Aggregate Price Changes and Price Expectations

by RAY C. FAIR

Economic events since 1965 have intensified interest in the problem of inflation. A fundamental question is how to forecast movements in the price level. Explaining and forecasting the price level has been one of the most difficult problems associated with econometric model building.

The following article by Professor Ray Fair of Princeton University was prepared for presentation to a seminar at this Bank. Professor Fair has developed a short-run forecasting model which includes the price level as one of the variables to be forecast. The key variable in his price equation is a measure of current and past demand pressure. In contrast to Andersen and Carlson (April 1970 REVIEW*), he has found, using nonlinear techniques of estimation, that it is not necessary to include explicitly a measure of price expectations in order to obtain a satisfactory explanation of changes in the price level. In addition, by refining the measure of potential output, the explanation of prices is improved further.*

Professor Fair's results suggest that the price level is demand-determined. Cost-push or mark-up factors do not need to be introduced explicitly in order to explain upward movements in prices in the face of sluggish economic activity. Such a phenomenon can be explained as the result of the delayed effect of past demand pressure on prices.

This article is presented in hopes of stimulating further discussion and research into the problems of explaining and forecasting movements in the price level.

A PROBLEM common to models in which nominal GNP is determined independently of the price level is the determination of the price level given the level of nominal GNP. Once the price level is determined, real GNP is then by definition equal to nominal GNP divided by the price level. In Section I of this paper the theory and basic specification of the price equation developed in an earlier paper[1] are discussed, and various versions of the equation are estimated and examined. In Section II the Andersen-Carlson price equation[2] is then analyzed. Andersen and Carlson for their model have a price expectations term in their basic equation, and the primary aim in Section II is to evaluate the importance of this term.

[1]Ray C. Fair, "The Determination of Aggregate Price Changes," Research Paper No. 25, Econometric Research Program, Princeton University, February 1970.

[2]Leonall C. Andersen and Keith M. Carlson, "A Monetarist Model for Economic Stabilization," this *Review* (April 1970), pp. 7-25.

The Determination of Aggregate Price Changes[3]

In most macroeconomic models the expenditure equations are in real terms, prices are determined in a wage-price sector by various cost and excess demand variables, and money expenditures are determined by multiplying the real expenditures by their respective prices. In most of these models the wage-price sector has tended to be a large source of error.[4] The simultaneous and lagged relationships

[3]The price equation described in this section is discussed in more detail in Fair, "The Determination of Aggregate Price Changes." The price equation is also discussed in Ray C. Fair, *A Short-Run Forecasting Model of the United States Economy* (Lexington, Massachusetts: D. C. Heath and Company, forthcoming 1971), Chapter 10, within the context of an overall forecasting model. In Andersen and Carlson, footnote 17, my paper, "The Determination of Aggregate Price Changes," was listed as forthcoming in the *Journal of Political Economy*. This is an incorrect reference, and I assume responsibility for this error.

[4]See, for example, Gary Fromm and Paul Taubman, *Policy Simulations with an Econometric Model* (Washington, D.C.: The Brookings Institution, 1968), p. 11, for a discussion of the limited success so far achieved by the Brookings model in this area.

in the wage-price sector make the sector difficult to specify and estimate with precision, and the possibility of errors compounding in the sector during simulation is generally quite large.

The model of price determination described here bypasses the whole wage-price nexus and essentially takes prices as being determined by current and past aggregate demand pressures. The price equation of the model can thus be considered to be a reduced form equation of a more general wage-price model. The equation is also similar to simple Phillips-curve equations, where wage changes (or price changes) are taken to be a function of excess supply (as approximated by the unemployment rate) in the labor market.

The Theory

The theory behind the model is quite simple. Aggregate price changes are assumed to be a function of current and past demand pressures. Current demand pressures have an obvious effect on current prices. If there is current excess demand, then prices are likely to be bid (or set) higher, and if there is current excess supply, then prices are likely to be bid (or set) lower.

There are two ways in which past demand pressures can affect current prices. One way is through the lagged response of individuals or firms to various economic stimuli. It may take a few quarters for some individuals or firms to change their prices as a result of changing demand conditions. This may, of course, not be irrational behavior, since individuals or firms may want to determine whether a changed demand situation is likely to be temporary or permanent before responding to it. The other way in which past demand pressures can affect current prices is through input prices. If, for example, past demand pressures have caused past input prices to rise, this should lead to higher current output prices, as higher production costs are passed on to the customer. The lag in this case is the time taken for higher input prices to lead to higher costs of production[5] and for higher costs of production to lead to higher output prices. It may also take time for input prices to respond to demand pressures, which will further lengthen the lag between demand pressures and output prices.

Note that nothing specifically has been said about wage rates. Labor is treated like any other input — demand pressures are assumed to lead (usually with a lag) to higher wage rates, which then lead (perhaps with a lag) to higher output prices. The present approach avoids the problem of having to determine unit labor costs or wage rates before prices can be determined.

[5]Since firms stockpile various inputs, this lag is not necessarily zero.

The present model is thus based on the simple theory that price changes can ultimately be traced to the existence of excess demand or supply in the market. If this is true, then for purposes of explaining aggregate price changes, one may not have to specify the intermediate steps between demand pressures and price changes, but may be able to specify price changes as direct functions of current and past demand pressures.

