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A MONTHLY ANALYSIS OF CONSUMER DEMAND IN THE UNITED STATES

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A MONTHLY ANALYSIS OF CONSUMER DEMAND IN THE UNITED STATES*

Since consumer spending accounts for some two-thirds of the Gross National Product of the United States, the success of policies concerning economic stabilization, allocation, distribution, and growth require an understanding of the behavior of consumers. A long tradition exists in economics of estimating consumer demand equations, which summarize the aggregate structure of consumer behavior. Most consumer demand work with time series data has relied on annual data and in a few cases quarterly data, but only rarely has monthly data been applied and never across a broad range of commodities. Both government and business increasingly require information about short-run aspects of consumer expenditure, which annual and even quarterly analysis cannot provide. A knowledge of the intra-year structure and dynamics of consumer expenditure should improve the design of policies to deal with major current economic problems such as short duration cyclical movements and inflation. There is a need to understand short-term movements in the demand for the products of specific sectors of the economy to manage inventories and production schedules and to anticipate shortages.

This study estimates monthly consumer demand equations for fifteen major commodities based on data for 1947-1972. The equations are estimated within the framework of the Nerlove partial adjustment model. By extrapolating from retail sales data, it was possible to generate the consumer expenditure data needed to combine with published monthly series on income and prices to estimate a series of consumer demand equations. The commodity groups studied accounted for 53 percent of total consumer expenditure in 1965 and range from electricity to alcoholic beverages. The analysis of monthly data can provide insights into consumer behavior, which are obscured by relying on annual data alone. Consumer expenditure analysis based on short-term data also offers certain econometric advantages over annual data. A comparison is made with the annual equations in order to draw a number of significant conclusions about the dynamics of consumer behavior and answer some questions posed by the preceding literature concerning the effect of aggregation over time on the estimated structure of demand.

ADVANTAGES OF MONTHLY EQUATIONS

Equations based on monthly data offer a number of advantages over those based on an analysis of annual data:[1/]

1. Monthly data have the obvious advantage of presenting a much larger sample of observations during a given period of time. The post-war period of this study, 1947-1972, contains 26 annual, 104 quarterly, and 312 monthly observations. Larger samples are especially crucial in the estimation of distributed lag models because in many cases only the large-sample properties of the estimates of equations containing lagged endogenous variables are known. However, monthly series do not contain twelve times as much information as an annual series.[2/]

2. The greater the number of years covered by the analysis, the more likely it is that significant structural changes will have occurred in the economy, which will distort the estimated relationships. The struc-

tural stability of demand is greater the shorter the period studied. With monthly data, intervals as short as five years, which contain 60 observations could be analyzed to insure structural stability. By comparing the estimates based on five year periods, structural shifts in demand could be studied. Monthly analysis could possibly provide better forecasts, because projections could be based on only a very recent period which enhances the similarity between the sample period and the future.

3. Single-equation estimation is theoretically defensible only if the system is recursive. The assumption of a recursive system becomes more realistic as the time unit of analysis grows shorter. In addition, the assumption of the price variable as the predetermined factor is more appropriate with monthly data rather than annual data. During a short-term period such as a month, producers can supply the quantity demand at a set price. The short-run supply is flexible due to inventories. Because of inventories, a case can be made that with monthly data price not quantity is the predetermined variable even for food.

4. Monthly analysis affords the opportunity to gain new insights into short-term consumer behavior and the dynamics of consumer expenditure. With short-term data, certain hypotheses regarding consumer demand can be tested such as the effect of aggregation over time on the adjustment process and the effect of the length of run on the price and income elasticities.

THE MODEL

In selecting a model for this investigation, a dynamic formulation which internally generates short and long-run parameters was desired. The model should have an empirical record of providing good estimates over a wide range of commodities and should offer some flexibility with regard to functional form. A fairly simple model was desired, so that various estimating techniques to alleviate problems of autocorrelation could be applied without giving rise to an unduely complicated estimation situation. Based on these consideration, the Nerlove partial adjustment model was chosen.

