INFLATIONARY EXPECTATIONS AND PRICE SETTING BEHAVIOR

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Abstract—This paper tests for the existence of expectational effects in very disaggregate price equations. Price equations are estimated using monthly data for each of 40 products. The dynamic specification of the equations is also tested, including whether the equations should be specified in level form or in change form.

The results support the hypothesis that aggregate price expectations affect individual pricing decisions. The results do not discriminate very well between the level and change forms of the price equation, although there is a slight edge for the level form. The lag and lead lengths are not estimated precisely. The average lag length is about 38 months, and the average lead length is about 5 months.

I. Introduction

IT is often said that expectations of future prices may affect current prices or that inflationary expectations may get "built into the system" and make inflation difficult to stop quickly. An important empirical question in macroeconomics is whether there is anything to this story. Do price expectations matter, and if so, how? This paper tries to answer this question. A simple theoretical model of price setting behavior, borrowed from the industrial organization literature, is used as a starting point. In this model a firm's price setting behavior is affected by its expectations of other firms' prices. If a firm expects that its competitors are going to raise their prices, the firm will raise its own price. The empirical work consists of testing for this effect in very disaggregate price equations. Monthly price data for 40 products have been collected, and price equations are estimated for each of these products. Expectational effects are examined by adding a price expectations variable to the equations and seeing if it is statistically significant. The results strongly support the hypothesis that aggregate price expectations affect individual pricing decisions and thus provide micro evidence for the common finding of price inertia in the estimation of aggregate price equations.

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II. A Theoretical Model

A simple duopoly game with asymmetric information can be used to illustrate the way expectations may affect price setting behavior. Tirole (1988, section 9.1.1), for example, discusses the case where the duopolists sell differentiated products and firm 2 has incomplete information about firm 1's cost. The demand curves are assumed to be symmetric and linear:

$$D_i(p_i, p_j) = a - bp_i + dp_j, \qquad 0 < d < b. \tag{1}$$

Both firms have constant marginal costs: c_1 and c_2, respectively. c_2 is common knowledge, but only firm 1 knows c_1. Tirole shows that firm 2's profit maximizing price is

$$p_2 = (a + dp_1^e + bc_2)/2b, \tag{2}$$

where p_1^e is firm 2's expectation of firm 1's price. p_1^e depends among other things on firm 2's expectation of firm 1's marginal cost.

Equation (2) says that firm 2's price is a function of the demand parameter a, firm 2's marginal cost c_2, and firm 2's expectation of firm 1's price p_1^e. Since d is positive, firm 2's price is a positive function of its expectation of firm 1's price. The main purpose of this paper is to test for the significance of a price expectations variable in an empirical version of equation (2).

III. The Tests

A standard price equation in macroeconomics contains cost variables and demand variables. The cost variables are represented by c_2 in equation (2), and the demand variables are represented by a. For the empirical work in this paper a number of variables have been used for the cost variables and the demand variables, and the equation is taken to be in log form. Also, p_1^e in equation (2) is assumed to be an aggregate price expectations variable, denoted PA^e. There are two ways to justify this latter assumption in light of the above model. First, firm 2 may expect that firm 1's costs are affected by the aggregate price level, in which case p_1^e and firm 2's expectation of the aggregate price level will be correlated. PA^e can then be used as a proxy for the unobserved p_1^e. Second, if there are more than two firms in the industry, p_1^e can be thought of as representing firm 2's expectation of the average price level of many firms, which can then be proxied by PA^e.

Let P_t denote the log of the price of a firm's good in period t, and let X_t denote a vector of cost and demand variables that may affect P_t.[1] Write the price equation as

$$P_t = X_t'\beta + u_t, \qquad t = 1, \ldots, T, \tag{3}$$

where β is a vector of parameters to be estimated and u_t is an error term. The vector X_t is meant to capture the effects of a and c_2 in equation (2). Regarding expectations, let PA_{t+j}^e be the firm's expectation of the log of the aggregate price level in period $t+j$ $(j \geq 0)$, the expectation being made at the beginning of period t (before information for period t is available). Adding PA_t^e, PA_{t+1}^e, etc. to equation (3) provides a test of whether expectations matter. If X_t adequately captures all the non-expectational variables that affect P_t and if expectations don't matter, then PA_t^e, PA_{t+1}^e, etc. do not belong in the equation and should not be statistically significant. If they are significant, this is evidence in favor of the existence of expectational effects.

The danger with this approach is that one may have left out important explanatory variables from X_t that are correlated with the PA_{t+j}^e variables. Too much will then be attributed to the expectations variables. To guard against this, many variables have been included in X_t. The aim has been to err on the side of too many variables rather than too few. As discussed in the next section, more than one demand variable has been included in each equation and a number of cost variables have been included. In addition, a linear time trend and seasonal dummy variables have been included.[2] Finally, a fairly rich dynamic specification has been used for some of the equations. Because of the large number of variables included in X_t, some highly correlated with others, many of the individual parameters are not estimated precisely. This is not, however, of direct concern here. The concern here is simply whether the PA_{t+j}^e variables have independent explanatory power in the equations once all the other variables have been included in X_t.

Another way of looking at this procedure is that an attempt has been made to specify a very general price equation that encompasses many of the specifications found in the literature. The existence of expectational effects is then tested using this equation; and so the results should be robust across many individual specifications.

The Expectational Hypotheses and Estimation Techniques

Two expectational hypotheses have been used regarding expectations of PA. The first, which is consistent with the adaptive expectations hypothesis, is that the expected future values of PA are a function of its past values (beginning with period $t-1$ for decisions made in period t). In this case the coefficients are assumed to lie on a linear polynomial with an end point constraint of zero at lag length q. q is estimated along with the other parameters, and the standard error of the estimate of q is computed along with the standard errors of the other estimated parameters. The method for estimating q and its standard error is discussed in Andrews and Fair (1992). Estimating the lag length avoids misspecification from picking an incorrect lag length and allows the data to indicate how far back agents look in forming their expectations (under the assumption that the first expectational hypothesis is valid). Estimating the standard errors of the lag-length estimates allows one to see how much confidence to place on the particular estimated lengths.

