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U.S. DEMAND FOR IMPORTED AND DOMESTICALLY-PRODUCED FOODS: AN INVESTIGATION OF INTERTEMPORAL AND CORSS SUBSTITUTION

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I. Introduction

Attempts to explain the time-series behavior of consumer purchases traditionally rely on econometric specifications that are alleged to reflect a utility-maximizing theory of consumer behavior. Most explicit presentations of the underlying theory view the consumer to be maximizing utility over a single-period horizon. Yet many econometric specifications include a list of lagged price variables that have no place in the single-period model of consumer choice.

Several rationalizations can be provided for the introduction and apparent explanatory power of lagged price variables. In some contexts consumer purchases may be related to earlier orders, and hence to prices prevailing when orders were placed. Alternatively, given that consumers in reality make their spending decisions in a multi-period context, lagged prices may contain information that helps consumers form

*/ Board of Governors of the Federal Reserve System. The analysis and conclusions of this paper should not be interpreted as reflecting the views of the Federal Reserve System or anyone else on its staff. We are indebted to an anonymous referee for a number of constructive criticisms of our earlier paper, and to Richard Berner and Peter Hooper for their comments on this revision.

their subjective expectations of future prices.[1/]

This paper invokes the multi-period model of consumer choice to specify consumer demands as functions of permanent income, current prices and expected future prices. Proxy variables are introduced, expressing permanent income in terms of current and lagged values of observed income, and expressing expected future prices in terms of current and lagged values of observed prices. For purposes of empirical estimation we focus on consumer choice between imported foods and domestically-produced foods,[2/] treating all other consumables as a composite numeraire. For each category of foods we estimate a nonlinear demand function using quarterly data spanning the period from fourth-quarter 1958 through second-quarter 1976. Our findings confirm that both groups of foods are necessities; permanent-income elasticities are less than unity. Intratemporal own-price elasticities are negative and in both cases significant; intratemporal cross-price elasticities are positive and in one case significant; intertemporal own-price elasticities are positive (specifically, current purchases are positively correlated with the expected future rate of own-price inflation); and intertemporal cross-price elasticities are negative. Although intertemporal price elasticities are not significantly different from zero, suppression of the influence of expected future prices on consumer demands raises the standard error of estimate substantially in the case of domestically-produced foods and slightly in the case of imported foods.

1/ Habit formation provides a third rationalization, with many variations. Habit formation is complicated to model, however, even under the simple assumption that current purchases repeat lagged purchases that were based on price information at some initial point in time.

2/ During our data period imports of (a) meats, (b) fish, (c) coffee and (d) sugar each represented roughly 15 per cent of total food imports, while imports of (e) fruits, nuts and vegetables and (f) alcoholic beverages each represented roughly 10 per cent.

II. The Model

Our multi-period model of consumer choice is developed in Isard, Lowrey and Swamy (1975), where we spell out a methodology for aggregating individual demands in a world in which consumer tastes are neither individual-invariant nor time-invariant. Here we merely write down our expressions for aggregate consumer demands during the first period of a multi-period horizon. These expressions are simplified by the assumption that consumers always expect prices to change over time at steady rates, though these expected rates will generally differ across commodities and can change from period to period as consumers revise their expectations on the basis of experience. Thus, expectations held currently about the price of a given commodity on some particular date in the future can be expressed in terms of two variables: the current price and the currently-expected value of the future rate of inflation for that commodity.

We use the following notation, where all variables are in logrithmic form:

c_t^d, c_t^m -- consumer purchases of domestically-produced and imported foods in period t

y_t^p -- permanent income in period t

y_t -- current income in period t

p_t^d, p_t^m -- prices of domestically-produced and imported foods in period t

π_t^d, π_t^m -- period-t values of expected inflation factors attached to domestically-produced and imported foods

Permanent income and the current prices of foods are measured relative to the current price of "all other consumable goods and services" (the numeriare), while expected future prices of foods are measured relative to expected contemporaneous future prices of all other consumables. Thus, prices represent current and expected future real terms of exchange between foods and all other consumables. Permanent income should ideally be measured to reflect initial wealth plus the present discounted value of the expected stream of future income, expressed in terms of real current purchasing power over the numeriare.