The partial adjustment model is specified as follows:

$$(1)\quad \bar{q}_t = a_o + a_1 y_t + a_2 p_t$$

$$(2)\quad q_t - q_{t-1} = \gamma(\bar{q}_t - q_{t-1})$$

where $\bar{q}_t$ is the long-run equilibrium quantity demanded or its logarithm, y_t is current income or its logarithm, and p_t is the relative price or its logarithm. In equation (2), q_t is the actual quantity purchased and (γ) is the coefficient or elasticity of adjustment depending on whether logarithms are utilized or not. In a given period, consumers adjust their current demand towards the equilibrium level by some constant proportion (γ) of the difference between the equilibrium quantity and the quantity demanded in the preceding period. If logarithms are utilized, a_1 and a_2 are the long-run income and price elasticities. The substitution of equation (1) into (2) and solving for q_t yields:

$$(3)\quad q_t = a_o\gamma + (1-\gamma)q_{t-1} + a_1\gamma\ y_t + a_2\gamma\ p_t$$

The addition of an error turn to equation (3) yields the estimating equation. In equation (3), $a_1\gamma$ and $a_2\gamma$ are the short-run elasticities or coefficients of income and price. The relation between the short and long-run parameters is determined by (γ).[3/]

In this analysis, the variables are specified as follows:

q_t = per capita consumption expenditure on the commodity in question in 1967 dollars.

y_t = per capita personal income in 1967 dollars.

p_t = relative price index for the commodity in question with a 1967 base.

All the monthly data series are seasonally adjusted.[4/] The needed data are available in U. S. government publications.[5/]

DATA

Monthly personal income figures and monthly consumer price indices for many major commodities are available. By extrapolating from retail sales data, consumer expenditure data can be generated for fourteen commodities.[6/] Retail sales are given by store type, whereas consumer expenditure data on a commodity basis are desired. For example, monthly retail sales by shoe stores are given, but the desired data is personal consumption expenditure on shoes. However, all shoes are not sold through shoe stores. The transformation is made by deriving the ratio between the expenditure and sales figure for corresponding categories for each year, since both annual sales and expenditure data are available. The conversion ratio ($^a/b$) is obtained by dividing (a) - consumer expenditure by commodity by (b) - the equivalent store type retail sales. By applying this conversion ratio to the monthly retail sales data, monthly consumer expenditure data could be derived. The ratios transform store type sales into consumer expenditure data by commodity. This procedure assumes that the annually derived conversion ratio is a satisfactory proxy for the unknown monthly ratio.[7/]

The price data were another problem, since the monthly series are neither complete for several commodities nor do the categories always conform with the expenditure series. When the price data were only available quarterly for some of the early years for a few commodities, the series were completed by simple linear extrapolation between the quarterly prices. Price data for some of the other commodities were not collected until some time after 1947. Therefore, the equations in Table 1 for alcoholic beverages (13) and purchased meals (14) cover 1953-1972, and gasoline (15) only covers 1957-1972. All the other equations are based on 312 monthly observations and 26 annual observations. The annual data series were derived by aggregating the monthly series, so the results are comparable.

EMPIRICAL RESULTS

The estimated equations based on monthly and annual data for fifteen commodities are presented in Table 1. The logarithmic functional form of the partial adjustment model provides highly satisfactory results for all but two commodities, purchased meals (14) and gasoline (15). The results for (14) and (15) are based on the linear form of the equation. Overall, both the monthly and annual results are very good by the usual statistical criteria of explained variance (R^2) and statistical significance (t statistic).[8/] The results are, in general, satisfactory in terms of the level of autocorrelation. The high degree of explanation achieved by the monthly equations is quite remarkable. Overall, the values of the R^2 obtained are about equally as good with monthly data as with annual data. Although the monthly R^2 is markedly lower than the annual value for shoes (6) and alcoholic beverages (13), the R^2 based on monthly analysis is higher for automobiles (2), furniture (8), food (11), auto parts (12), and purchased meals (14). The results in many cases could probably be improved by altering the specification and including additional variables. The purpose of this analysis, however, was to apply as consistent a specification as possible across a broad range of commodities. The next several sections discuss specific aspects of the empirical results.