When a linear polynomial is used with an end point constraint imposed, there is one coefficient to estimate for the polynomial (in addition to the lag length q). The variable that corresponds to this coefficient will be denoted Q_t. Q_t is a function of the past values of PA and of q. Given the estimate of the coefficient of Q_t and given the estimate of q, the sum of the lag coefficients can be computed. This sum will be denoted λ. Again, see Andrews and Fair (1992) for more details.

[1] The price, wage, and cost variables are taken to be in logs in the empirical work. For ease of exposition, P_t will simply be referred to as the price rather than the log of the price, and similarly for the wage and cost variables.

[2] Even though most of the variables in the estimated equations are seasonally adjusted, the seasonal dummies were included to pick up possible seasonal effects not captured in the data. This procedure is consistent with the theme of erring on the side of too many rather than too few variables in X_t.

The second expectational hypothesis is that expectations are rational. In this case the coefficients of the expected future values that enter the equation are assumed to lie on a linear polynomial with a constraint of zero at lead length r. r is estimated along with the other parameters, and the standard error of the estimate of r is computed along with the other standard errors. The method for estimating r and its standard error is also discussed in Andrews and Fair (1992). The method is a combination of Hansen's (1982) method of moments, Almon's (1965) polynomial distributed lag (PDL) technique, and the adjustments that are needed to allow r to be estimated. In this case polynomial distributed *leads* rather than lags are estimated. An estimate of r is an estimate of the length ahead that expectations matter for current decisions. The analogous variable to Q_t for the rational expectations hypothesis will be denoted R_t. R_t is a function of the future values of PA and of r.

Dynamic Specifications

It is of interest to see if the disaggregate data used in this study can discriminate among various dynamic specifications of the price equation. A key issue is whether the price equation should be specified in level form or in change form. Theories differ on which specification is likely to be better. In the Phillips curve literature, the choice variable is the change in price, whereas in industrial organization models like the one in section II, the choice variable is the price level. Fortunately, it is possible to test empirically which specification is better, which is done here.

Assume for now that equation (3) is to be estimated and that in X_t there is only one cost (input price) variable, I_{t-1}, one demand variable, D_{t-1}, and no seasonal dummy variables.[3] In *level form* the price equation is

$$P_t = \beta_0 + \beta_1 t + \beta_2 D_{t-1} + \beta_3 I_{t-1} + \beta_4 P_{t-1} - \gamma_1 Q_t + u_t, \qquad (4)$$

and in *change form* the equation is

$$\begin{aligned} P_t - P_{t-1} = {} & \eta_0 + \eta_1 t + \eta_2 D_{t-1} \\ & + \eta_3 (I_{t-1} - I_{t-2}) \\ & + \eta_4 (P_{t-1} - P_{t-2}) \\ & - \gamma_1 (Q_t - Q_{t-1}) + v_t. \end{aligned} \qquad (5)$$

The key difference between equations (4) and (5) is that D_{t-1} and not $D_{t-1} - D_{t-2}$ is included in (5). Equation (5) is *not* the first difference of (4). If β_4 is less than one in (4), a permanent change in D results in a permanent change in the level of P but not in the change in P. In (5) a permanent change in D results in a permanent change in the change in P. The time trend t is included in (4) to pick up any trend in the price level not captured by the other variables. It is included in (5) to pick up any trend in the price change not captured by the other variables. The constant term η_0 in (5) picks up any trend in the price level not captured by the other variables. The lagged change in price is added to (5) to allow a more complicated dynamic specification. The statistical tests below are based on the assumption that all the variables are trend stationary.

It is not possible to nest (4) within (5) or vice versa, but they can each be nested in a more general model. This model is

$$\begin{aligned} P_t = {} & \delta_0 + \delta_1 t + \delta_2 D_t + \delta_3 I_{t-1} + \delta_4 I_{t-2} \\ & + \delta_5 P_{t-1} + \delta_6 P_{t-2} + \delta_7 Q_t \\ & + \delta_8 Q_{t-1} + w_t. \end{aligned} \qquad (6)$$

The restrictions in (6) implied by the level specification in (4) are $\delta_4 = \delta_6 = \delta_8 = 0$. The restrictions in (6) implied by the change specification in (5) are $\delta_3 = -\delta_4$, $\delta_5 = -\delta_6$, and $\delta_7 = -\delta_8$. These restrictions can be tested. If both sets of restrictions are accepted,[4] then the test has not discriminated between the two specifications. If neither set is accepted, then neither specification is supported by the data. Otherwise, one specification will be selected over the other. In what follows equation (6) will be called the *unrestricted* form of the price equation.

Equations (4) and (5) are also tested against a more general dynamic specification than that in (6). The more general specification considered here is equation (6) with P_{t-3}, P_{t-4}, and P_{t-5}

[3] Agents are assumed to make period t decisions on the basis of period $t-1$ information, and so a lag of one is used for I and D in the following discussion. The empirical implications of this assumption are discussed at the end of section V.

[4] By "accepted" is meant that the restrictions are not rejected at whatever confidence level is being used.

added:

$$\begin{aligned} P_t = \delta_0 + \delta_1 t + \delta_2 D_{t-1} + \delta_3 I_{t-1} + \delta_4 I_{t-2} \\ + \delta_5 P_{t-1} + \delta_6 P_{t-2} + \delta_7 Q_t \\ + \delta_8 Q_{t-1} + \delta_9 P_{t-3} + \delta_{10} P_{t-4} \\ + \delta_{11} P_{t-5} + w_t. \end{aligned} \tag{7}$$

The three further restrictions implied by equations (4) and (5) are then $\delta_9 = \delta_{10} = \delta_{11} = 0$. In other words, testing (4) and (5) against (7) is testing the implicit assumption in (4) and (5) that the further lagged values of the price do not belong in the equation. Equation (7) will be called the *general* form of the price equation. Equation (7) is general enough to encompass the dynamic specifications of many of the price equations found in the literature.