The Measurement of Potential Output

Potential output plays an important role in the work below, and two measures of potential output have been considered in this study. The first measure is the potential GNP measure of the Council of Economic Advisers (CEA), which grew at a 3.5 per cent annual rate from II/1955 through IV/1962, at a 3.75 per cent annual rate from I/1963 through IV/1965, and at a 4 per cent annual rate from I/1966 through II/1970. The second measure considered here, a potential GNP measure developed by the author,[6] is similar in concept to the CEA measure. "Potential GNP" is meant to refer to that level of GNP that could be produced at a 4 per cent unemployment rate.

In Table I on the next page, the actual values of real GNP, the estimated values of this second measure of potential GNP, and the percentage changes (at annual rates) of the second measure of potential GNP are presented quarterly for the I/1954-II/1970 period. One of the basic differences between the potential GNP series presented in Table I and the CEA series, aside from the smoother nature of the latter, is the relatively slow growth of the series in Table I during the last two quarters of 1965 and all

[6]The measure is described in Fair, "The Determination of Aggregate Price Changes," and in Fair, *A Short-Run Forecasting Model of the United States Economy,* Chapter 10. There is one basic difference between the measure of potential output described in these two works and the measure used in this paper. In a recent study by the author, "Labor Force Participation, Wage Rates, and Money Illusion," Research Memorandum No. 114, Econometric Research Program, Princeton University, September 1970, wage rates were found to have a significant effect on the labor force participation of some age-sex groups, and in the construction of the potential labor force series in this study (a series that is needed for the construction of the potential output series), account was taken of this effect.

Table I

ESTIMATES OF POTENTIAL REAL GNP

(Billions of 1958 Dollars)

Quarter	Real GNP (X)	Potential GNP (X^F)	Percentage Change* in Potential GNP
1954 I	402.9	426.0	3.7%
II	402.1	429.6	3.3
III	407.2	432.8	3.0
IV	415.7	436.6	3.5
1955 I	428.0	440.6	3.7
II	435.4	444.7	3.7
III	442.1	449.1	3.9
IV	446.4	453.0	3.5
1956 I	443.6	456.5	3.1
II	445.6	460.1	3.1
III	444.5	464.4	3.7
IV	450.3	468.0	3.1
1957 I	453.4	471.6	3.0
II	453.2	475.6	3.5
III	455.2	480.6	4.1
IV	448.2	485.8	4.3
1958 I	437.5	490.3	3.7
II	439.5	494.4	3.4
III	450.7	498.4	3.2
IV	461.6	503.4	4.1
1959 I	468.6	507.7	3.4
II	479.9	512.8	4.0
III	475.0	517.7	3.8
IV	480.4	521.7	3.1
1960 I	490.2	530.0	6.3
II	489.7	534.8	3.6
III	487.3	539.4	3.5
IV	483.7	545.0	4.1
1961 I	482.6	550.6	4.1
II	492.8	555.7	3.7
III	501.5	560.6	3.6
IV	511.7	564.1	2.5
1962 I	519.5	567.8	2.6
1962 II	527.7	572.9	3.6%
III	533.4	579.0	4.3
IV	538.3	585.6	4.5
1963 I	541.2	592.5	4.8
II	546.0	598.8	4.2
III	554.7	604.4	3.7
IV	562.1	609.1	3.1
1964 I	571.1	615.4	4.2
II	578.6	621.1	3.7
III	585.8	627.3	4.0
IV	588.5	632.4	3.3
1965 I	601.6	638.3	3.7
II	610.4	644.2	3.7
III	622.5	648.8	2.9
IV	636.6	653.6	2.9
1966 I	649.1	657.0	2.1
II	655.0	660.2	2.0
III	660.2	664.2	2.5
IV	668.1	667.8	2.2
1967 I	666.6	672.8	3.0
II	671.6	678.1	3.2
III	678.9	685.3	4.2
IV	683.6	691.4	3.5
1968 I	693.5	696.6	3.0
II	705.4	701.5	2.9
III	712.6	707.3	3.3
IV	717.5	713.3	3.4
1969 I	722.1	720.0	3.8
II	726.1	726.0	3.3
III	730.9	733.5	4.2
IV	729.2	739.0	3.0
1970 I	723.8	746.9	4.2
II	724.9	753.6	3.6

*Annual rates of change computed here differ slightly from annual rates of change computed elsewhere in this Review and in other publications of this Bank. The formula for quarterly annual rates of change used here is as follows:

$$\text{quarter-to-quarter rate (in per cent)} = \left[\left(\frac{V_t}{V_{t-1}}\right) - 1\right] \cdot 4 \cdot 100$$

of 1966. This slow growth is due primarily to the Vietnam troop buildup during the period. As measured by the national income accounts, average output per government worker is less than average output per private worker, and the movement of workers from private to government work (as when the level of the armed forces is increased) has a negative effect on total potential output.