Problem of Autocorrelation

Serial correlation posed a potentially troublesome problem in this analysis because of the presence of a lagged dependent variable in the estimating equation and because monthly data series are likely to exhibit greater serial correlation than annual data. If serial correlation is present and the equation contains a lagged endogenous variable, ordinary least squares (OLS) leads to estimates of the parameters which are biased and inconsistent. The Durbin-Watson statistic is also biased when a lagged endogenous variable is present. In addition, the shorter the time unit of analysis, the greater the correlation one would expect to find between a variable and its past values. Since the residual term contains the net effect of many small factors which are omitted, it should tend to suffer from more serial correlation the shorter the unit time period. 9/

Two factors reduced the autocorrelation problem in this analysis to an acceptable level. First, the dynamic specification of the model goes a long way towards eliminating the problem of serial correlation in the data series. The model internally accounts for the correlation of current quantities and lagged quantities through the adjustment process. In some preliminary testing, the logarithmic partial adjustment model proved a much better specification than a static model, which was reflected by significantly less autocorrelation in the disturbance terms. Second, the Cochrane-Orcutt iterative procedure was used to obtain alternative coefficient estimates to those generated by OLS.[10/] The results from the Cochrane-Orcutt procedure are presented for three of the annual equations and eight of the monthly ones. Durbin's h statistic was utilized as an indication of the presence of autocorrelation.[11/] In a few cases, utilizing the Cochrane-Orcutt estimation technique substantially reduced the goodness of fit of an equation as reflected by the R^2, so the OLS results are presented even though the h statistic indicates the presence of serial correlation. This situation could possibly arise if the autocorrelation was predominately other than simply first-order serial correlation, which is all Cochrane-Orcutt corrects for.

The Adjustment Process

The elasticity of adjustment (γ) measures the inertia in consumer adjustment to the new equilibrium level. The length of the adjustment period (n) is derived by solving $(1 - \gamma)^n \leq .05$. Since full adjustment occurs only when $n = \infty$, the period derived is for 95 percent or more adjustment.

The effect of aggregation over time on the magnitude of the adjustment elasticity or coefficient gave rise to a considerable discussion in the literature. An article by Ironmonger (1959) argued that the Nerlove model was producing unrealistically long estimates of the lags in consumer behavior. Nerlove (1959) responded that substantially faster rates of adjustment would be obtained the more narrowly defined the commodities and the shorter the time unit of analysis. Utilizing numerical examples, Nerlove showed that estimated coefficients of adjustment based on annual time series usually understate the "true" parameters; hence the speed of adjustment is much faster than annual data indicate. Since the coefficients of adjustment based on annual data may be seriously in error, he suggested that "where possible, demand analysis should be based on quarterly or even monthly data".[12/] Mundlak (1961) provided a more rigorous analysis of the relationship of the annual, quarterly, and monthly parameter of adjustment. Cochrane and Tomek (1962) in some empirical work with meats using quarterly data found that the adjustment period for many foods is probably less than one year, so annual data is inappropriate. Monthly or quarterly observations are necessary. The work of Ladd (1964) with several food groups found that significant lags were more likely to arise when annual data was utilized, rather than with quarterly or monthly data. However, Ladd's results were somewhat inconclusive. The statistical quality of his results was poor and his quarterly and monthly estimates indicated one relationship and his quarterly and annual estimates indicated an opposite relationship.

This analysis is the first to test the effect of the time unit of analysis on the adjustment process over a broad range of commodities. Comparing the monthly and annual results for the 95 percent adjustment period in Table 1, the difference in the estimated speed of adjustment of consumers to the new equilibrium is remarkable. Although for every commodity except shoes (7) the estimated annual parameter of adjustment (γ) is larger than the monthly (γ), when translated into an adjustment period the annual analysis usually grossly overstates the length of the lags involved in consumption. The adjustment period averaged over the fifteen commodities is 9.01 years with annual data and only 19.86 months or 1.65 years with monthly data. For example, the period for 95 percent adjustment for clothing and shoes (3) is indicated as 11.32 years with annual data, but as only 25.61 months or 2.13 years with monthly data.

The monthly results indicate a significantly faster adjustment process than the annual data for every commodity, except for homefurnishings (7) and furniture (8), which will be discussed further in a separate section. For homefurnishings (7), an adjustment period of 4.83 months is indicated with monthly data and annual analysis indicates a period of less than a year. For furniture (8), the monthly figure is 6.29 months and the annual value is zero, meaning less than a year also. The only other estimates which are even approximately similar are for automobiles (2), the annual value is 2.89 years and the monthly 29.91 months or 2.48 years. The longest lags are indicated for electricity (1), 30.75 years for annual and 63.16 months or 5.26 years for monthly data. However, the parameter of adjustment is biased downwards and thus the adjustment period is overstated if a relevant variable is omitted which is positively serially correlated.[13/] Taste changes, which are expressed as a trend, are such a variable.[14/] And the trend factor is strong in the demand for electricity.[15/] Positive autocorrelation of the errors may be biasing various of the other estimates of (γ) downwards also, leading to overly long estimated lags. On the other hand, the estimates of (γ) are biased upwards if negative serial correlation is present.[16/]