The exact equations that were estimated for each product are presented in the next section after the data have been discussed.

IV. The Data

Monthly price data for 40 products were collected from the data on the producer price indexes compiled by the Bureau of Labor Statistics. The products are listed in table 1. They range from chewing gum to rubber hoses. Products were chosen that seemed likely to be fairly homogeneous across time and for which monthly data for a fairly long period of time were available. These data are the data for P_t. Although ideally one would like price data at the individual firm level,

TABLE 1.—THE FORTY PRODUCTS AND THEIR INPUTS

	Code Number
1. Chewing gum	02550201
1) Raw cane sugar	02520101
2) Flavoring syrup (fountain)	02640103
3) Cor. shp. cont. for food & beverages	09150323
4) Foil, plain (under .006 inches)	10250111
2. Bottled beer	02610101
1) Malt and malt byproducts	02640101
2) Cor. shp. cont. for food & beverages	09150323
3) Glass containers	138
3. Cola, bottled, excluding diet cola	02620106
4. Ginger ale	02620505
5. Club soda	02620507
1) Raw cane sugar	02520101
2) Flavoring syrup (fountain)	02640103
3) Glass containers	138
4) Cor. shp. cont. for food & beverages	09150323
5) Kola syrup, for use by bottlers (3 only)	02640105
(continued)	
6. Sole leather	042101
7. Upper leather, including patent	042102
1) Cattle hides	0411
8. Baseball glove	15120141
1) Finished cattlehide and kipside leather	0421
9. Household detergents	06710402
1) Fats and oils, inedible	064
2) Paperboard	091503
10. Shaving soap and cream	06750201
11. Cologne and toilet water	06750305
12. Cleansing creams	06750601
1) Essential oils (10 and 11 only)	067901
2) Metal cans and can components (10 only)	1031
3) Glass containers (11 and 12 only)	138
4) Fats and oils, inedible (12 only)	064
13. Passenger car/motorcycle inner tubes	07120221
1) Natural rubber	071101
2) Synthetic rubber	071102
14. Offset uncoated book paper	09130122
15. Unwatermarked bond, no. 4 grade	09130131
16. Cotton fiber writing paper	09130141
17. Newsprint	09130291
1) Woodpulp	0911
2) Softwood sulfate, bleached and semibleached	09110211
18. Paperboard	0914
1) Woodpulp	0911
19. Ice cream carton	09150327
20. Milk carton, 1/2 gallon	09150329
21. Paper cups, hot	09150333
22. File folders	09150645
23. Index cards	09150647
1) Woodpulp	0911
24. Insect wire screening	10880721
25. Barbed and twisted steel wire	10880951
26. Galvanized nails	10880213
1) Plain wire, carbon steel	10170511
27. Wrench, open-end	10420131
28. Wrench, box	10420132
29. Adjustable wrench, including pipe	10420133
30. Screwdrivers	10420141
31. Pliers	10420151
32. Hammers, light forged	10420161
1) Bars, c.f., alloy	0170831
33. Cap screws	10810231
1) Bars, c.f., alloy	0170831
34. Ball and roller bearings	114905
1) Bars, c.f., alloy	0170831
2) Closed die forging, carbon steel	10151351
35. Dry cell size d flashlight batteries	11790211
1) Carbon and graphite products	117903
2) Lead, pig, common	10220127
36. Cutlery, razors and razor blades	1267
1) Strip, c.v., stainless	10170755
37. Portland cement	13220131
1) Sand, construction	13210101
2) Gravel, for concrete	13210111
38. Black lead pencil	15950125
1) Carbon and graphite products	117903
2) Other wood products	084
39. Toothbrush	15970245
1) Plastic resins and materials	066
40. Rubber hose	071304
1) Natural rubber	071101
2) Synthetic rubber	071102

the data collected here are probably as close as one can come to this ideal using government data. In future work it would be interesting to see whether enough data at the individual firm level could be collected to perform the kinds of tests reported in this paper.

The aggregate price variable, PA_t, was taken to be the producer price index for all commodities.

Table 1 also lists some of the main inputs for each product. Monthly price data on these inputs were also collected. The inputs for each product were chosen through examinations of input–output tables and from talking with various people in the government who are involved in the collection of the data and who are knowledgeable about specific industries. Some of the inputs in table 1 pertain to more than one product.

The price data in table 1 are classified by product rather than by industry. The other data that were collected are classified by industry. First, monthly seasonally adjusted data on industrial production for each of the relevant industries were collected from the Federal Reserve. Let Y_t denote the production index for a given industry. The data on Y_t were used to create a capacity utilization variable, CU_t. Peak-to-peak interpolations of Y_t were made, and capacity, C_t, was assumed to lie on the interpolation lines. Given C_t, CU_t is equal to Y_t/C_t. If capacity utilization is large (close to one), this may indicate that the demand curve facing the firm has shifted out, which may lead the firm to raise its price. The one-month lagged value of CU_t, CU_{t-1}, was taken to be one of the demand-variables to be included in X_t.

Second, monthly seasonally adjusted data on inventories and shipments were collected from the Bureau of the Census for each of the relevant industries. Let V_t denote the stock of inventories at the end of month t, and let S_t denote the level of shipments in month t. If the ratio of inventories to shipments, V_t/S_t, is low, this may also indicate that the demand curve facing the firm has shifted out, which may lead the firm to raise its price. V_{t-1}/S_{t-1} was also taken to be one of the demand variables to be included in X_t.