These definitions justify the specification

$$c_t^d = \alpha_0 + \alpha_1 y_t^p + a_2 p_t^d + a_3 p_t^m + \sum_{k=1}^{T} [a_{4k}(p_t^d + k\pi_t^d) + a_{5k}(p_t^m + k\pi_t^m)]$$

where $p_t^d + k\pi_t^d$ and $p_t^m + k\pi_t^m$ respectively represent (the logrithms of) the prices of domestically-produced and imported foods that are currently (in period t) expected to prevail in period t+k, and where T is the length of the consumer horizon. Substituting

$$\alpha_2 = a_2 + \sum_{k=1}^{T} a_{4k}$$

$$\alpha_3 = a_3 + \sum_{k=1}^{T} a_{5k}$$

$$\alpha_4 = \sum_{k=1}^{T} ka_{4k}$$

$$\alpha_5 = \sum_{k=1}^{T} ka_{5k}$$

and adding an error term, $\alpha_6 z_t + u_t$, yields

$$(1) \quad c_t^d = \alpha_0 + \alpha_1 y_t^p + \alpha_2 p_t^d + \alpha_3 p_t^m + \alpha_4 \pi_t^d + \alpha_5 \pi_t^m + \alpha_6 z_t + u_t$$

Similarly

$$(2) \quad c_t^m = \beta_0 + \beta_1 y_t^p + \beta_2 p_t^d + \beta_3 p_t^m + \beta_4 \pi_t^d + \beta_5 \pi_t^m + \beta_6 z_t + v_t$$

The terms u_t and v_t are stochastic disturbances, and z_t is a dummy variable introduced to capture the influence of dock strikes on imports. Due to data limitations, c^m_t is measured as (the logrithm of) purchases of foods by importers, based on international trade statistics, rather than final sales of imported foods to consumers.[3/] The dummy variable z_t, taken from Isard (1975), is constructed as (the logrithm of) the ratio of observed imports to an estimate of the level of imports that would have been recorded in the absence of dock strikes. Thus, we expect β_6 to be approximately equal to one. Since purchases of domestically-produced foods during the sample period were roughly 20 times as great as purchases of imported foods, we expect any impact of dock strikes on purchases of domestically-produced foods (α_6) to not be more negative than -.05.[4/]

We require definitions of y^p_t, π^d_t and π^m_t in terms of variables that can be observed. There is some precedent (see Nerlove, 1967, pp. 142-3) for using weighted averages of current and lagged levels of income, and of current and lagged observations of one-period inflation factors, with weights that decline geometrically as the

3/ The literature pays surprisingly little attention to the fact that final sales of imported goods to end users (the dependent variable in most theoretical import-demand hypotheses) can differ substantially from recorded imports due to changes in the inventories of imported goods held by intermediaries, on which available data are sparse. Roughly half of U.S. food imports are imperishable (e.g., coffee, sugar, alcoholic beverages), and consequently our dependent variable is influenced by the demand for food as a stock as well as by the demand for food as a flow.

4/ That is, a one per cent decline in imports of foods due to a dock strike should be associated with no more than a one-twentieth of one per cent increase in purchases of domestically-produced foods.

length of lag increases. Thus, we define

(3) $$y_t^p = (1-\lambda_y)\sum_{j=0}^{\infty}(\lambda_y)^j y_{t-k} \qquad \text{with } 0\le\lambda_y<1$$

(4) $$\pi_t^d = (1-\lambda_d)\sum_{j=0}^{\infty}(\lambda_d)^j (p^d_{t-k}-p^d_{t-k-1}) \qquad \text{with } 0\le\lambda_d<1$$

(5) $$\pi_t^m = (1-\lambda_m)\sum_{j=0}^{\infty}(\lambda_m)^j (p^m_{t-k}-p^m_{t-k-1}) \qquad \text{with } 0\le\lambda_m<1$$

Substitution of (3) - (5) into (1), after appropriate Koyck transformations and manipulation, yields the complicated expression[5/]