The Role of Price

In Table 1, the price variable yields statistically significant results at the five percent level for 11 of the 15 annual equations and for 14 of the monthly equations. For the one other monthly equation, shoes (6), the t statistic indicates the price term is significant at the 10 percent level. These results are remarkable and important. Price plays a central role in the theory of consumer behavior, yet few empirical studies of consumer demand have succeeded in measuring the effects of price changes. Previous demand analyses concerned with a broad range of commodities, such as the work of Houthakker and Taylor (1970), have given price a very insignificant role in consumer behavior. In the Houthakker and Taylor study, price is only statistically significant at the five percent level in equations for 30 of the total 82 commodities. And the 30 equations which include a significant price term apply primarily to services and the more narrowly defined commodity categories.

The strong results concerning the effects of prices in this analysis can best be attributed to three factors. First, the dynamic specification and utilization of the logarithmic functional form. In some preliminary tests, the partial adjustment model gave much better fits and much stronger results for the price term than a static specification.

The use of logarithms also produced an improvement for most of the commodities. Second, the monthly series provide twelve times the number of observations and greater price variation than the annual series. The role of price is decreased by the temporal aggregation of data. Third, the last several years in the data series contain the kind of independent movement among the variables necessary to obtain good estimates with multiple regression analysis. A major problem with time series data is that the data are so strongly dominated by trends that multicollinearity becomes a severe problem because of insufficient independent variation. Also relative prices frequently present too little variance to be picked up by regression analysis. The statistical quality of these results is far better than Houthakker and Taylor's (1970) post-war equations for 1947-1964. The period 1965-1972 witnessed appreciable variation in the growth rate of real per capita income. In addition, inflation had an uneven impact. Relative prices for many commodities had substantial movement. This period provides the requisite diversity of movement of relative prices and income. The economic disturbances since 1972 add even a richer source of potential information about the effects of price and income changes on consumer expenditure patterns. Houthakker (1976) obtained good statistical results with a significant price term in estimating food demand with quarterly data for 1953-75.

The degree of responsiveness to price changes is at the very core of questions concerned with the performance of the market system.[17/] A low price responsiveness has disturbing overtones for the stability of the economic system and for economic policy. Low price elasticities of demand boost the inflationary pressures in the economy, since excessive changes in price are necessary to reduce excess demand. Prices also become relatively ineffectual instruments of economic policy, if consumers do not exhibit a prompt response to changing prices. If prices cannot handle allocation problems without creating undue stresses, then controls outside the market mechanism such as rationing will be considered.

This analysis, which finds the price effect to be significant even in a period as short as a month across a broad range of commodities, is very reassuring. These results indicate price changes should be an effective means of bringing demand into balance with supply. The estimated long-run elasticity of demand is greater than one for electricity (1), automobiles (2), shoes (6), drugs (10), auto parts (12), purchased meals (14), and gasoline (15) with monthly data. Positive autocorrelation of the residual though, tends to bias the long-run estimate of the price elasticity upwards.[18/] The other long-run elasticities are usually of a substantial magnitude, although they indicate demand for those commodities is inelastic with regard to price. The estimated price elasticities in Table 1 show a flexibility in our economic system to adapt to external shocks and to respond to price as a policy instrument.

The Effect of the Length of Run on the Elasticities

The effect of the length of run on the magnitude of the elasticities, particularly for price changes, has given rise to considerable discussion. The viewpoint traditionally has been that the elasticity of demand for a good increases as the period of time that the price change has been in effect increases.[19] The own elasticity of demand is assumed to be smaller in the short-run than in the long-run.[20] However, some recent work has argued that the long-run elasticity of demand may be smaller than the short-run elasticity. Tweeten (1967), for example, obtained long-run demand elasticities for food which were smaller than the short-run elasticities. A number of others found similar results for other commodities. Shepherd (1963), Manderscheid (1964) and Pasour and Schrimper (1965) supported the idea that the elasticity of demand initially becomes smaller in absolute terms and then becomes larger as the adjustment period grows longer. In other words, own price elasticity has a u-shaped pattern as a function of the length of run.