Specification of the Price Equation

The first question that arises in specifying the price equation is what measure of demand pressure should be used. Two measures, denoted as D_t^* and D_t respectively, were considered in this study:

(1) $D_t^* = X_t^F - X_t$

(2) $D_t = (X_t^F - X_{t-1}) - (Y_t - Y_{t-1})$

Y_t denotes the level of money (current dollar) GNP during period t, X_t denotes the level of real (constant dollar) GNP, and X_t^F denotes the level of potential (real) GNP. D_t^* as defined by (1) is the difference between potential and actual real GNP and is a commonly used measure of demand pressure.[7] $(X_t^F - X_{t-1})$ in (2) is the change in real GNP during period t that would be necessary to make real GNP equal to potential real GNP (to be referred to as the "potential real change in GNP"), and $(Y_t - Y_{t-1})$ is the actual change in money GNP during period t. D_t as defined by (2) is thus the difference between

[7]The notation adopted for this article is designed to be as consistent as possible with the notation in Andersen and Carlson. Note, however, that the sign of D_t in equation (2) is reversed from that in Andersen and Carlson.

the potential real change in GNP and the actual money change. D_t can also be considered to be a measure of demand pressure. If, for example, the potential real change in GNP is quite large, then the money change can be quite large and still lead to little pressure on available supply, but if the potential real change is small, then even a relatively small money change will lead to pressures on supply.

By definition, money GNP is equal to real GNP times the GNP deflator. If the deflator is taken to be endogenous, then whether D_t^* or D_t should be used as the measure of demand pressure in the equation determining the deflator depends on whether real GNP is taken to be endogenous, with money GNP being treated as the "residual," or whether money GNP is taken to be endogenous, with real GNP being treated as the "residual." In the Fair model, for example, the expenditure equations are in money terms and money GNP is endogenous. Likewise, in the Andersen and Carlson model, the expenditure equation is in money terms. In these models it would not be appropriate to use D_t^* in the equation determining the deflator, since the real GNP part of D_t^* is determined as money GNP divided by the deflator (that is, as the residual) and thus the deflator enters on both sides of the equation. It would be appropriate to use D_t, however, as long as it could be assumed that the variables and error terms that determine money GNP in the models are independent of the error term in the equation determining the deflator. Conversely, for models in which real GNP is endogenous and is determined by variables and error terms that are independent of the error term in the equation determining the deflator, it would be appropriate to use D_t^* in the equation, but not D_t.

In most large-scale macroeconomic models, of course, money GNP, real GNP, and the GNP deflator are all endogenous in that they are all determined within a simultaneous system of equations. No one variable can be considered to be determined simply as the ratio or product of the other two. Since in most of these models the expenditure equations are in real terms, however, it is probably true that money GNP is closer to being the residual variable in these models than is real GNP.

Whether a given expenditure equation in a model should be specified in real or money terms depends on whether spending units take money income and other money variables as given and determine how much money to spend as a function of these (and other) variables, or whether they deflate money income and the other money variables by some price level and determine how many goods to purchase as a function of these "real" (and other) variables. In the first case the number of goods purchased is the residual variable (people plan to spend a given amount of money, and real expenditures are determined merely as money expenditures divided by the price level), and in the second case the money value of goods purchased is the residual variable (people plan to purchase a given number of goods, and money expenditures are determined merely as real expenditures times the price level).

In the long run it seems clear that real expenditures are determined by real variables, as standard economic theory suggests, but in the short run the case is not so clear. Given the uncertainty that exists in the short run and the lags involved in the collection and interpretation of information on price changes, people may behave in the short run in a way that is closer to the first case described above than it is to the second.

An argument can thus be made for specifying expenditure equations in short-run models in money terms, although even for short-run models it may be the case that some equations should be specified in real terms. It may also be the case that consumption expenditure equations should be specified in the manner suggested by Branson and Klevorick[8] to incorporate money illusion directly. Whatever the case, D_t has been used as the excess demand variable for most of the work below, on the assumption that in the short run real GNP is closer to being the residual variable than is money GNP. Some results using D_t^* will also be presented.

The price deflator that has been used for the estimates below is actually not the total GNP deflator, but the private output deflator. Because of the way the government sector is treated in the national income accounts, the GNP deflator is influenced rather significantly by government pay increases, such as those that occurred in III/1968 and III/1969, and the private output deflator is likely to be a better measure of the aggregate price level. The private output deflator will be denoted as P_t.

In the table on the next page, values of the private output deflator and demand pressure are presented

[8]William H. Branson and Alvin K. Klevorick, "Money Illusion and the Aggregate Consumption Function," *The American Economic Review* (December 1969), pp. 832-849.

Table II

VALUES OF PRIVATE OUTPUT DEFLATOR (P_t) AND DEMAND PRESSURE (D_t)

