison of the a priori figures with Table 4 indicates that the estimates are not only widely dispersed, but also far from the a priori estimate on average. In general, the estimated elasticities are not far from unity. This upward bias is what would be expected from an estimation that omits variables (such as materials and capital costs) that are positively correlated with unit labor costs.

2. Materials costs. Although prices of raw materials are clearly a component of costs, most authors chose to exclude them. This omission is due in part to the fact that (at least until recently) good indexes of prices for inputs into different sectors have not been available. 66 Some authors use farm

<table>
<thead>
<tr>
<th>A priori coefficients</th>
<th>Variable</th>
<th>Long-run elasticity</th>
<th>Capacity utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>(.12)</td>
<td>.47</td>
<td>1.84</td>
<td>.18</td>
</tr>
<tr>
<td>(.12)</td>
<td>.68</td>
<td>1.77</td>
<td>.122</td>
</tr>
<tr>
<td>(.12)</td>
<td>.47</td>
<td>1.11</td>
<td>.12</td>
</tr>
<tr>
<td>(.12)</td>
<td>.68</td>
<td>1.41</td>
<td>.12</td>
</tr>
<tr>
<td>(.12)</td>
<td>.42</td>
<td>.81</td>
<td>.15</td>
</tr>
<tr>
<td>(.12)</td>
<td>.20</td>
<td>.44</td>
<td>.166</td>
</tr>
<tr>
<td>(.12)</td>
<td>.42</td>
<td>1.42</td>
<td>.477</td>
</tr>
<tr>
<td>(.12)</td>
<td>.95</td>
<td>.166</td>
<td>.12</td>
</tr>
</tbody>
</table>

* This variable was apparently excluded when it proved insignificant.

66 Eckstein and Fromm ([15], p. 1,167) use "special indexes prepared by Dr. Faith Halfter Ando. These indexes are composed only of crude raw materials. The published materials price indexes are not suitable for price equations because they include a considerable share of semifinished goods which are actually value added of manufacturing."
prices (or the farm deflator) under the presumption that this is a good proxy for the correct raw materials price index; it would probably be more suitable to use the farm deflator as an instrumental variable in the formal sense.

The estimated elasticities of price with respect to raw materials are shown in Table 4. The estimates range from a low of 0.0647 for Solow to a high of 0.436 for Eckstein and Fromm. It is difficult to rationalize the use of the farm deflator for a serious estimate of the effect of raw materials. It may well be that omitting the Korean war period also gives lower estimates of the elasticity.

How do these elasticities square with theoretical results of Section IV? Recall that (in the Cobb-Douglas case) the estimates elasticity should be approximately the share of raw materials. For manufacturing, the share of raw materials is approximately 50 per cent. It would appear, therefore, that (except for the Eckstein-Fromm estimates) the estimates in Table 4 for manufacturing are inconsistent with a Cobb-Douglas production function. The observed elasticities imply that the elasticity of substitution between raw materials and other inputs is significantly larger than unity. Solow’s estimate, on the other hand, is probably not far off for non-farm products.

3. Capital costs. As noted earlier, none of the studies surveyed here introduce capital costs; most, indeed, do not even discuss the question. This lapse is explained as follows by Eckstein and Fromm:

\[ UCC = \frac{qK}{X} \]

The traditional version of the classical theory of the firm calls for no direct influence of the size of the capital stock on short-run, profit maximizing, price-output decisions; the capital stock makes itself felt through the short-run cost curve. . . . Alternatively, short-run cost can be defined to include the quasi-rent on capital, with the quasi-rent varying with the rate of utilization. However the traditional exposition does not solve explicitly for the quasi-rents and hence leaves the influence of the utilization of capital vague.

Whereas the omission of capital costs can be rationalized in “the classical theory of the firm” as determining the level of the short-run cost curve (but not changes in this curve) most authors rely on mark-up or target-return pricing as the theoretical underpinning of the empirical work. In target-return pricing, changes in unit capital costs are as legitimate a part of costs as unit labor and unit materials costs. Although they recognize capital should be included, Eckstein and Fromm argue:

However, the available time series on capital are not sufficiently precise to reveal the inevitably small quarterly changes in [the capital/normal output ratio], and so this approach could not be used.