Third, monthly seasonally adjusted data on wage rates, hours, and overtime hours were collected from the Bureau of Labor Statistics for each of the relevant industries. Let WT_t denote the average hourly wage, H_t the number of hours worked per week, and HO_t the number of overtime hours worked per week. WT_t is not adjusted for overtime hours, and so a new wage variable, W_t, was constructed, where $W_t = (WT_tH_t)/(H_t + .5HO_t)$. W_t is adjusted for overtime hours under the assumption that overtime hours are paid time and a half. For some industries not enough data on H_t and HO_t were available to construct W_t, and in these cases WT_t was used in place of W_t.

W_{t-1} (or WT_{t-1}) was included in X_t as one of the cost variables. In addition, the one-month lagged ratio of overtime hours to total hours, HO_{t-1}/H_{t-1}, was included in X_t (data permitting) as another demand variable. If overtime hours are high, this may indicate that the demand curve facing the firm has shifted out, which may lead the firm to raise its price.

The industry matching to the 40 products is presented in an appendix available from the author.

Table 2 presents the equations that were estimated for each product and the sample periods that were used. The table is self-explanatory, and it will be discussed only briefly here. The change form is equation (4); the level form is equation (5); the unrestricted form is equation (6); and the general form is equation (7). All the sample periods cover the turbulent period of the 1970s. Some are shorter than others because of data limitations. The number of observations ranges from 162 to 359. More than half of the sample periods have over 300 observations. The number of explanatory variables in the level and change forms varies from 18 to 23, counting the aggregate price expectations variable as one.[5] The number of explanatory variables in the unrestricted form varies from 21 to 31. The general form includes three more variables, namely, the three lagged values of the price.

When the unrestricted and general forms were estimated, the same value of q was assumed for both Q_t and Q_{t-1} and the same value of r was assumed for both R_t and R_{t-1}. This treatment is consistent with the fact that Q_{t-1} is simply Q_t lagged one month and that R_{t-1} is simply R_t lagged one month.

[5] The number of parameters estimated is one greater than the number of explanatory variables listed because the lag length q or the lead length r is estimated along with the other parameters.

TABLE 2.—THE EQUATIONS AND SAMPLE PERIODS

Each equation contains a constant term, a linear time trend, and 11 seasonal dummy variables. Let A_t denote the vector of these variables for month t. Let P_{it} denote the price of input i for a given product, where the inputs are listed in table 1. i runs from 1 up to a maximum of 5. Let B_t denote the vector $(P_{1t}, \ldots, P_{nt})$, where n is the number of inputs for the given product (n may be 1). Let DB_t denote the vector $(P_{1t} - P_{1t-1}, \ldots, P_{nt} - P_{nt-1})$. The specifications are

Level Form:

LHS variable: P_t
RHS variables: A_t, B_{t-1}, W_{t-1} or WT_{t-1}, CU_{t-1}, V_{t-1}/S_{t-1}, HO_{t-1}/H_{t-1}, P_{t-1}, and Q_t or R_t.

Change Form:

LHS variable: $P_t - P_{t-1}$
RHS variables: A_t, DB_{t-1}, $W_{t-1} - W_{t-2}$ or $WT_{t-1} - WT_{t-2}$, CU_{t-1}, V_{t-1}/S_{t-1}, HO_{t-1}/H_{t-1}, $P_{t-1} - P_{t-2}$, and $Q_t - Q_{t-1}$ or $R_t - R_{t-1}$.

Unrestricted Form:

LHS variable: P_t
RHS variables: A_t, B_{t-1}, B_{t-2}, W_{t-1} or WT_{t-1}, W_{t-2} or WT_{t-2}, CU_{t-1}, V_{t-1}/S_{t-1}, HO_{t-1}/H_{t-1}, P_{t-1}, P_{t-2}, Q_t or R_t, and Q_{t-1} or R_{t-1}.

General Form: Same as unrestricted form with P_{t-3}, P_{t-4}, and P_{t-5} added.

Special Features:
Neither W nor WT appear in 24–31 and 35. W appears in 6–8, 13–23, 34, and 36–40. WT appears in 1–5, 9–12, and 32. HO/H appears only in 6–8, 13–23, 34, and 35–40. CU does not appear in 1.

Notation:
A: See above.
B: See above (the P_i variables are in logs).
CU: Capacity utilization.
DB: See above (the P_i variables are in logs).
H: Total hours per worker.
HO: Overtime hours per worker.
P: Price of the product (in logs).
Q: Aggregate price expectations variable for the first expectational hypothesis (in logs).
R: Aggregate price expectations variable for the second expectational hypothesis (in logs).
S: Sales.
V: Stock of inventories.
W: Wage rate adjusted for overtime hours (in logs).
WT: Wage rate not adjusted for overtime hours (in logs).

Product	Sample Period	T	k_1	k_2	Product	Sample Period	T	k_1	k_2
1	1961.07–1985.12	294	21	28	21	1967.07–1985.06	216	20	24
2	1967.07–1987.12	246	21	27	22	1958.07–1988.05	359	20	24
3	1969.07–1985.12	198	23	31	23	1958.07–1980.07	265	20	24
4	1961.07–1985.07	289	22	29	24	1958.07–1988.05	359	18	21
5	1961.07–1985.12	294	22	29	25	1958.07–1988.05	359	18	21
6	1958.07–1983.08	302	20	24	26	1964.07–1988.05	287	18	21
7	1958.07–1988.05	359	20	24	27	1958.07–1984.07	313	18	21
8	1958.07–1985.02	320	20	24	28	1958.07–1988.10	328	18	21
9	1958.07–1988.05	359	20	25	29	1958.07–1988.05	359	18	21
10	1958.07–1986.12	342	20	25	30	1958.07–1988.05	359	18	21
11	1958.07–1988.05	359	20	25	31	1958.07–1988.05	359	18	21
12	1958.07–1988.05	359	20	25	32	1958.07–1988.05	359	18	21
13	1958.07–1985.12	330	21	26	33	1964.07–1988.05	251	19	23
14	1958.07–1988.05	359	21	26	34	1961.07–1988.05	323	21	26
15	1958.07–1988.05	359	21	26	35	1961.07–1988.05	323	19	23
16	1958.07–1987.12	354	21	26	36	1958.07–1988.05	359	20	24
17	1958.07–1988.05	359	21	26	37	1958.07–1988.05	359	21	25
18	1958.07–1988.05	359	20	24	38	1967.07–1985.12	222	21	26
19	1964.06–1985.06	253	20	24	39	1958.07–1981.12	282	20	24
20	1964.06–1985.06	253	20	24	40	1972.07–1985.12	162	21	26

Notes: T is the total number of observations.
k_1 is the number of explanatory variables in the change form and in the level form.
k_2 is the number of explanatory variables in the unrestricted form. The number of explanatory variables in the general form is $k_2 + 3$.