This analysis provides the opportunity to examine the effect of the length of run on the price and income elasticities over a broad range of goods. And very importantly, the effect of the time dimension on the measured elasticities can be directly observed by aggregating the monthly data series rather than relying solely on a model that generates short and long-run estimates. The problem is that the existing dynamic models frequently place restrictions on the relationship of the short and long-run parameters. The long-run coefficients in the Nerlove model must necessarily be greater than the short-run estimates for values of (γ) greater than zero and less than one.[21] Additionally, most past studies have used annual data and in a few cases quarterly data, which they have then referred to as the short-run. By utilizing monthly data, we can observe a truly short-run period.

Looking at the short-run elasticities in Table 1, the income elasticities based on monthly data are smaller than the annual ones for every category except for alcoholic beverages (13), where the opposite holds. The monthly values are quite small relative to the annual elasticities, less than one-fifth their size, for automobiles (2), drugs (10), and auto parts (12). Initial response to income changes is slow in these goods. The monthly estimates are greater than half the annual values for electricity (1), men's clothing (4), women's clothing (5), and homefurnishings (7). Initial response is quite rapid for these commodities. For the price elasticities, again only for alcoholic beverages (13) is the monthly value greater in absolute terms than the annual value. The monthly price elasticities are highest relative to the annual values, at least half their size, for electricity (1), shoes (6), and homefurnishings (7). The monthly values are less than one-fifth the annual values for automobiles (2), drugs (10), and auto parts (12).

Examining the long-run elasticities, the monthly and annual data produce remarkably similar estimates for most commodities. For the long-run income elasticities, the monthly and annual values are substantially different for only electricity (1), men's clothing (4), and shoes (6). The largest differences in the long-run price elasticities from monthly and annual data occur for men's clothing (4), shoes (6), auto parts (12), and alcoholic beverages (13). Overall, these results tend to support the conclusion that the long-term elasticities depend only on the equilibrium level of demand. The short-term income and price parameters vary with the rate of adjustment and length of the data unit.[22/]

The simple Nerlove model, however, restricts income and price to the same adjustment process.[23/] If the lag structure of the income and price response differ, this specification will distort the results.

Greater bias is produced in the short-term elasticities than in the long-term estimates.[24/] Although Martin (1967) presented a specification which allows for a separate lag distribution for income and price, his specification involves so many lagged values of the independent variables that serious collinearity problems arise in its estimation.[25/]

Results for the Durables

The results given in Table 1 seem somewhat implausible for some of the durables. Previous work, particularly that of Stone and Rowe (1958 and 1960) and common sense would make us expect to find the longest lags showing up for the durables. Adjustment should be slow for durables and relatively quick for nondurables. In fact, the shortest periods of adjustment occur for homefurnishings (7) and furniture (8). The value of (γ) is also relatively large; hence the period of adjustment relatively short for automobiles (2) and appliances (9). In the equations for durables, relatively large estimated short-run responses to price and income lead to relatively smaller differences between the short and long-run elasticity estimates than for the non-durables. This situation means that the parameter of adjustment (γ) will be relatively large, and infers a fast adjustment process. Commodities (7) and (8) with annual data represent the extreme case in which the estimated short and long-run elasticities are equal, which means (γ) must be equal to one and implies adjustment to the new equilibrium in a shorter period than the annual time unit of analysis.[26/]

If the short-run elasticities are over-estimated, too fast an adjustment process will be indicated. This situation may arise in this analysis for the durables, because current income, not some measure of permanent income, is used as a variable. If the consumer "saves" part of his transitory income in the form of purchasing durables as Friedman argues (1957), this factor helps account for the high estimated short-run income elasticities for durables. Small changes in current income can have a large effect on durable spending. And as pointed out in the previous section, the same lag structure must apply to the income and price response in the basic Nerlove model. Other studies have avoided this problem by using total consumption expenditure, which serves as a proxy measure of permanent income.[27/] However, this variable is not available on a monthly basis. In addition, Westin (1975) has shown that due to discretionary replacement demand, the short-run income elasticity is normally biased upwards and the long-run price elasticity is underestimated for durables, which also would bias (γ) towards one and overstate the speed of the adjustment process.