In light of recent work in investment theory, it is surprising that no attempt has been made to incorporate a “unit capital cost” variable into price behavior analysis. Whereas it is true that movements in the ratio of book-value or replacement cost of capital to normal output would move quite slowly, the same cannot be said about unit capital cost. Using the definition of service cost of capital given in subsection III-C, we note that unit cost of capital (UCC) is

\[ UCC = \frac{qK}{X} \]

\[ (15), p. 1,163) .

\[ \text{Ibid.}, p. 1,198. \]
where \( q = (i + \delta) p_k, T(t) \), where \( i \) is the relevant interest rate, \( \delta \) is the depreciation rate, and \( T(t) \) are functions of tax rates (especially investment tax credit and depreciation allowances). Part of \( q \) will reflect "quasi-rents," and thus will be irrelevant to the classical competitive firm; part will reflect user-cost (in Keynes' sense) and thus will be relevant to all firms. But for the true target-return firm, the total unit cost of capital (UCC) should enter in pricing decisions.

Once this is realized, the claim that UCC does not move much from quarter to quarter is easily perceived to be incorrect. The \( q \) term moves mightily when changes in tax legislation occur. Thus, for example, using the theoretical model in Section III it would be expected that the investment tax credit of 1962 would lower long-run price by about 0.8 per cent (=.07 \times .22 \times .5) and that its repeal in 1969 would raise long-run price by the same percentage.\(^{20}\)

4. Over-all effect of costs on price. Finally, let us examine the over-all effect of costs on price. It is easily verified that (for small changes in price) the sum of the elasticity of factors costs should equal \( 1/m \) (where \( m \) is the degree of homogeneity of the production function). Let us designate \( E_w, E_y \), and \( E_r \), the elasticity of price with respect to wages, capital cost, and materials cost (Table 4); and \( E = E_w + E_y + E_r \). We would be slightly surprised if \( E \) were very far from unity. A few are close to unity but many are way out of line. Solow's results imply a homogeneity factor of 2.3, while Schultz-Tryon's indicate one of 0.56. These values are hard to accept. Again, we must turn to misspecification and the correlation of included with excluded variables if we are to rationalize the results.

---

\(^{20}\) For this example we note that the investment tax credit applies to machinery in the entire economy and that about half of the cost of capital is machinery cost.

---

C. SPECIFIC VARIABLES: DEMAND

As noted earlier, demand variables do not show up consistently and significantly. The following successes have been reported.

1. Capacity utilization. The only variable that has been tried and proven in several equations is an index of capacity utilization. Eckstein and Fromm, Solow, and Klein report success using the Wharton index of capacity utilization, whereas Perry uses an index of the output/capital ratio. The only elasticities reported or easily derived are given in Table 4.

It is not clear from the estimates how responsive price is to demand changes. Since a "normal" recession involves perhaps a 10 per cent change in the Wharton capacity utilization index, expected decline (relative to what would otherwise occur) is between 1.5 and 4.8 per cent in prices. There will also be effects through decline in unit labor costs. This effect is not insubstantial.

2. Inventories. The Brookings Model has consistently used the inventory/sales ratio (more precisely the deviation of the ratio from a 12-quarter moving average) as an explanatory demand variable.\(^{21}\)

3. Orders. Orders variables have also been used as a demand variable. Gordon uses the rate of change of the (new orders/sales) ratio and reports favorable results. Eckstein and Fromm use the lagged change in the (unfilled orders/sales) ratio and get barely significant results.

4. Actual unit labor cost: A hidden demand variable? Some authors include actual unit labor cost (or current compensation per manhour) as part of the cost side of full-cost pricing. Actual unit labor cost is \( w, MH, X_t \). It is quite clear that both output \( (X_t) \) and

---

\(^{21}\) Eckstein and Fromm appear to use the same variable but report no results. They state the capacity utilization is superior statistically to other demand variables that they tried.
productivity \((X_i/\text{MH}_i)\) are cyclically related variables. Also, it is probably more correct to identify changes in output with changes in demand than with productivity. Therefore, it seems useful to inquire how much of the power of actual unit labor cost is demand-related and how much cost-related. As the two have opposite signs, estimates of the effect of unit labor cost should be biased downward unless the separate and correctly specified demand effect is included elsewhere. The short-run bias may explain the fact that price equations in first differences give substantially lower coefficients on actual unit labor costs than price equations run in levels; it may also explain why the coefficient on short-run labor costs is generally lower than that on normal labor costs.

5. Demand variables: A hidden cost misspecification? A second kind of bias could arise if short-run deviations of labor costs from normal labor costs do not enter pricing decisions, but short-run unit labor costs are the independent variable. In this case there will be an error introduced that will be a function of the difference between actual and normal unit labor costs. Because this variable is highly and negatively correlated with capacity utilization, the coefficient on capacity utilization will be biased upward.