Quarter	P_t	Percentage Change* in P_t	D_t	Quarter	P_t	Percentage Change* in P_t	D_t
1956 I	93.15	4.07%	8.3	1963 II	105.70	1.19%	50.8
II	93.97	3.52	10.9	III	105.88	.69	47.9
III	95.14	4.99	14.4	IV	106.23	1.30	43.3
IV	95.89	3.16	14.6	1964 I	106.47	.91	41.4
1957 I	96.87	4.07	13.9	II	106.82	1.31	39.7
II	97.52	2.70	19.2	III	107.21	1.49	37.8
III	98.45	3.82	21.0	IV	107.70	1.82	40.4
IV	98.82	1.50	35.4	1965 I	108.24	2.02	32.1
1958 I	99.52	2.84	48.9	II	108.77	1.93	29.7
II	99.77	1.02	53.3	III	108.96	.71	23.0
III	100.07	1.20	45.8	IV	109.30	1.27	12.2
IV	100.48	1.61	39.7	1966 I	110.08	2.84	.9
1959 I	100.99	2.02	36.5	II	111.15	3.88	−2.7
II	101.23	.99	31.3	III	112.03	3.18	−3.4
III	101.64	1.61	40.7	IV	112.91	3.14	−7.2
IV	101.78	.55	40.2	1967 I	113.54	2.24	1.0
1960 I	102.24	1.79	37.1	II	114.08	1.89	1.4
II	102.67	1.69	42.9	III	115.19	3.89	−2.7
III	102.84	.67	50.2	IV	116.28	3.79	−2.5
IV	103.34	1.95	58.6	1968 I	117.21	3.18	−6.0
1961 I	103.58	.92	66.6	II	118.38	4.01	−15.2
II	103.61	.12	61.8	III	119.37	3.34	−15.8
III	103.59	−.08	58.5	IV	120.65	4.29	−14.9
IV	104.10	1.96	48.1	1969 I	122.08	4.74	−13.7
1962 I	104.44	1.31	46.0	II	123.54	4.78	−12.2
II	104.58	.52	44.0	III	124.88	4.34	−11.5
III	104.79	.82	44.1	IV	126.33	4.61	−1.0
IV	105.09	1.13	44.6	1970 I	127.96	5.16	9.9
1963 I	105.38	1.13	48.8	II	129.22	3.94	18.2

*Annual rates of change computed here differ slightly from annual rates of change computed elsewhere in this Review and in other publications of this Bank. The formula for quarterly annual rates of change used here is as follows:

$$\text{quarter-to-quarter rate (in per cent)} = \left[\left(\frac{V_t}{V_{t-1}}\right) - 1\right] \cdot 4 \cdot 100$$

quarterly for the I/1956-II/1970 period.[9] The values of demand pressure were constructed using the potential GNP measure presented in Table I. Notice that demand pressure was quite large during the early 1960's, when there was little increase in the aggregate price level, and that it was much smaller (and in fact negative) during the late 1960's, when the price level was increasing quite rapidly. (Low values of D_t correspond to periods of high demand pressure).

The basic equation explaining the change in the deflator is specified as:

$$(3)\quad P_t - P_{t-1} = \alpha_0 + \alpha_1 \left(\frac{1}{\alpha_2 + \frac{1}{n} \sum_{i=1}^{n} D_{t-i+1}} \right) + \varepsilon_t ,$$

where ε_t is the error term and n is the number of periods over which lagged values of the demand pressure variable have an influence on the current change in the deflator. $\frac{1}{n} \sum_{i=1}^{n} D_{t-i+1}$ is the simple n-quarter moving average of D. Equation (3) is consistent with the theory expounded above. The current change in the price level is taken to be a function of current and past demand pressures, as measured by the n-quarter moving average of D. A nonlinear functional form has been chosen, the functional form being similar to that used in studies of the Phillips curve, where the reciprocal of the unemployment rate is most often used as the explanatory variable.

Equation (3) is nonlinear in α_2 and must be estimated by a nonlinear technique.[10] In studies of the Phillips curve in which the reciprocal of the unemployment rate is taken to be the explanatory variable, a coefficient like α_2 in equation (3) does not arise, since it is assumed that as the unemployment rate (excess supply) approaches zero, the

[9]P_t is taken to be in units of 100, rather than in units of 1.

[10]The technique that was used for this purpose is described in footnote 11.

change in wages (or prices) approaches infinity. In the present case, no such assumption can be made. D_t is a simple and highly aggregative measure of demand pressure, and there is no reason why zero values of D_t should correspond to infinite changes in the private output deflator. Indeed, D_t has actually been negative during part of the sample period, as can be seen from the accompanying table. Even D_t^* (potential minus actual real GNP) has been negative during part of the sample period, and again there is no reason to think that a zero or slightly negative gap between potential and actual real GNP should result in an infinite change in the price level. Potential GNP is not meant to refer to maximum GNP, but to that GNP level that is capable of being produced when the unemployment rate is 4 per cent. Including α_2 in equation (3) allows the equation to *estimate* the value of the moving average variable that would correspond to an infinite rate of change of prices. Including α_2 in equation (3), in other words, allows the excess demand variable in the equation to differ from the "true" measure of excess demand ("true" meaning that zero values of this variable correspond to infinite price changes) by some constant amount and still not bias the estimates of α_0 and α_1. The error will merely be absorbed in the estimate of α_2.

The Results

Equation (3) was estimated for the I/1956-II/1970 sample period for various values of n.[11] Various weighted averages of the current and past values of D were also tried in place of the simple average specified in equation (3). The equation finally chosen used the simple average of current and past values of D and a value of n equal to 8. The results of

[11]The quarters III/1959, IV/1959, I/1960, IV/1964, I/1965, and II/1965 were omitted from the sample period because of the steel and automobile strikes. These six quarters were also omitted for the work in Fair, *A Short-Run Forecasting Model of the United States Economy.*

The equation was estimated by an iterative technique. The equation to be estimated is first linearized by means of a Taylor series expansion around an initial set of parameter values. Using the linear equation, the difference between the true value and the initial value of each of the parameters is then estimated by ordinary least squares. The procedure is repeated until the estimated difference for each of the parameters is within some prescribed tolerance level. Convergence is not guaranteed using this technique, but for most of the work in this study, achieving convergence was no problem.