CONCLUSIONS

Since consumer decisions regarding the purchase of most commodities are made on a considerably more frequent basis than once a year, studies based on annual data as the shortest time unit of analysis will obscure crucial information about the structure of consumer demand in the short-term. This research shows that monthly analysis offers certain econometric and conceptual advantages over analysis with annual data and the problem of serial correlation can be reduced to a tolerable level. Specifically, annual analysis provides grossly overstated estimates of the length of the lags involved in consumption. In addition, this analysis indicates that the price and income elasticities are a monotonically increasing function of the length of run. However, this area deserves further examination with a model which allows a separate lag structure for income and prices. Also, for further research, quarterly and semi-annual data could be aggregated from the monthly series and the time path of an income or price effect can be directly observed. Finally, the results of this study provide strong evidence that prices still play a key role in our economy in inducing changes in the pattern of consumption in response to shifts in the relative availability of various commodities.

This research leads to one very specific recommendation. The derivation of monthly consumer expenditure series for this study on the basis of retail sales information, is bound to entail certain inaccuracies. Because of the usefulness of monthly data and since the essential information is already collected, the Department of Commerce should refine the derivation procedure and start the publication of monthly series for major commodities.

An understanding of the structure of consumer demand in an intra-year period is increasingly needed for forecasting purposes and in the formulation of economic policies. The time horizon of government and business decisionmakers has grown shorter in recent years. Decisions are frequently based on an ad hoc analysis of the latest changes in monthly economic factors. Monthly consumer demand equations provide a more rigorous means of analyzing monthly consumption data and developing short-run projections of consumer expenditure. The analysis of consumer demand based on monthly data can make contributions to the formulation of anti-inflationary and anti-cyclical policy, which annual models cannot. Especially in an inflationary period, effective economic policies require a knowledge of the immediate magnitude and the speed of the response of consumer expenditures to changes in income and prices. There is interest not simply in the impact of a gasoline price increase in a year period, but in the effect on demand next month. To reduce inflationary and cyclical pressures, an understanding of the time pattern involved in the effect of price and income changes on consumer demand is necessary. Monthly analysis indicates not only the immediate effect of a price or income change on demand, but the full impact can be traced across a sequence of months, rather than years if a dynamic model is utilized. In addition, the intra-year time path of the effects could be observed directly by the temporal aggregation of the monthly series.

FOOTNOTES

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1/ A number of these points have been made previously by Nerlove (1962) in regard to quarterly macro models and by Zellner (1957) concerning quarterly consumption functions.

2/ Nerlove (1962), p. 155.

3/ See Nerlove (1958) and Nerlove and Addison (1958).

4/ Seasonally adjusted series were used because earlier work by the author suggested that they would provide better estimates for forecasting purposes. In addition, the equations estimated on the basis of seasonally adjusted data provide much simpler results, since they need not be encumbered with large numbers of dummy variables to account for seasonal shifts.

5/ U.S. Department of Commerce, Business Statistics, Washington (published biennually--1951 through 1971 editions utilized). Also, U.S. Department of Commerce, The National Income and Product Accounts of the United States, 1929-1965, Washington. For 1971 and 1972 data, U.S. Department of Commerce, "Survey of Current

Business," Washington (January 1972 and January 1973 editions utilized). For price data, U.S. Department of Labor, Bureau of Labor Statistics, "Consumer Price Index Series for Urban Wage Earners and Clerical Workers: U.S. City Average," (not a publication, but available as mimeographed sheets).

6/ The electricity series is a quantity measure in kilowatt hours used for residential purposes and is available monthly.

7/ A moving average was utilized in applying the annual conversion ratios on a monthly basis to spread the year to year changes evenly across each month.

8/ The standard errors for the long-run income and price elasticities are not presented, because they are only indirect approximations and laborious to compute.

9/ Nerlove (1962), p. 166.

10/ A two-step and an instrumental variable approach were experimented with before settling on the Cochrane-Orcutt procedure. See Johnston (1972), pp. 317-320.

11/ The h statistic is a large sample test for autocorrelation to use when a lagged dependent variable is present and represents an adjustment of the conventional Durbin-Watson statistic. As applied to the partial adjustment model, the statistic is derived as follows:

$$\text{Define } r \approx 1 - 1/2\, d$$

where d is the Durbin-Watson statistic.

Then compute

$$h = r \sqrt{\frac{n}{1 - \hat{n}V\,(1 - \gamma)}}$$

where n = sample size

$\hat{V}(1-\gamma)$ = the sampling variance of $(1-\gamma)$, the coefficient on q_{t-1}.