D. SPECIFIC VARIABLES: MISCELLANEOUS

A few other variables have been thrown into the kettle from time to time.

1. Guidepost dummy. Solow introduces a "guidepost dummy" to represent that "the wage-price guidepost effort might have had some effect on restraining the rise in manufacturing prices." He reports favorable \(t\) statistics for the dummy variable, and these suggest that guideposts might have restrained prices by 0.5 per cent. Gordon, however, reports that in his equation the guidepost dummy is insignificant.

2. Expected rate of inflation. As an attempt to separate out changing price expectations from the effect of guideposts, Solow also introduces the expected rate of inflation. He uses the model of adaptive expectations introduced by Cagan and calculates the "expected rate of inflation," \((\bar{p}/p)^e\), as

\[
\left(\frac{\bar{p}}{p}\right)^e = \theta \sum_{t=0}^{\infty} \left(\frac{\bar{p}}{p}\right)_{t-1} (1-\theta) + \left(\frac{\bar{p}}{p}\right)_{t-1}^e
\]

He then estimates his price equation for \(\theta\) running from 0.0 to 0.9. He finds that the maximum likelihood is at \(\theta = 0.9\), which implies a very short lag. On the other hand, the standard error of \(\theta\) at \(\theta = 0.9\) is apparently fairly large.

It is difficult to know what to make of Solow's result because he gives no theoretical reason for including price expectations in the price equation. As has been suggested by several authors, it might be appropriate to include them in the wage equation, as Gordon [19] does. The most plausible reason is that Solow is running a "reduced-form" price equation, having solved the price and wage equations.

---

71 Gordon ([19], p. 17). Note that because of the particular method Solow used (searching over a grid), his \(t\) statistic on the guidepost dummy overestimates the correct \(t\) statistic. His estimate is conditional on \(\theta\) (the rate of adaptation of price expectations) whereas the correct \(t\) statistic is unconditional on \(\theta\). The correct statistic would be obtained by calculating the sum squared residuals when searching over \(\theta\) for \(D\) included and \(D\) excluded and then calculating the appropriate \(F\) statistic.

72 Mr. W. Godfrey has pointed out that there is a bias in the estimate of the coefficient "inflation expectations" when four-quarter moving averages are used. If Solow's \(\pi^e\) variable is orthogonal to other independent variables, the bias is \(3\theta + 2\theta (1-\theta) + \theta (1-\theta^2)/4\). This arises because for quarterly data three of the terms in the \(\pi^e\) variable are also in the dependent variable.

73 Strictly speaking, of course, this is not a reduced form since two endogenous variables are contained in the same equation. Solow's equation is rather the solution of two equations in the system.
3. Rate of growth of employment rate.
Gordon includes the rate of change of "the employment rate" in his price equation. His reasoning is as follows: 77

In a classical view of the labor market, firms equate the marginal product of labor to the real wage of workers. And the marginal product declines at high rates of employment as more workers are added to a relatively fixed stock of capital. Thus an increase in employment can be achieved only if the real wage is reduced, which, for a given nominal wage rate, requires a price increase. In short, the ratio of prices to wages at standard capacity becomes an increasing function of the employment rate, and the employment rate (therefore) becomes a variable in the price equation.

It is difficult to see exactly the purpose of Gordon's discussion. It might be assumed that equilibrium real wage would be lower at high rates of employment, but why should firms raise price in response to higher employment? If price is raised because wages are higher, then this increase would be reflected by higher unit labor costs; if because productivity is lower, then the increase in price should show up in unit labor costs through lower productivity.

Whatever the theory, my guess about why the employment rate shows up is that (through Okun's law) it is a proxy for changes in capacity utilization. Since capacity utilization has proved successful, the employment rate should also be a good variable.

E. "MONETARIST" PRICE EQUATION

Although the so-called "monetarist" school has been extremely active on many fronts, only recently has a formal entry been put into the competition for best price equation. The study by Andersen and Carlson [1], which is primarily designed as a model for explaining short-run movements in GNP, also contains an explicit and novel price equation. Their equation contains two variables, a "demand" variable and a price "anticipations" variable. (See Table 4 for the exact definitions.)