Table III

PARAMETER ESTIMATES OF EQUATION (3)*

$$P_t - P_{t-1} = \alpha_0 + \alpha_1 \left(\frac{1}{\alpha_2 + \frac{1}{n} \sum_{i=1}^{n} D_{t-i+1}} \right) + \varepsilon_t$$

	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	S.E.	R^2	D-W	Actual and Predicted Values of the percentage change in P_t (annual rates): 1969 I	1969 II	1969 III	1969 IV	1970 I	1970 II	
							4.74%	4.78%	4.34%	4.61%	5.16%	3.94%	Actual
(a)	−.99 (−1.01)	156.4 (1.37)	76.1 (2.36)	.184	.827	1.83	4.41	4.55	4.63	4.55	4.27	3.78	Predicted
(b)	−1.85 (−.90)	309.9 (0.62)	115.8 (1.18)	.220	.755	1.33	4.04	4.06	4.05	3.88	3.58	3.13	Predicted
(c)	−.51 (−1.48)	67.2 (1.70)	35.4 (2.29)	.190	.817	1.75	4.41	4.52	4.53	4.45	3.99	3.41	Predicted
(d)	1.08 (27.16)	−.0176[a] (−14.29)		.195	.803	1.61	4.08	4.13	4.14	4.10	3.93	3.66	Predicted
(e)	.87 (24.76)	−.0203[a] (−12.12)		.221	.746	1.31	3.88	3.90	3.85	3.75	3.51	3.19	Predicted
(f)	−3.21 (−0.58)	948.6 (0.35)	225.0 (0.63)	.186	.734	1.95	3.88	3.96	3.98	3.94	3.77	3.44	Predicted

*Assumptions used to estimate equation (3):

(a) n=8, Table I values of XF_t

(b) n=8, CEA values of XF_t

(c) n=8, Table I values XF_t, D^* used instead of D.

(d) linear version of (a)

(e) linear version of (b)

(f) n=8, Table I values of XF_t, sample period ending in IV/1968.

[a]Estimate of the coefficient of the demand pressure variable.

Note: "t" statistics appear with each regression coefficient, enclosed by parentheses. R^2 is the percent of variation in the dependent variable which is explained by variations in the independent variable. S.E. is the standard error of the estimate. D-W is the Durbin-Watson statistic.

estimating this equation are presented in line (a) of Table III. The potential GNP series presented in Table I was used for the estimates in line (a).

The estimates of α_0, α_1 and α_2 are fairly collinear, and thus the t-statistics presented in line (a) of Table III are low. When, for example, the value of α_2 was set equal to 76.1 (the estimated value) and equation (3) estimated by ordinary least squares, the resulting t-statistics for α_0 and α_1 were 9.02 and 15.48 respectively. The fit of the equation is quite good, with a standard error of only .184.[12] The inflation in 1969 and the first half of 1970 was captured fairly well, with errors in the six quarters of −.33, −.23, +.29, −.06, −.89, and −.16 per cent respectively.[13] As measured by the Durbin-Watson statistic, there appears to be little evidence of serial correlation in the equation.

Equation (3) was also estimated using the CEA measure of potential GNP, and these results are presented in line (b) of Table III. The standard error of the equation is .220, which is considerably larger than the standard error in line (a), and the inflation in 1969 and 1970 was considerably underpredicted by the equation. The results are clearly not as good as those achieved in line (a) using the potential GNP estimates presented in Table I, which perhaps indicates that the potential GNP series in Table I is a better measure of supply constraints than is the trend series of the CEA.

Equation (3) was also estimated using D* instead of D as the demand pressure variable, and these results are presented in line (c) of Table III. The results are almost as good as those achieved in line (a) using D, but the fit is slightly worse and the inflation in 1969 and 1970 was not captured quite as well. The results thus seem to indicate that D is the better measure of demand pressure, although as discussed above, whether D* or D should be used in the equation depends on whether real GNP or money GNP is closer to being determined as the residual variable in the short run.

As mentioned above, equation (3) was estimated for values of n other than 8 and for weighted averages other than the equally weighted average. In particular, various declining weighted averages were tried. None of these results were an improvement over the results presented in line (a) of Table III. The fits were worse, and for the values of n less than 8 and for the declining weighted averages, the inflation in 1969 and 1970 was underpredicted much more than it is in line (a) of Table III. As can be seen from Table II, D_t was negative and large in absolute value throughout 1968. Only including the current and one-, two-, and three-quarter lagged values of D in the equation, for example, was not enough to capture the demand pressure which built up during 1968 and which presumably led to the large price increases in 1969 and 1970. Going from n equal to 4 to n equal to 8 substantially improved the ability of the equation to explain the inflation in 1969 and 1970.

Various linear versions of equation (3) were also estimated, and the fit of each of the linear versions was always worse than the fit of the corresponding non-linear version, and the inflation in 1969 and 1970 was always underpredicted more. An example of this can be seen from line (d) of Table III, where the results of estimating the linear version of the equation estimated in line (a) are presented. Also, for purposes of comparison in the next section, the results of estimating the linear version using the CEA measure of potential GNP are presented in line (e) of Table III.