The statistic h is then simply tested as a standard normal deviate, so with an $h > 1.645$ the hypothesis of zero serial correlation would be rejected with a Type I error only five percent of the time. The test breaks down if $n\hat{V}(1-\gamma) \geq 1$, which is why the statistic is not presented for two equations. In addition, the validity of the test is only reliable for large samples (say $n \geq 30$). The annual equations, therefore, present a border line case in terms of the test's reliability. See Johnston (1972), pp. 312-313.

12/ Nerlove (1959), p. 639.

13/ Tomek and Cochrane (1962), p. 729.

14/ Nerlove (1959), p. 639.

15/ In some earlier experimentation, a trend variable was included, but the level of collinearity was too high and nothing was added to the explanatory powers of the equations.

16/ Fuller and Martin (1961), p. 81.

17/ Houthakker (1976), p. 261.

18/ Tomek and Cochrane (1962), p. 729.

19/ Stigler (1962), p. 26.

20/ Subotnik (1974) has shown this assumption is only true for the compensated demand function.

21/ The specification of the Houthakker and Taylor model also restricts the results. The long-run price and income parameters are larger than the short-run values for non-durables because of habit formation and the opposite occurs for durables because of stock adjustment.

22/ Stone and Rowe (1960), p. 411.

23/ The Houthakker and Taylor model also imposes the same lag structure on price and income changes.

24/ Martin (1967), p. 167.

25/ His specification calls for y_t, y_{t-1}, y_{t-2}, p_t, p_{t-1}, p_{t-2}, and q_{t-1}, q_{t-2}, q_{t-3} as variables. And the correlation between y_t and y_{t-1}, for example, is .99 during this period.

26/ Part of the problem may be that the model does not explicitly contain a stock adjustment mechanism or account for depreciation. As Houthakker and Taylor (1970) have shown, a stock adjustment effect can account for estimates in which the short-run elasticities of income and price are greater in absolute magnitude than the long-run values.

27/ Houthakker and Taylor (1970) and Stone and Rowe (1958 and 1960).

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Table 1. Statistical Results of the Demand Analysis with Annual and Monthly Data[a/]