The general assumption behind the price equation is that price is determined by the intersection of an aggregate demand and supply curve. It is assumed that "the observed values fall on the supply line." From this, it is easily seen that change in price is a function of change in demand and change in supply. It does not seem possible, however, to reconcile the description of the assumptions with the authors' conclusion. 78

A second assumption is that the price anticipations term displaces the supply curve upward. Here, again, there seems to be a minor misspecification for Andersen and Carlson add in price anticipations directly, whereas the price response should be a function of the slopes of the curves. 79

---

77 The description is contained in Andersen and Carlson ([1], Appendix A). An algebraic version runs as follows. The supply function is \( p = S(X, X') \), whereas demand is \( p = Y \), where \( Y \) is predetermined by the total spending equation. Andersen and Carlson assume that the slope is a linear function of \( (X'-X) \); therefore \( \frac{dp}{dX} = a_0 + a_1(X'-X) \). Integrating this function yields \( p = a_0 X + a_1 X'X' - \frac{1}{2} a_1 X' + a_0 \). Inserting the demand relation into the supply relation yields Equation i:

\[
(i) \quad p = a_0 Y + a_1 \frac{YX'}{p} - \frac{1}{2} a_1 (\frac{Y}{p})^2 + a_0
\]

which is of third degree in \( p \). The form of the equation "derived" by Andersen and Carlson is

\[
(ii) \quad \Delta p = \beta_0 + \beta_1 (\Delta Y + (X'-X))
\]

How this equation can be derived from Equation i is an interesting puzzle. In fact, Equation ii does not appear integrable. Moreover, the figure on p. 22 of the Andersen-Carlson article appears to assume price is a linear function of \( 1/(X'-X) \), much in the spirit of Phillips curves.

78 Thus, if \( a \) and \( b \) are the price-elasticities of demand and supply, and \( c \) is the percentage rise in the supply curve for each percentage rise in anticipated price, then the coefficient on anticipated price in the reduced form should be \(-\frac{bc}{a+b}\) not simply \( c \). Since by assumption the price elasticity of supply, \( (b) \), is a function of \( (X-X') \), so is the term \(-\frac{bc}{a+b}\).
We have noted that the "demand" variable actually used by Andersen and Carlson does not square with the theoretical specification. The price anticipations variable is also difficult to understand. Recall that anticipated price change is

$$\Delta p_{t} = \rho_{t}^{\text{GNP}, t-1} \left\{ \left( \sum_{i=1}^{17} \theta_{i} \frac{u_{i-t}}{u_{t-4}} \right) \cdot 0.01 + 1 \right\} - 1$$

In the first place the weights in the anticipations (the $\theta_{i}$) are derived from the long-run interest rate equation. There is no explanation for this; one could, perhaps, argue that the same price expectations should hold for firms setting prices as for owners of securities. The second unusual feature is that Andersen and Carlson divide the rate of inflation by the ratio $(u_{t-4}/u)$, where $u_{t-4}$ is the percentage unemployment rate. Their explanation is as follows: 80

In the process of constructing a measure of anticipated price change, past changes in prices are adjusted by a summary measure of current economic conditions. Since price changes tend to lag changes in total spending, the degree of resource utilization as measured by the unemployment rate is used as a leading indicator of future price movements. For example, if unemployment is rising relative to the labor force, decision-making economic units would tend to discount current inflation in forming anticipations about future price movements. Reflecting this consideration, the price change in each quarter is divided by an index of the unemployment rate applicable to that quarter. Thus the measure of price anticipations would be less for a given inflation rate accompanied by high or rising unemployment than when unemployment is low or falling.

This is an interesting addition to the literature on price expectation. 81 Unfortunately, it is fallacious as it stands. Surely, if Andersen and Carlson are trying to take into account the change in conditions, the change in the unemployment rate ($\Delta U$) should be used. In fact, $U$ and $\Delta U$ have only an $R^{2} = .28$ for the postwar period. This error casts serious doubt on this price equation, for the term $(4\pi^{\text{GNP}}/u)$ is highly correlated with the general tightness of the economy, in much the same way the $(1/u)$ is so correlated in the Phillips curve analysis. It would appear that the monetarists have let the Keynesians' analysis in through the back door.

Since the proof of the pudding is in the eating, the final question about the monetarist price equation is how well it fits the data. Because of the peculiar form of the equation, 82 it is impossible to compare the equation on the basis of the data supplied in the article. On the other hand an inspection of Figure 1, a comparison with the Wharton Model (11), p. 24), and the root-mean error for the 1968–69 period reveal an unimpressive fit within the period. 83 The root-mean-squared error of the price level for 1963–65 (a period of the authors' choice) is 0.60 for the monetarist model and 0.33 for the Wharton Model.