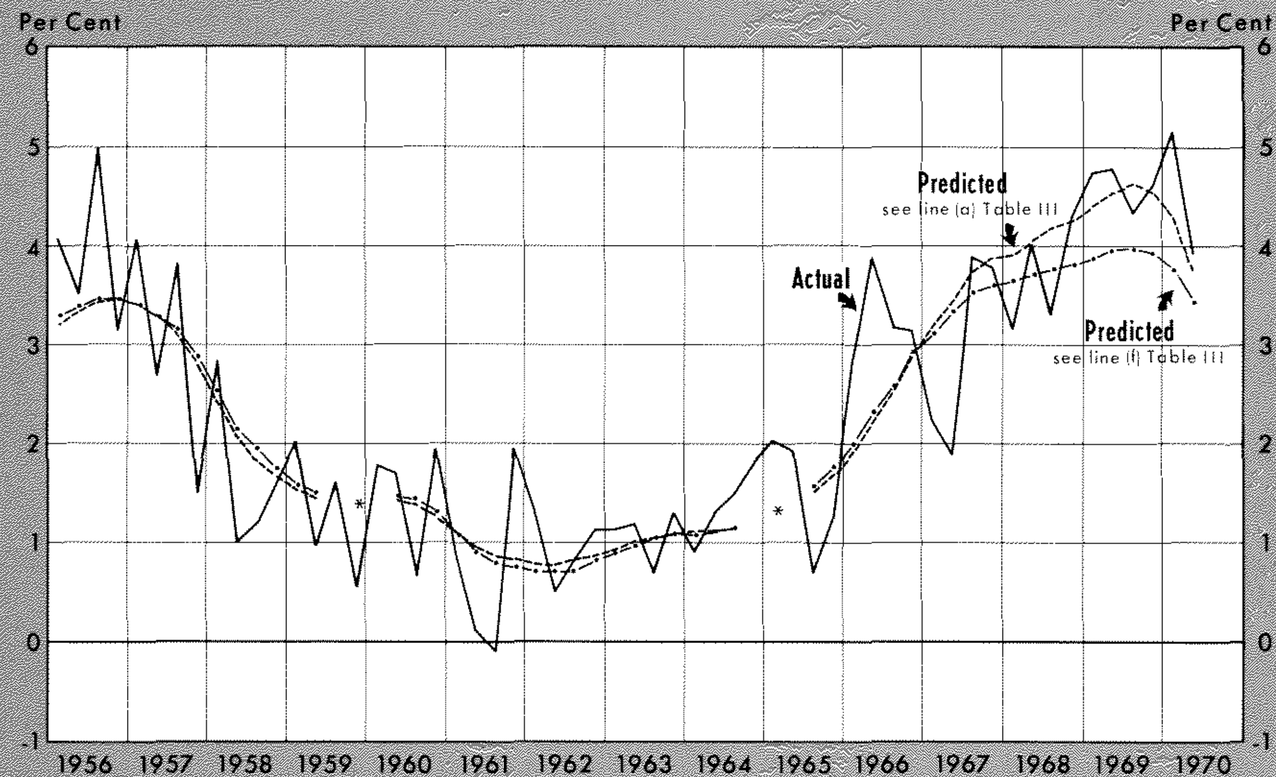
Finally, equation (3) was estimated for the sample period ending in IV/1968 instead of II/1970, and the equation was used to predict values for the four quarters of 1969 and the first two quarters of 1970 (D being treated as exogenous). The results are presented in line (f) of Table III. The coefficient estimates are much different for the shorter period, although the collinearity among the estimates makes the results look more different than they actually are. More importantly, however, the equation did not extrapolate as well into 1969 and 1970. A fairly high rate of inflation was still forecast by the equation for the I/1969-II/1970 period, but not as high as actually occurred. It was necessary, in other words, to estimate equation (3) through the end of the sample period before it was capable of accounting for the rapid rate of inflation in 1969 and in the first half of 1970.

This result is not necessarily surprising, however. As can be seen in Table II, the price increases in the four quarters of 1969 and the first quarter of 1970 were considerably larger than for any other quarter of the sample period, and similarly the values of $\frac{1}{8}\sum_{i=1}^{8} D_{t-i+1}$ were considerably smaller in 1969 than for the rest of the sample period. As a practical

[12]Remember that P_t is in units of 100.

[13]Although the equations in Table III were estimated using $P_t - P_{t-1}$ as the dependent variable, the actual and predicted values given for the I/1968-II/1970 period in the table are in terms of percentage changes at annual rates.

Annual Rates of Change in Prices: Actual and Predicted Values [1]



*The following quarters were excluded: III/59, IV/59, and I/60 because of the steel strike, and IV/64, I/65, and II/65 because of the automobile strike.

[1] Implicit price deflator for total private gross national product, 1958=100.

Note: Annual rates of change computed here differ slightly from annual rates of change computed elsewhere in this Review and in other publications of this Bank.