Commodity Group	Time Unit[b/]	Constant ($a_0 \gamma$)	Coefficient on q_{t-1} ($1-\gamma$)	Elasticity of Adjustment (γ)	Short-Run Elasticity: Income ($a_1 \gamma$)	Short-Run Elasticity: Price ($a_2 \gamma$)	Long-Run Elasticity: Income (a_1)	Long-Run Elasticity: Price (a_2)	Period of 95% Adjustment[c/] (years)	Period of 95% Adjustment[c/] (months)	R^2	Durbin-Watson statistic	h statistic
1. Electricity	a)annual		.9071 (82.08)	.0929	.1792 (6.61)	-.1413 (4.77)	1.928	-1.521	30.75	-----	.99	1.96	.10
	b)monthly*		.9536 (61.43)	.0464	.1107 (2.76)	-.0825 (2.53)	2.386	-1.778	-----	63.16	.99	1.66	3.12
2. New & Used Automobiles	a)annual		.3544 (2.36)	.6456	.7844 (3.99)	-.6722 (3.36)	1.215	-1.041	2.89	-----	.90	2.21	.84
	b)monthly		.9047 (41.40)	.0953	.1261 (3.92)	-.1001 (3.53)	1.323	-1.050	-----	29.91	.97	2.01	.08
3. Clothing & Shoes	a)annual		.7675 (7.31)	.2325	.2127 (2.98)	-.0974 (3.24)	.9148	- .4189	11.32	-----	.98	2.07	.24
	b)monthly*		.8895 (34.16)	.1105	.0777 (4.29)	-.0252 (3.14)	.7032	- .2280	-----	25.61	.97	2.09	.90
4. Men's & Boys' Clothing	a)annual		.8359 (7.33)	.1641	.1563 (2.29)	-.1210 (2.29)	.9525	- .7374	16.72	-----	.96	1.54	2.02
	b)monthly*		.8615 (29.95)	.1385	.0828 (4.50)	-.0506 (3.69)	.5978	- .3653	-----	20.11	.94	2.00	.0
5. Women's & Girls' Clothing	a)annual		.7802 (6.68)	.2198	.2035 (2.50)	-.1248 (2.73)	.9258	- .5678	12.07	-----	.95	2.32	1.01
	b)monthly*		.8480 (29.96)	.1520	.1081 (5.41)	-.0564 (4.51)	.7112	- .3710	-----	18.17	.95	2.06	.61
6. Shoes	a)annual*	1.261 (1.29)	.8184 (11.23)	.1816	.2237 (2.88)	-.4544 (1.66)	1.232	-2.502	14.95	-----	.89	2.27	.74
	b)monthly	.9564 (1.99)	.7805 (22.14)	.2195	.1001 (2.26)	-.2828 (1.86)	.4560	-1.288	-----	12.09	.64	2.54	6.05
7. Homefurnishings	a)annual		.2319 (1.087)	1.000	.8044 (3.69)	-.5633 (3.72)	.8044	- .5633	0	-----	.98	1.08	----
	b)monthly*		.5380 (11.32)	.4620	.4864 (9.62)	-.3310 (9.38)	1.053	- .7164	-----	4.83	.97	1.95	.81
8. Furniture	a)annual		-.0642 (.366)	1.000	.9997 (6.05)	-.7673 (5.53)	.9997	- .7673	0	-----	.94	1.57	2.45
	b)monthly		.6211 (14.26)	.3789	.3547 (8.55)	-.2836 (8.37)	.9361	- .7485	-----	6.29	.97	1.95	.72
9. Appliances	a)annual		.4106 (2.16)	.5894	.6334 (3.20)	-.5580 (3.19)	1.075	- .9467	3.36	-----	.98	1.46	5.53
	b)monthly		.7268 (18.46)	.2732	.2963 (6.91)	-.2529 (6.85)	1.084	- .9257	-----	9.39	.98	1.98	.24
10. Drugs & Sundries	a)annual		.8296 (8.89)	.1704	.2035 (1.88)	-.2245 (1.79)	1.194	-1.317	16.04	-----	.98	1.74	.74
	b)monthly*		.9783 (92.90)	.0217	.0269 (2.07)	-.0277 (2.01)	1.240	-1.276	-----	13.65	.99	2.01	.90
11. Food	a)annual	3.386 (2.17)	.6565 (4.69)	.3435	.0773 (1.40)	-.4197 (1.58)	.2250	-1.222	7.11	-----	.92	1.26	2.70
	b)monthly	.9513 (3.19)	.8586 (31.09)	.1414	.0306 (2.90)	-.1346 (2.46)	.2164	- .9519	-----	19.65	.95	2.51	5.18
12. Auto Parts	a)annual		.7355 (7.14)	.2645	.4194 (3.73)	-.5524 (3.84)	1.556	-2.0[illegible]8	9.75	-----	.93	2.44	1.34
	b)monthly*		.9432 (56.91)	.0568	.0758 (3.71)	-.0845 (3.67)	1.334	-1.488	-----	51.22	.97	2.02	.18
13. Alcoholic Beverages	a)annual*		.5684 (12.16)	.4316	.2187 (14.82)	-.0514 (1.87)	.5067	- .1191	5.30	-----	.97	1.97	.08
	b)monthly*		.6484 (22.43)	.3516	.2365 (10.57)	-.2068 (9.22)	.6726	- .5882	-----	6.91	.89	2.05	.51
14. Purchased Meals[d/]	a)annual	198.80 (3.50)	.2243 (1.18)	.7757	.6692 .0299 (3.13)	-1.966 -2.020 (2.87)	.8627	-2.534	2.00	-----	.69	1.41	6.11
	b)monthly	6.582 (5.64)	.6896 (14.85)	.3104	.2596 .0116 (4.84)	-.7720 -.0661 (4.60)	.8363	-2.487	-----	8.06	.77	2.27	4.17
15. Gasoline[d/]	a)annual	102.8 (3.60)	.3637 (1.65)	.6363	.3265 .0108 (2.15)	-1.032 -.7894 (3.73)	.5131	-1.700	2.96	-----	.99	2.13	----
	b)monthly	3.401 (6.54)	.7119 (16.76)	.2881	.1572 .0052 (5.45)	-.4202 -.0261 (6.68)	.5456	-1.490	-----	8.81	.99	2.20	2.67

a/ The t statistics are given in parentheses below the coefficients.

b/ An asterisk indicates those equations that were estimated by the Cochrane-Orcutt estimation procedure.

c/ The period required for 95 percent adjustment to the new equilibrium level. Given in years for the annual equations and months for the monthly ones. See text for a further explanation.

d/ The results given for (14) and (15) are based upon the linear functional form. The price and income elasticities are determined for the mean values. In the short-run elasticity columns, the top figure is the elasticity, the next the coefficient, and then the t statistic. The coefficient rather than the elasticity of adjustment is given.