(6) $$\begin{aligned} c_t^d = {} & \alpha_0(1-\lambda_y)(1-\lambda_d)(1-\lambda_m) + (\lambda_y+\lambda_d+\lambda_m)c^d_{t-1} - (\lambda_y\lambda_d+\lambda_d\lambda_m+\lambda_m\lambda_y)c^d_{t-2} \\ & + \lambda_y\lambda_d\lambda_m c^d_{t-3} + \alpha_1(1-\lambda_y)y_t - \alpha_1(1-\lambda_y)(\lambda_d+\lambda_m)y_{t-1} + \alpha_1(1-\lambda_y)\lambda_d\lambda_m y_{t-2} \\ & + [\alpha_2+\alpha_4(1-\lambda_d)]p^d_t - [\alpha_2(\lambda_y+\lambda_d+\lambda_m)+\alpha_4(1-\lambda_d)(1+\lambda_y+\lambda_m)]p^d_{t-1} \\ & + [\alpha_2(\lambda_y\lambda_d+\lambda_d\lambda_m+\lambda_m\lambda_y)+\alpha_4(1-\lambda_d)(\lambda_y+\lambda_m+\lambda_y\lambda_m)]p^d_{t-2} \\ & - [\alpha_2\lambda_y\lambda_d\lambda_m+\alpha_4(1-\lambda_d)\lambda_y\lambda_m]p^d_{t-3} + [\alpha_3+\alpha_5(1-\lambda_m)]p^m_t \\ & - [\alpha_3(\lambda_y+\lambda_d+\lambda_m)+\alpha_5(1-\lambda_m)(1+\lambda_y+\lambda_d)]p^m_{t-1} + [\alpha_3(\lambda_y\lambda_d+\lambda_d\lambda_m+\lambda_m\lambda_y) \\ & +\alpha_5(1-\lambda_m)(\lambda_y+\lambda_d+\lambda_y\lambda_d)]p^m_{t-2} - [\alpha_3\lambda_y\lambda_d\lambda_m+\alpha_5(1-\lambda_m)\lambda_y\lambda_d]p^m_{t-3} \\ & + \alpha_6 z_t - \alpha_6(\lambda_y+\lambda_d+\lambda_m)z_{t-1} + \alpha_6(\lambda_y\lambda_d+\lambda_d\lambda_m+\lambda_m\lambda_y)z_{t-2} - \alpha_6\lambda_y\lambda_d\lambda_m z_{t-3} \\ & + u_t - (\lambda_y+\lambda_d+\lambda_m)u_{t-1} + (\lambda_y\lambda_d+\lambda_d\lambda_m+\lambda_m\lambda_y)u_{t-2} - \lambda_y\lambda_d\lambda_m u_{t-3} \end{aligned}$$

5/ This can be verified by transposing the terms in c^d_{t-k} to the left-hand side, substituting equation (1) -- appropriately dated -- for each of these terms, and noting from (3) - (5) that the left-hand side terms in y^p (respectively, π^d, π^m, z, u) are equivalent to the right-hand side terms in y(resp., p^d, p^m, z, u).

Similarly, based on conditions (2) - (5),

$$(7)\quad c^m_t = \text{same as (6) with } c^m_{t-k} \text{ replacing } c^d_{t-k}\ (k=1,2,3)$$

$$\beta_j \text{ replacing } \alpha_j\ (j=0,\ldots,6)$$

$$\text{and } v_{t-k} \text{ replacing } u_{t-k}\ (k=0,\ldots,3)$$

Each of these consumer demand equations is overidentified, with a total of 19 coefficients determined by 10 basic parameters. Consequently, we must estimate the 10 parameters under 9 nonlinear constraints.[6/] In doing so we make the simplifying assumption that the u_t and v_t follow third-order autoregressive processes such that the combined stochastic terms in (6) and (7) have the conventionally-assumed properties of being independently distributed with zero means and constant variances.