In summary, the major innovation in the monetarist price equation is an attempt to explain price behavior on the basis of a demand variable and price anticipations without any cost variables. In the current form, the results are largely unsatisfactory.

F. GENERAL OBSERVATIONS

From this survey of recent econometric equations of price behavior, I conclude with the following observations.

80 Andersen and Carlson (11), p. 13).
81 The same argument was used by Lipsey [30] in his discussion of Phillips curves.
82 The dependent variable is actually $(\Delta p) \text{GNP}$, rather than $\Delta p$. This form is due to the authors' desire to explain the change in GNP due to price changes. The authors could circumvent many of the problems by using logarithms of variables.
83 The estimates are "ex post dynamic simulations," according to Andersen and Carlson.
1. Most of the specifications and interpretations have proceeded without the benefit of formal theory. As a result, the implicit elasticities of price with respect to different costs are difficult to understand. The simple theoretical apparatus outlined in Section III indicates that (under conditions where production is roughly Cobb-Douglas) the elasticities should be approximately equal to the relative shares. In practice, the estimated elasticities range from 0.3744 to 1.845 for labor costs and from 0.0647 to 0.436 for materials costs. Moreover, capital costs are usually omitted from the analysis, even in the long-run analysis. One would hope that, by putting a heavier weight on theoretical specification, and a smaller weight on goodness of fit, the results might coincide more closely with what theoretical specification would indicate.

2. A second problem revealed by this survey is the wide disparity in approaches to the lag structures. As can be seen in Table 3, most authors assume that compensation affects price with no lag, whereas productivity is smoothed over as much as 12 quarters. The only author who allows flexible lags (Gordon) does not, however, allow for different lags on compensation and productivity; therefore, the hypothesis of different lags is not really tested.

3. The equations reviewed above make it plain that very little is known about the structure of the impact of demand on prices (apart from the effect through the unemployment rate on wages). The only variable that appeared in several studies was capacity utilization, which had an elasticity between 15 and 45 per cent. It might be suspected, however, that the capacity utilization effect could be conflated with the productivity effect, as well as simultaneous equation bias, since in most equations capacity utilization entered in an unlagged form. In any case, given the wide disparity of results, forecasters should probably be wary of inclusion of most demand variables (except capacity utilization) because of the high probability of spurious correlation. The inclusion may perhaps account for some of the high unreliability of wage and price forecasts noted at the beginning of this section.

4. Finally, there are some disturbing details of econometric technique. In most of the studies, very little attention has been given to the structure of errors. It has apparently become customary to use four-quarter differences for variables in price and wage equations. This custom follows the work of Dow and Dicks-Mireaux. The following explanation is given by Perry:

If wage negotiations are spread evenly throughout the year, one-fourth of all wages will be negotiated in each quarter. In a given quarter, this will result in a change in an aggregate wage index about one-fourth as great as the change in those wages that were actually negotiated that quarter. The change in an aggregate wage index over a year will span four such quarters. . . . All the preceding variables are used as four-quarter averages.

Solow, Perry, and Eckstein-Fromm are quite explicit about using this form for price behavior, whereas Gordon is ambiguous on this count. However reasonable it may be to use four-quarter moving averages for wage equations, the same rationale does not exist for prices since there is no general pattern of setting prices for contractual periods of 1 year.

It is also noted that authors are quite casual about whether they use prices in levels or in first logarithmic differences. Given the upward trend of prices, it might appear more logical to run regression in the logarithms, or the first differences of loga-

---

31 Perry ([37], pp. 31–32).
32 In a private communication, George de Menil has indicated that explicit tests of the structure of errors cast serious doubts on the validity of Perry’s technique.
arithms, rather than in natural units. Moreover, given the evident serial correlation in the residual pattern in the level equations, it would appear that much more attention should be given to the structure of errors. As Eckstein and Fromm's results indicate, taking the first difference of an equation can have drastic effects on the coefficients of an equation.86

86 The single most important coefficient is on unit labor costs. It is disturbing to note that taking first

There is also a persistent habit of omitting outlying observations such as the Korean war and early postwar periods of high demand. Finally, there has been no serious attention given to the simultaneous equation bias. This is especially disturbing, given the inclusion of current output and current wages in almost all equations.

difference of their standard equation (Equation (2)-1) lowers the sum of coefficients on $ULC^*$ from 0.810 to 0.390.
REFERENCES