Estimation under the second (rational) expectations hypothesis requires a set of instrumental variables. The variables that were used are the following. First, all the explanatory variables in the general form of the equation for the given product were used except for R_t and R_{t-1} (for all the forms estimated). Second, PA_{t-1}, PA_{t-2}, PA_{t-3}, PA_{t-4}, and PA_{t-5} were used. Finally, the one-month and two-month lagged values of the unemployment rate, the overall industrial production index, the three-month Treasury bill rate, and the 10-year government bond rate were used. These are the variables that agents are assumed to use (perhaps along with others) in forming their expectations.

It should be noted that q and r cannot be less than one. In a number of cases the optimum occurred at a value of q or r of one, and these are the estimates reported below.[6] Also, a maximum of q of 132 (11 years) was set, and in a few cases the optimum occurred at a value of q of 132. Similarly, a maximum of r was set at 12, and in a few cases the optimum occurred at this value.

V. The Results

Tables 3 and 4 present a summary of all the results, and this section contains a discussion of these two tables. Table 3 summarizes the results for the first expectational hypothesis, and table 4 summarizes the results for the second. A fairly systematic procedure was followed in the estimation work. Consider first the results in table 3. Four equations were estimated per product[7]—the level, change, unrestricted, and general forms—and from these estimates four F-values were computed. The first F-value tests the restrictions in the level form relative to the restricted form; the second tests the restrictions in the level form relative to the general form; the third tests the restrictions in the change form relative to the unrestricted form; and the fourth tests the restrictions in the change form relative to the general form.[8]

If the restrictions implied by the level form are rejected at the 1% level in both cases, i.e., compared to both the unrestricted and general forms, the estimates of λ, the sum of the PDL coefficients, and q are not recorded in table 3. When these two rejections take place, it is a clear rejection of the level form of the price equation, and so further examination of the equation is not of interest. Similarly, if the restrictions implied by the change form are rejected at the 1% level in both cases, the estimates of λ and q are not recorded. Note that this procedure gives the benefit of the doubt to the level and change forms regarding what is recorded in the tables. The estimates are not presented only if the restrictions are rejected at the 1% level for both tests. For purposes of reporting the results it seemed better to err on the side of presenting too many estimates than too few.

When the estimates are recorded for a given product, the estimate of λ and its t-statistic are presented. The t-statistic tests whether the sum of the coefficients of the past values of the aggregate price variable is significantly different from zero. If the t-statistic is quite low, which is taken here to be less than one, then the aggregate price variable is clearly not significant. In this case it is of no interest to examine the estimate of q, and so when a t-statistic is less than one in table 3, the estimate of q is not presented. Similarly, if the estimate of λ is negative, which is not sensible, the estimate of q is not presented. When the estimate of q is presented in the table, its estimated standard error is also presented unless the estimate of q is one, where the standard error does not exist.

A fifth F-statistic is also presented in table 3. This statistic tests whether Q_t and Q_{t-1} are jointly significant in the general form of the equation. Computing this statistic requires that a fifth regression be run for each product, namely, the general form without Q_t and Q_{t-1} included. This F-test is particularly useful when both the level

[6] When $\hat{q}$ is equal to one, its standard error cannot be computed (the covariance matrix of the coefficient estimates including $\hat{q}$ is singular), and so no standard error for $\hat{q}$ is reported when $\hat{q}$ is equal to one. When $\hat{q}$ is equal to one, the standard error for $\hat{\lambda}$ (for which the t-statistic in table 3 is needed) is computed under the assumption that q is known with certainty (and equal to one). The same considerations apply for $\hat{r}$ when it is equal to one.

[7] The estimates were obtained by searching over values of q. The final grid search was 0.01. The estimates in table 4 were obtained by searching over values of r. The final grid search in this case was 0.1. See Andrews and Fair (1992) for more discussion of the computation of the estimates.

[8] The degrees of freedom for the F-test (and for the χ^2-test in table 4) can be calculated from the numbers presented in table 2.