III. The Data

Our estimates of equations (6) and (7) are based on imperfect measures of the dependent variables, because data on final sales to consumers are not available. For c^d we used seasonally-adjusted data on manufacturers' shipments of food and kindred products, as published

6/ We have used a nonlinear estimation program that incorporates Marquardt's (1973) iterative procedure.

by the U.S. Department of Commerce, Bureau of the Census. For c^m we used seasonally-adjusted data on end-use imports of foods, feeds and beverages, also published by the Bureau of the Census. Both c^d and c^m are deflated, as discussed below. For y we used seasonally-adjusted personal disposable income, as published by the U.S. Department of Commerce, Bureau of Economic Analysis. For p^m we constructed a fixed-weighted average of unit value indexes for imports of crude foods and manufactured foods, which we then adjusted to include tariff rates; the unit value indexes are computed by the Bureau of the Census. A moving-weighted average of the same tariff-adjusted unit value indexes was constructed as a deflator for c^m, with the moving weights appropriately reflecting changes in the composition of imports. For p^d we used the wholesale price index for consumer foods, published by the Department of Labor, Bureau of Labor Statistics; and (because we could not easily construct a moving-weighted price index) we also used this fixed-weighted index as a deflator for c^d. Our choice of a wholesale price index for p^d, rather than a consumer price index, was based partly on the fact that the former assigns a smaller weight to import prices, and partly on a desire to measure p^d and p^m at similar stages of marketing.

To conform with the discussion following our notational definitions above, we expressed y, p^d and p^m in terms of purchasing power over "all other consumables", the numeraire. The deflator for personal disposable income was chosen to represent the price of "all other consumables".

Before estimation all variables were transformed into their natural logrithms. Quarterly data were used, with t running from fourth-quarter 1958 through second-quarter 1976.

IV. Empirical Results

Tables 1 and 2 present our empirical results. For each category of foods, unconstrained estimates of the 10 parameters are shown as case 1, and 5 sets of constrained estimates are shown as cases 2-6. Constraints are described in the left-most column of each table. The α and β parameters are defined in the equations at the tops of the tables, corresponding to equations (1) and (2) of the model, and the λ parameters are defined in equations (3) - (5).

For each category of foods, cases 1-4 suggest that: (i) the data do not pin down λ_y within the interval between 0 and 1; and (ii) the data support the hypothesis that $\lambda_m=\lambda_d=0$, or that expectations of future inflation are based solely on the most recent observation of actual inflation. The first of these conclusions is strengthened by unreported regressions in which λ_y was respectively constrained to equal 0, .25, .5, and .75 (under the additional constraint that $\lambda_m=\lambda_d=0$). Although estimates of λ_y are significantly different from zero in some cases, the unreported regressions fail to confirm that permanent income--as defined by the general form of equation (3) -- contains significantly more explanatory power than current income.

Cases 1-4 establish that the model fits the data well. The standard errors of estimate are roughly 0.2 percent of the sample mean for domestically-produced foods and 0.9 percent for imported foods. Estimates of α and β parameters are similar in all four cases. The estimated magnitudes of α_1 and β_1 confirm that both domestically-produced and imported foods are necessities;

Table 1: Demand for Domestically-Produced Foods[1/]

$$c_t^d=\alpha_0+\alpha_1 y_t^p+\alpha_2 p_t^d+\alpha_3 p_t^m+\alpha_4 \pi_t^d+\alpha_5 \pi_t^m+\alpha_6 z_t+u_t$$

	α_0	α_1	α_2	α_3	α_4	α_5	α_6	λ_y	λ_d	λ_m	standard error of estimate
Case 1: 10 Free parameters 2/	7.66 (.296)	.561 (.0177)	-.550 (.112)	.281 (.0871)	.0315 (.108)	-.0445 (.154)	.0405 (.0514)	.557 (.405)	-.197 (.232)	.182 (.190)	.0218
Case 2: 9 Free $\lambda_m=\lambda_d$	7.57 (.300)	.560 (.0177)	-.546 (.118)	.297 (.0904)	.0376 (.144)	-.0192 (.128)	.0379 (.0518)	.999 (.498)	.00766 (.495)	λ_d	.0221
Case 3: 8 Free 3/ $\lambda_m=\lambda_d=0$	7.45 (.295)	.574 (.0180)	-.632 (.117)	.387 (.0915)	.0984 (.147)	-.0723 (.129)	.0390 (.0536)	.999 (.0111)	0	0	.0228
Case 4: 8 Free 3/ $\lambda_m=\lambda_d=0$	7.45	.576	-.635	.389	.0810	-.0956	.0374	.741	0	0	.0230
Case 5: 6 Free $\lambda_m=\lambda_d=0$ $\alpha_4=\alpha_5=0$	7.13 (.490)	.679 (.0311)	-.724 (.221)	.406 (.162)	0	0	-.463 (.241)	.680 (.275)	0	0	.0435
Case 6: 5 Free $\lambda_y=\lambda_m=\lambda_d=0$ $\alpha_4=\alpha_5=0$	7.13 (.447)	.679 (.0292)	-.724 (.196)	.406 (.145)	0	0	-.455 (.237)	0	0	0	.0428