The formula for quarterly annual rates of change used here is as follows: $\text{quarter-to-quarter rate (in per cent)} = \left[\left(\frac{V_t}{V_{t-1}}\right)-1\right]\cdot 4\cdot 100$

matter, one generally cannot expect an equation that has been estimated by least squares to extrapolate well into periods in which the values of the dependent and independent variables are considerably different from what they were during the period of estimation. It is encouraging that the equation did not forecast a lessening of the rate of inflation in the I/1969-II/1970 period, but only failed to forecast the acceleration of the rate of inflation. It is also somewhat encouraging that a Chow test rejected the hypothesis that the coefficients of equation (3) were different for the I/1969-II/1970 period than they were for the I/1956-IV/1968 period.[14]

To give the reader an idea of how well the model has explained the price deflator, the actual and predicted values of the percentage change in P_t are plotted in the chart above. The predicted values from the equations estimated in lines (a) and (f) of Table III are plotted in the chart. As can be seen from the chart, the rate of inflation in 1969 and 1970 is not captured as well by the equation estimated only through 1968. Otherwise, the price deflator appears to be explained quite well by the two equations.

In summary, then, a simple excess demand equation like (3) appears to be capable of explaining most of the inflation in 1969 and in the first half of 1970, in addition to explaining quite well the price changes in the other quarters of the sample period. However, the equation did have to be estimated through the end of the sample period in order to account for the acceleration of the rate of inflation in the I/1969-II/1970 period, which means that the possibility that the equation is not stable over time cannot be ruled out. More observations are needed before the usefulness of an equation like (3) for forecasting or other purposes can be established.

[14]The estimated value of the F-statistic was 1.38, which compares with a 5 per cent value of 2.81 (at 3,46 degrees of freedom). Because of the nonlinear nature of equation (3), the use of the Chow test in the present circumstances must be interpreted with some caution.

The Effect of Expectations on Aggregate Price Changes

Andersen and Carlson have a price expectations term in a linear version of an equation like (3). They use a polynomial distributed lag of D as the demand pressure variable and take the dependent variable to be the dollar change in total GNP due to the price change. The price expectations term is a 17-quarter distributed lag of past changes in the GNP deflator divided by the unemployment rate.[15] The lag coefficients are taken from a long-term interest rate equation. Andersen and Carlson's results indicate that the demand pressure variable and the price expectations term are about equally important in explaining the change in price, although they state that "the influence of these two variables should perhaps be viewed in combination, rather than as independent and separate influences."[16] They do report in footnote 24, however, that the fit of the equation was much worse without the price expectations term, and that the estimates of the coefficients of the demand pressure variable were only slightly larger. This, they argue, provides some evidence that the price expectations term can be interpreted as an independent and separate influence.

Given the reduced form and highly aggregative nature of an equation like (3), it is not clear that a price expectations term like that of Andersen and Carlson should be interpreted as providing an estimate of the effect of price expectations on aggregate price changes. Since the price expectations term is a distributed lag of past price changes, it is likely that this term and the lagged values of the demand pressure variable will be picking up similar effects. As discussed in the previous section, the lagged values of the demand pressure variable are designed to pick up the lagged behavioral response of individuals and firms and the effect of changing input prices, and it is likely that lagged price changes will pick up some of these effects as well. Conversely, it is likely that the lagged values of the demand pressure variable will pick up some of the effects of price expectations, since past demand pressures may be as important in determining future price expectations as are past price changes. It thus seems that very little confidence should be placed on the results of any attempt to separate the influence of price expectations from other influences by including both a distributed-lag price term and a distributed-lag demand pressure term in an aggregative equation like (3).

A number of distributed-lag price terms were added to equation (3) to see if these terms improved the explanatory power of the equation. The results were not very sensitive to the use of alternative distributed lags, and only the results achieved using the Andersen-Carlson distributed lag will be presented here. The distributed lag that was used is the following:

$$(4) \quad DLAG_t = \sum_{i=1}^{17} p_i \frac{(P_{t-i} - P_{t-i-1})}{U_{t-i}} ,$$

where U_{t-i} is the unemployment rate during quarter $t-i$. The values of p_i are presented in Andersen and Carlson, Table II, page 12. The one-quarter lagged value of Moody's Aaa corporate bond rate (denoted as R_{t-1}) was also added to some of the equations, and some of these results will be reported below. The bond rate is significantly influenced by past price changes, and Andersen and Carlson found R_{t-1} to be significant when included instead of the distributed-lag price term in their price equation.

The results of adding $DLAG_t$ and R_{t-1} to the equation estimated in line (a) of Table III are presented in lines (a) and (b) of Table IV. The coefficient estimates of both variables are of the wrong sign, and the fits of the equations are not improved from the fit of the equation in line (a) of Table III. Because of collinearity problems, the t-statistics in Table IV are low. When the value of α_2 was set equal to the estimated value for each equation and the equation estimated by ordinary least squares, the resulting t-statistics for α_0 and α_1 were -7.63 and -10.51 for the equation in line (a) of Table IV, and -7.87 and -10.70 for the equation in line (b). The resulting t-statistic for the coefficient of $DLAG_t$ was $-.78$, and the resulting t-statistic for the coefficient of R_{t-1} was $-.12$. In summary, then, the demand pressure variable completely dominated $DLAG_t$ and R_{t-1} for the price equation estimated in line (a) of Table III.

Since Andersen and Carlson used the Council of Economic Advisers' measure of potential GNP and the linear version of the price equation, $DLAG_t$ and

[15]The price expectations term is also multiplied by GNP lagged one quarter to scale the term in dollar units. The unemployment rate is used "as a leading indicator of future price movements." The price change each quarter is divided by the unemployment rate of that quarter to reflect the fact that "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." (Andersen and Carlson, p. 13.)