TABLE 3.—RESULTS USING THE FIRST EXPECTATIONAL HYPOTHESIS

	Level Form						Change Form						General Form	
Product	F_1	$\hat{\lambda}$	t_λ	$\hat{q}$	SE_q	F_2	F_3	$\hat{\lambda}$	t_λ	$\hat{q}$	SE_q	F_4	F_5	$\hat{q}$
1	6.94[b]					5.35[b]	2.42[a]	0.831	2.58	2.60	1.37	2.16[a]	2.35	
2	1.19	.036	1.19	5.92	12.27	2.03[a]	1.81	0.400	2.58	27.65	16.50	2.46[a]	1.71	
3	1.83[a]	.301	3.95	76.70	10.48	2.57[b]	3.77[b]					4.06[b]	5.52[b]	57.06
4	1.22	−.036	−1.68			1.21	2.44[a]	0.891	3.08	30.82	15.05	2.07[a]	1.74	
5	3.04[b]					2.74[b]	2.47[a]	0.821	1.78	31.25	27.27	2.34[a]	1.26	
6	4.59[b]					3.13[b]	10.94[b]					6.76[b]	3.78[a]	1.00
7	13.95[b]					8.56[b]	4.19[b]					2.97[b]	0.55	
8	3.94[b]					3.82[b]	4.90[b]					4.38[b]	4.59[a]	29.60
9	1.25	.071	3.43	1.00	—	0.95	3.19[b]	0.704	3.70	25.16	10.03	2.16[a]	3.66[a]	1.00
10	2.46[a]	.408	6.43	115.84	15.63	5.46[b]	14.60[b]					13.71[b]	8.29[b]	132.00
11	6.49[b]					7.66[b]	12.74[b]					11.84[b]	4.52[b]	4.71
12	2.07	.129	2.95	62.38	16.82	2.13[a]	3.36[b]					2.94[b]	2.59	
13	1.83	−.056	−1.56			1.15	2.56[a]	1.840	3.87	28.57	11.18	1.61	2.12	
14	3.31[b]					6.49[b]	4.35[b]					7.20[b]	7.79[b]	22.77
15	3.60[b]					3.10[b]	1.46	0.377	2.64	8.51	4.61	1.75	3.25[a]	24.56
16	8.42[b]					6.50[b]	3.08[b]					3.10[b]	2.67[a]	7.26
17	2.18	.033	1.03	95.26	108.04	2.73[b]	5.12[b]					4.60[b]	0.65	
18	9.37[b]					6.40[b]	2.27[a]	0.750	4.34	19.13	8.28	2.30[a]	1.01	
19	1.54	.124	3.63	1.00	—	1.39	2.93[a]	0.677	4.32	2.64	0.73	2.19[a]	5.87[b]	2.40
20	3.87[b]					3.10[b]	5.36[b]					3.96[b]	5.38[b]	132.00
21	0.67	.156	3.03	132.00	86.76	0.76	4.27[b]					2.81[b]	2.76[a]	124.47
22	7.28[b]					4.67[b]	2.32[a]	0.867	3.32	30.08	14.57	1.84	1.41	
23	8.22[b]					5.13[b]	3.21[a]	0.387	1.37	5.32	3.80	2.27[a]	1.05	
24	18.67[b]					9.96[b]	2.34	0.921	6.31	4.26	1.04	1.78	14.28[b]	1.89
25	11.05[b]					11.25[b]	2.52	0.856	5.05	3.67	1.11	6.63[b]	9.43[b]	3.23
26	20.96[b]					17.86[b]	2.73[a]	0.868	4.67	3.29	1.05	7.60[b]	10.94[b]	3.07
27	1.31	.097	4.32	5.79	5.89	1.71	13.36[b]					7.80[b]	8.45[b]	63.40
28	2.68[a]	.099	3.97	17.94	7.95	1.43	12.79[b]					6.44[b]	6.32[b]	90.25
29	2.66[a]	.072	4.03	1.00	—	1.69	3.59[a]	0.861	4.73	20.83	8.11	2.15[a]	6.97[b]	21.67
30	0.70	.066	4.66	1.00	—	2.43[a]	4.73[b]					4.50[b]	8.62[b]	23.77
31	4.51[b]	.126	4.10	27.90	6.32	2.63[a]	12.50[b]					6.62[b]	8.17[b]	132.00
32	4.82[b]					3.15[b]	6.71[b]					4.10[b]	7.86[b]	31.03
33	5.51[b]					3.29[b]	3.28[b]	0.393	1.78	1.55	1.33	2.02	4.09[b]	30.59
34	4.06[b]					3.01[b]	3.11[b]	0.799	5.30	23.57	7.99	2.41[a]	4.59[b]	6.51
35	8.62[b]					5.18[b]	3.39[b]	−0.708	−1.22			2.20[a]	1.26	
36	0.32	.078	2.88	22.82	8.93	0.77	2.85[a]	0.762	3.11	63.15	24.45	2.22[a]	3.45[a]	25.49
37	1.54	.119	4.14	13.05	5.79	2.09[a]	4.83[b]					4.00[b]	6.91[b]	10.29
38	2.00	.097	2.50	6.61	10.04	1.30	4.97[b]					3.13[b]	2.92[a]	4.59
39	6.48[b]	−.021	−0.45			2.11[a]	7.81[b]					2.83[b]	0.96	
40	1.41	.155	1.35	118.24	22.99	1.57	4.63[b]					3.61[b]	0.48	

F_1—F-statistic for the hypothesis that the restrictions in the level form relative to the unrestricted form are valid.
F_2—F-statistic for the hypothesis that the restrictions in the level form relative to the general form are valid.
F_3—F-statistic for the hypothesis that the restrictions in the change form relative to the unrestricted form are valid.
F_4—F-statistic for the hypothesis that the restrictions in the change form relative to the general form are valid.
F_5—F-statistic for the hypothesis that the coefficients of the price expectations variables (Q_t and Q_{t-1}) in the general form are zero.
$\hat{\lambda}$—Estimate of λ, the sum of the PDL coefficients.
t_λ—t-statistic for $\hat{\lambda}$.
$\hat{q}$—Estimate of q.
SE_q—Estimated standard error for $\hat{q}$.
[a] Significant at the 5% level.
[b] Significant at the 1% level.

and change forms have been rejected. It tests for the significance of the aggregate price expectations variable in an equation that is less likely to be dynamically misspecified. This test has three degrees of freedom in the numerator, one each for Q_t and Q_{t-1} and one for q. When Q_t and Q_{t-1} are jointly significant at the 5% level, the estimate of q is also presented in table 3. This is the estimate of q under the most general dynamic specification.