1/ Numbers in parentheses are standard errors. The mean of the dependent variables is approximately 10.0.

2/ The program was truncated after 300 iterations.

3/ Case 3 is a least-squares solution. Case 4 shows the standard error of estimate associated with alternative parameter values that the computer tested in its search for a least-squares solution.

Table 2: Demand for Imported Foods[1/]

$$c_t^m=\beta_0+\beta_1 y_t^p+\beta_2 p_t^d+\beta_3 p_t^m+\beta_4 \pi_t^d+\beta_5 \pi_t^m+\beta_6 z_t+v_t$$

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	λ_y	λ_d	λ_m	standard error or estimate
Case 1: 10 Free parameters	4.00 (.792)	.747 (.0689)	.400 (.327)	-.749 (.239)	-.135 (.358)	.899 (.523)	.990 (.149)	.999 (.660)	-.177 (.370)	.146 (.331)	.0618
Case 2: 9 Free $\lambda_m=\lambda_d$	4.00 (.806)	.749 (.0651)	.399 (.340)	-.750 (.250)	-.0978 (.455)	.768 (.463)	1.01 (.148)	.798 (.441)	-.00408 (.444)	λ_d	.0619
Case 3: 8 Free 2/ $\lambda_m=\lambda_d=0$	4.15 (.799)	.733 (.0651)	.317 (.324)	-.678 (.239)	-.0361 (.400)	.741 (.347)	1.02 (.146)	.182 (.0316)	0	0	.061394
Case 4: 8 Free 2/ $\lambda_m=\lambda_d=0$	4.14	.733	.319	-.680	-.0373	.742	1.02	.734	0	0	.061395
Case 5: 6 Free $\lambda_m=\lambda_d=0$ $\beta_4=\beta_5=0$	4.00 (.724)	.750 (.0459)	.400 (.326)	-.750 (.240)	0	0	1.07 (.356)	.735 (.407)	0	0	.0644
Case 6: 5 Free $\lambda_y=\lambda_m=\lambda_d=0$ $\beta_4=\beta_5=0$	4.00 (.666)	.750 (.0435)	.400 (.292)	-.750 (.216)	0	0	1.07 (.353)	0	0	0	.0639

1/ Numbers in parentheses are standard errors. The mean of the dependent variable is approximately 7.0.

2/ In Case 3 the program was truncated after 300 iterations. Case 4 shows the standard error of estimate associated with alternative parameter values that the computer tested in its search for a least-squares solution.

income elasticities are significantly greater than zero and significantly less than one. Insofar as $\alpha_1 < \beta_1$, the estimates suggest that as income grows, _ceteris paribus_, consumption of imported foods increases relative to consumption of domestically-produced foods. Cases 1-4 also provide estimates of the dock-strike parameters, α_6 and β_6, that support our prior expectations (recall the discussion following the presentation of equations (1) and (2) above). In particular, the estimates of β_6 are not significantly different from one.

Estimates of the intratemporal own-price and cross-price elasticities all have correct signs in cases 1-4. The intratemporal own-price elasticities, α_2 and β_3, are both significantly different from zero, as is the elasticity of demand for domestic foods with respect to the contemporaneous price of imports, α_3. In addition, for each group of foods demand is estimated to be more sensitive to current own price than to current cross price; that is, α_2 exceeds α_3 in absolute value, and β_3 exceeds β_2.