[16]Andersen and Carlson, p. 13.

Table IV

Results of Adding Distributed-Lag Price Term ($DLAG_t$) and Moody's Aaa Corporate Bond Rate (R_{t-1}) to Equations (a) and (e) of Table III*

	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	Coeff. est. of $DLAG_t$	Coeff. est. of R_{t-1}	S.E.	R^2	D-W	Actual and Predicted Values of the percentage change in P_t (annual rates) 1969 I	1969 II	1969 III	1969 IV	1970 I	1970 II	
									4.74%	4.78%	4.34%	4.61%	5.16%	3.94%	Actual
(a)	−.81	126.2	64.9	−.0050		.185	.829	1.85	4.44	4.59	4.66	4.55	4.21	3.63	Predicted
	(−1.58)	(1.54)	(2.51)	(−0.69)											
(b)	−.93	147.3	73.2		−.0040	.186	.827	1.83	4.41	4.55	4.63	4.55	4.27	3.78	Predicted
	(−1.08)	(1.08)	(1.73)		(−0.08)										
(c)	.65	−.0168[a]		.0177		.203	.790	1.55	4.14	4.23	4.31	4.29	4.18	3.97	Predicted
	(8.42)	(−8.98)		(3.19)											
(d)	.52	−.0176[a]			.0697	.215	.766	1.41	4.01	4.13	4.11	4.08	3.96	3.72	Predicted
	(2.85)	(−8.44)			(2.02)										

*Combinations used:
(a) $DLAG_t$ added to (a) of Table III
(b) R_{t-1} added to (a) of Table III
(c) $DLAG_t$ added to (e) of Table III
(d) R_{t-1} added to (e) of Table III

[a]Estimate of the coefficient of the demand pressure variable.

Note: "t" statistics appear with each regression coefficient, enclosed by parentheses. R^2 is the percent of variation in the dependent variable which is explained by variations in the independent variables. S.E. is the standard error of the estimate. D-W is the Durbin-Watson statistic.

R_{t-1} were also added to this type of an equation. In particular, the variables were added to the equation estimated in line (e) of Table III.[17] The results are presented in lines (c) and (d) of Table IV. Both $DLAG_t$ and R_{t-1} are now significant in the equation, and the fits have been improved over the fit of the equation in line (e) of Table III. In particular, the addition of $DLAG_t$ has improved the equation considerably. This result is thus similar to the result achieved by Andersen and Carlson. The distributed-lag price term is not as significant here as it was for Andersen and Carlson, but this is due in large part to the different demand pressure variables used. The use of the eight-quarter moving average here instead of the five-quarter declining average used by Andersen and Carlson took away some of the significance of $DLAG_t$.

It should be noted, of course, that the fit of the equation in line (c) of Table IV is worse than the fit of the equation in line (a) of Table III, and that the inflation in 1969 and 1970 was not captured quite as well. It was very evident from all of the results that $DLAG_t$ and R_{t-1} (and the other distributed-lag price variables considered) were most significant in the equations using the CEA measure of potential GNP and in those equations using weighted averages of the demand pressure variable of less than about six quarters. The variables were also significant in many of the linear versions of the price equation, although they were not significant for the linear equation in line (d) of Table III.

The overall results thus indicate that the distributed-lag price variables do not improve the explanatory power of the best-fitting versions of equations like (3), but that they are of some help in the poorer fitting versions. Because the importance and significance of the distributed-lag price variables are dependent on the particular demand pressure variable used and on the functional form of the equation, the results also suggest that it would be unwise to interpret the distributed-lag price term in a particular equation as measuring the effect of price expectations. Both the distributed-lag price terms and the distributed-lag demand pressure terms appear to be picking up similar effects.

Finally it should be stressed that equation (3) was developed primarily for forecasting purposes and should be judged primarily on these grounds. Its reduced-form nature makes it of little use in analyzing questions about the structure of wage and price determination. In line with this comment, this paper should not necessarily be interpreted as a serious criticism of the Andersen and Carlson specification of the price equation. It does not appear that the distributed-lag price term is really needed in the best-fitting versions of the price equation, but there is nothing wrong theoretically with including it in

[17]It should be noted that this equation is not identical to the Andersen-Carlson equation because of the different weighted averages used for the demand pressure variable and the different price variables used. The periods of estimation also differ slightly.

those versions in which it is significant. Both lagged values of the demand pressure variable and lagged price changes are likely to be picking up similar effects, and it is an empirical question as to which is the best way to specify these effects.

An important property of the Andersen-Carlson version of the price equation is that it takes a relatively long time for the rate of inflation to subside in their model once it has begun. This is because of the large coefficient estimate of the distributed-lag price term in their equation and thus the large weight given to the sum of past price changes.[18] The forecasts from the Andersen-Carlson model thus tend to be rather pessimistic with respect to slowing down the rate of inflation in 1971 and 1972. This is in contrast to the forecasts from the Fair model, which tend to be much more optimistic in this regard. The events during 1971 and 1972 should thus provide a good test of the forecasting accuracy of the two equations.

[18]From Tables II and III of Andersen and Carlson, it can be seen that the sum of past price changes has a weight of .96(.86) = .8256 in their equation.

This article is available as Reprint No. 61