It will be useful to discuss the results in table 3 before considering table 4. Consider the level versus change forms first. The level form is rejected in 20 of the 40 cases, and the change form is rejected in 21 of the 40 cases. For 8 products both forms are rejected, and for 7 products both

TABLE 4.—RESULTS USING THE SECOND EXPECTATIONS HYPOTHESIS

	Level Form						Change Form						General Form	
Product	χ_1^2	$\hat{\lambda}$	t_λ	$\hat{r}$	SE_r	χ_2^2	χ_3^2	$\hat{\lambda}$	t_λ	$\hat{r}$	SE_r	χ_4^2	χ_5^2	$\hat{r}$
1	51.81[b]					59.12[b]	19.34[b]					24.99[b]	2.95	
2	4.48	.025	1.06	12.0	36.23	13.70	7.76	0.385	2.17	8.9	9.83	20.09[a]	0.80	
3	21.01[b]					38.19[b]	24.05[b]					42.67[b]	4.30	
4	10.34	.020	0.61			14.74	18.09[a]	0.564	3.07	1.0	—	22.36[a]	1.37	
5	21.51[b]					29.47[b]	13.40[a]	0.950	2.88	1.0	—	20.41[a]	4.40	
6	20.40[b]					25.01[b]	39.74[b]					44.72[b]	10.64[a]	1.0
7	60.86[b]					67.61[b]	13.82[b]					20.02[b]	0.92	
8	9.30	.051	1.84	1.9	15.30	20.64[b]	15.07[b]					30.20[b]	6.26	
9	5.87	.063	3.60	9.6	13.24	7.98	28.42[b]					28.98[b]	15.06[b]	11.2
10	11.58[a]	.113	2.16	1.9	8.13	53.57[b]	27.05[b]					70.27[b]	11.24[a]	3.0
11	64.47[b]					136.84[b]	55.16[b]					92.16[b]	12.93[b]	12.0
12	11.22[a]	.074	2.99	1.0	—	20.64[b]	31.54[b]					33.91[b]	12.40[b]	1.0
13	9.21	.071	1.78	11.5	42.71	9.27	15.31[b]	1.705	4.27	1.7	0.58	15.04	7.00	
14	8.25	.125	3.44	6.2	8.85	45.95[b]	10.14	0.947	4.34	2.9	0.85	46.48[b]	21.27[b]	11.0
15	15.57[b]					22.95[b]	12.03[a]	0.262	1.61	1.7	1.33	17.85[a]	7.57	
16	40.23[b]					54.72[b]	14.55[a]	0.292	2.29	7.9	11.45	27.33[b]	8.08[a]	2.9
17	17.65[b]					25.89[b]	34.94[b]					46.14[b]	1.33	
18	38.32[b]					37.03[b]	5.59	0.953	4.77	3.0	1.55	11.26	3.98	
19	2.83	.114	3.70	1.8	3.32	10.16	22.79[b]					28.79[b]	19.11[b]	1.9
20	22.49[b]					33.78[b]	17.74[b]					26.15[b]	11.33[a]	1.2
21	1.60	.103	1.99	7.9	12.99	10.59	7.12	0.826	3.68	6.9	6.63	13.92	6.63	
22	35.65[b]					31.89[b]	15.48[b]	0.635	3.57	9.9	11.66	16.89[a]	6.20	
23	34.00[b]					39.02[b]	14.69[b]					19.99[b]	1.06	
24	19.21[b]					21.66[b]	11.07	0.949	3.86	3.9	2.65	13.27[a]	18.26[b]	3.0
25	32.37[b]					66.68[b]	8.25[a]	1.402	4.32	7.9	4.77	35.73[b]	24.23[b]	1.9
26	58.12[b]					103.68[b]	8.53[a]	1.206	3.78	9.9	6.91	41.91[b]	19.94[b]	12.0
27	4.14	.085	4.28	1.9	4.17	7.58	37.38[b]					43.45[b]	22.71[b]	2.9
28	6.65	.075	3.33	1.9	5.90	11.76	33.64[b]					36.55[b]	16.15[b]	11.7
29	2.98	.075	3.61	9.0	17.53	5.50	13.22[b]	0.738	3.37	1.8	0.67	16.52[a]	17.64[b]	1.9
30	1.77	.062	4.78	12.0	14.16	15.18[a]	13.89[b]					24.04[b]	22.62[b]	3.0
31	6.65	.059	2.84	1.9	7.60	12.72[a]	27.02[b]					33.47[b]	14.49[b]	8.0
32	4.19	.062	3.39	11.3	13.59	7.52	20.16[b]					24.55[b]	14.66[b]	1.0
33	26.18[b]					26.58[b]	17.86[b]					19.29[b]	12.94[b]	1.9
34	19.61[b]					23.28[b]	30.45[b]					30.61[b]	19.94[b]	4.9
35	40.64[b]					42.28[b]	14.73[b]	−0.291	−1.34			17.57[a]	3.31	
36	2.15	.039	2.80	1.0	—	6.66	14.01[b]	0.505	3.02	1.0	—	17.61[a]	8.69[a]	1.0
37	5.35	.073	4.35	2.9	7.13	14.29	35.96[b]					40.29[b]	27.34[b]	1.5
38	10.41	.090	3.00	5.9	16.31	10.83	26.99[b]					27.98[b]	11.57[b]	5.9
39	10.55	.005	0.23			13.25	20.79[b]					24.08[b]	2.11	
40	7.56	.057	1.06	9.0	18.48	16.83[a]	29.94[b]					41.81[b]	4.44	

Notes:
χ_1^2—χ^2-statistic for the hypothesis that the restrictions in the level form relative to the unrestricted form are valid.
χ_2^2—χ^2-statistic for the hypothesis that the restrictions in the level form relative to the general form are valid.
χ_3^2—χ^2-statistic for the hypothesis that the restrictions in the change form relative to the unrestricted form are valid.
χ_4^2—χ^2-statistic for the hypothesis that the restrictions in the change form relative to the general form are valid.
χ_5^2—χ^2-statistic for the hypothesis that the coefficients of the price expectations variables (R_t and R_{t-1}) in the general form are zero.
$\hat{\lambda}$—Estimate of λ, the sum of the PDL coefficients.
t_λ—t-statistic for $\hat{\lambda}$.
$\hat{r}$—Estimate of r.
SE_r—Estimated standard error for $\hat{r}$.
[a] Significant at the 5% level.
[b] Significant at the 1% level.

are accepted. It thus seems at first glance that both forms do about the same. However, for all 7 of the products for which both are accepted, the level form has a better fit (and thus a lower F-statistic) than does the change form. If one counts these 7 cases as a rejection for the change form, the change form is then rejected in 28 of the 40 cases compared to only 20 for the level form. There is thus at least a slight edge in favor of the level form, although only slight.