The most distinguishing feature of our model is the assumption that expected future prices play an explicit role in determining current demands. The data support this assumption, although our estimates of relevant parameters cannot be distinguished from zero with much statistical confidence. For each group of foods, current demand is positively related to the expected future rate of own-price inflation (α_4 and β_5 are positive in cases 1-4), confirming our prior beliefs about the sign of intertemporal own-price elasticities. Elasticities of demand with respect to expected future rates of cross-price inflation (α_5 and β_4) are estimated to be negative. This is consistent with our estimates of the intertemporal own-price effects, insofar as the increase in current purchases of imported foods (respectively, domestically-produced foods) that is stimulated by an increase in the expected future rate of import-price inflation (resp., domestic price inflation) is likely to be partially offset by a decline in current purchases of domestically-produced foods (resp., imported foods). In this connection, since purchases of domestically-produced foods were roughly 20 times larger than purchases of imported foods during our sample period, it is appropriate that β_4 is less than 20 times as large as α_4 in absolute value, while it is inappropriate that all but the case-2 estimates of α_5 are greater than one-twentieth as large as β_5 in absolute value.

Cases 5 and 6 provide additional support for the assumption that expected future prices influence current demands, particularly in the case of domestically-produced foods. When the role of expected future prices is suppressed (under the constraint $\alpha_4=\alpha_5=\beta_4=\beta_5=0$), standard errors of estimate increase, roughly doubling in the case of domestically-produced foods.7/

7/ In addition, estimates of the dock-strike parameter, α_6, become implausibly negative in the case of domestically-produced foods.

V. Summary and Conclusions

By conventional standards our model fits the data well. For domestically-produced foods the standard error of estimate is roughly 0.2 percent of the sample mean, and for imported foods roughly 0.9 percent. Moreover, the estimated income and price elasticities have correct signs and plausible magnitudes.

The distinguishing features of our model derive from the view that the problem of consumer choice should be posed in a multi-period context. In this context current consumer purchases depend on both current and expected future prices, as well as on initial wealth and the expected stream of future income, which Friedman (1957) has combined into the summary concept of permanent income.

The explicit introduction of expected future prices is a novel feature of consumer-demand estimation. We assume that expectations of future prices are based on observations of current and lagged prices, and for empirical purposes we assume a conveniently-simplified relationship between expected future prices and historically-observed prices. Nonlinear estimation techniques are used to explain quarterly data from 1958 through mid-1976, a period during which food prices exhibited moderate cyclical variation relative to prices of other consumables.

The form in which our model is estimated relates current purchases of foods to current and lagged price variables. In this sense our model is similar to conventional models of consumer demand. Unlike conventional models, however, our relationship between current purchases and historically-observed prices involves structural parameters that describe the relationship between current purchases and expected future prices. We interpret our empirical results as weak confirmation that current purchases do depend on expected future prices. Stronger confirmation should be pursued in other empirical investigations[8/]--not because there is much doubt of the theoretical presumption, but rather because of the importance of relating current purchases to lagged prices in a manner that is consistant with the underlying theory.

References

Friedman, M. (1957): A Theory of the Consumption Function, Princeton, Princeton University Press.

Isard, P. (1975): "Dock Strike Adjustment Factors for Major Categories of U.S. Imports and Exports, 1958-1974," Federal Reserve Board, International Finance Discussion Paper No. 60.

__________, B. Lowrey and P.A.V.B. Swamy (1975): "Theory and Estimation of the Demand for Imports of Consumer Goods," Federal Reserve Board, International Finance Discussion Paper No. 61.

Marquardt, D.W. (1963): "An Algorithm for Least-Squares Estimation of Nonlinear Parameters," Journal of the Society for Industrial and Applied Mathematics, 11; pp. 431-4.

Nerlove, M. (1967): "Distributed Lags and Unobserved Components in Economic Time Series," pp. 127-69 in W. Fellner et al., Ten Economic Studies in the Tradition of Irving Fisher, New York, John Wiley and Sons.

8/ Ideally our hypothesis should be compared and/or integrated with a model of order-delivery lags and, perhaps more importantly, with a model that recognizes that consumers may be slow to adjust their habits following changes in prices or other behavior-determining variables.