The estimate of λ is significant[9] in 14 of the 20 cases in which the level form is accepted, and it is significant in 15 of the 19 cases in which the

[9] The estimate of λ will be said to be significant if its t-statistic is greater than two in table 3.

change form is accepted. For the general form the aggregate price expectations variable is significant at the 5% level or greater in 26 of the 40 cases. This is thus fairly strong evidence in favor of the hypothesis that aggregate price expectations matter. In over half the cases the price expectations variable is significant.

The estimates of q vary considerably across the products, and in general they have large standard errors. The data clearly seem better at tacking down the sum of the PDL coefficients (λ) than they do at choosing the lag length. The average of the 26 values of $\hat{q}$ in the last column in table 3 is 37.95, which says that on average firms look back about 38 months in forming their expectations of the future values of the aggregate price level.

The results for table 4 were obtained in a similar manner as they were for table 3, where χ^2-tests are used in place of F-tests.[10] The results in table 4 are qualitatively similar to those in table 3. The level form is rejected in 19 of the 40 cases, and the change form is rejected in 24 of the 40 cases. These compare to 20 for the level form and 21 for the change form in table 3. For 10 products both forms are rejected, compared to 8 in table 3, and for 7 products both are accepted, the same as in table 3. In all 7 cases in which both are accepted, the level form has a better fit (and thus a lower χ^2 value) than the change form has. There is thus again slight evidence in favor of the level form.

The estimate of λ is significant in 14 of the 21 cases in which the level form is accepted, and it is significant in 14 of the 16 cases in which the change form is accepted. For the general form the aggregate price expectations variable is significant at the 5% level or greater in 23 of the 40 cases. Again, as in table 3, this is fairly strong evidence in favor of the hypothesis that aggregate price expectations matter.

The estimates of r in table 4 range from 1.0 to 12.0, the minimum and maximum allowed. The average of the 23 estimates of r in the last column is 4.6, which says that on average the horizon of firms regarding the effect of aggregate price expectations on current behavior is about 5 months.

As noted in section III, the present results are based on the assumption that agents make decisions for month t based only on information through month $t-1$. If it is instead assumed that information through month t is available for month t's decisions, then the various right hand side variables should be unlagged rather than lagged one month. To examine this assumption, the equations behind table 3 were estimated in the unlagged case (including PA not lagged).[11] The results were still supportive of the use of the aggregate price expectations variable, although not quite as strongly. For the fifth F-test, for example, 21 instead of 26 equations had a significant price expectations variable at the 5% level or greater. The slightly weaker results may cast some doubt on the assumption that agents know month t's information for month t's decisions.

VI. Conclusion

The results in tables 3 and 4 strongly support the hypothesis that aggregate price expectations affect individual pricing decisions. Even under the most general dynamic specification of the price equation, the expectations variables are significant in over half the cases. The results do not discriminate very well between the level and change forms of the price equation. There is a slight edge for the level form, but only slight. The lag length for the first expectational hypothesis is not estimated precisely; its average value for the

[10] When the rational expectations hypothesis is used, the objective function that is minimized is $v'ZM^{-1}Z'v$, where v is the vector of error terms, Z is the matrix of instrumental variables, and M is an estimate of $\lim(1/T)E(Z'vv'Z)$. See Andrews and Fair (1992) for a discussion of this, where the formula for the covariance of the parameter estimates, including the estimate of r, is also presented.

Regarding the χ^2 test, let S^* be the value of the objective function in the unrestricted case, and let S^{**} be its value in the restricted case. Then $(S^{**} - S^*)/T$ is asymptotically distributed as χ^2 with k degrees of freedom, where k is the number of restrictions. A general proof of this is in Andrews and Fair (1988). In performing this test the value of M must be the same for both estimates. This meant that for the results in table 4 the level form had to be estimated twice, once using the estimate of M computed from the residuals from the unrestricted form and once using the estimate of M from the residuals from the general form. Likewise, the change form had to be estimated twice. Also, for the fifth χ^2-test the general form without R_t and R_{t-1} included had to be estimated using the same M matrix that was used to estimate the general form with the two variables included.

[11] It seems unlikely that simultaneity bias is much of a problem for the unlagged estimates because each product is such a small fraction of total output in the economy or even of total output in the relevant industry. In other words, it seems unlikely that there is much correlation between the error term in any one price equation and the contemporaneous explanatory variables. Therefore, no attempt was made to correct for possible simultaneity bias for these estimates.

most general form is 37.97 months. The lead length for the second (rational) expectational hypothesis is also not estimated precisely; its average value for the most general form is 4.6 months.

As noted in the Introduction, the current results provide some micro evidence for the common finding of price inertia in the estimation of aggregate price equations. Gordon (1982), for example, finds a mean lag of 5.7 quarters (based on the use of a total lag length of 20 quarters) for an aggregate price equation estimated using postwar data. This result is not out of line with many of the estimated lag lengths in table 3. The current results, of course, indicate that one of the main reasons for the finding of aggregate price inertia is the price expectations effect.

As noted in section IV, it would be interesting in future work to see if tests similar to those performed in this paper could be performed using individual firm data. The better the data, the less likely it is that the price equation has omitted variables that are correlated with the aggregate price expectations variable, thus biasing the results in favor of the expectations hypothesis.

In future work with individual firm data it might also be of interest to test the first (naive) expectational hypothesis against the second (rational) one. No attempt was made to test the two hypotheses in this paper. Collinearity problems are likely to be severe in carrying out this test, and the main conclusions of this paper are not sensitive to the particular hypothesis used.[12]

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[12] The rational expectations hypothesis is tested in Fair (1993) using aggregate data, and the results provide only mild support for it.