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The U.S. Demand for Imported and Domestically Produced Foods: An Investigation of Intertemporal and Substitution Effects

Peter Isard[1], Barbara Lowrey[2], P.A.V.B. Swamy[3] and Roger Conway[4]

[1] *Research Department, International Monetary Fund, Washington, DC 20431 (U.S.A.)*
[2] *Office of the Secretary, Board of Governors, Federal Reserve System, Washington, DC (U.S.A.)*
[3] *Special Studies Section, Board of Governors, Federal Reserve System, Washington, DC (U.S.A.)*
[4] *Productivity and Public Policy Section, Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Washington, DC 20005-4788 (U.S.A.)*

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Abstract

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This article extends the literature on time series estimation of U.S. consumer demand by presenting a coherent theoretical structure with a multi-period planning horizon for consumer choice and a more general treatment of the aggregation problem that allows the possibility that consumers' tastes change over time and vary across individuals. Based on our theoretical model, an econometric model is used to obtain estimates in a multi-period context of U.S. demand for imported foods and domestically produced foods. The hypothesis that current purchases depend on expected future prices is supported by the empirical results for imported foods.

Introduction

The existing literature on the time series behavior of U.S. consumer demands for imports and domestically produced goods suffers from at least two major deficiencies: (i) no attempt has been made to integrate the consumers' expectations about *future* prices into empirical studies of the choices between imports and domestically produced goods; and (ii) there is no theoretically

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rigorous treatment of the fact that individuals may differ in behavior and undergo changes in tastes over time. This article attempts to remedy these deficiencies.

In the following section the general theoretical demand model is developed. The emphasis is on a multi-period planning horizon for consumer choice. Conditions under which the existence of a stable aggregate demand equation is consistent with a world in which consumer tastes are neither individual-invariant nor time-invariant are demonstrated. The multi-period framework provides a clear rationale for relating current demands to lagged income and price variables (both of which have no place in the single-period model of consumer choice). This information is used by consumers in forming expectations about future incomes and prices. We also discuss restrictions placed on the empirical model as a result of data problems and the need for tractability.

Empirical results for imported foods and domestically-produced foods are presented in the next section. An innovative feature of our estimated model is the use of proxy variables for expected future rates of inflation. Some summary remarks are offered in the final section.

Theoretical foundations for aggregate consumer demand functions

We begin with the individual's problem of utility maximization over a multi-period horizon. Following the traditional quest for estimable aggregate demand functions, we separate the income and price terms of the individual's demand function by taking the total logarithmic derivative of a general demand function. Constancy of the coefficients of these demand functions, taken strictly, implies that the individual consumer maximizes a Cobb–Douglas type utility function; see Goldberger (1967, p. 111) and Theil (1975). We avoid the Cobb–Douglas case by assuming that the coefficients of demand functions are time-varying. We also assume that tastes change over time and are different for different individuals. To be consistent with this assumption, we allow all coefficients to differ among individuals both at a point in time and through time. After aggregating we introduce measures of the expected values of future variables that enter multi-period consumption decisions. Because individuals are viewed to have different tastes, community utility functions may not exist. Therefore, our results are not subjected to the restrictions that maximization of a community utility function would imply.

We follow Friedman (1957) and Modigliani and Brumberg (1954) by considering an individual consumer who is concerned with the allocation of his resources among goods for current and future consumption, where his resources are defined by his current net worth plus the sum of current and discounted future earnings. We take into account his anticipated consumption of goods and services in future periods $T+1, \ldots, T+L$, with L being the anticipated period in which he dies. His bequests are represented as goods in period $T+L+1$.

We first consider behavior under conditions of complete certainty. In this context, Green (1978, p. 187) formulates the consumer's problem as follows: Maximize

$$u(\boldsymbol{c}_0, \boldsymbol{c}_1, \boldsymbol{c}_2, \ldots, \boldsymbol{c}_{L+1}) \tag{1}$$

subject to

$$\begin{aligned} W_0 &= V_0 + H_0 \\ &= V_0 + f_0 E_0 + f_1 E_1 + \ldots + f_L E_L \end{aligned} \tag{2}$$

where

$\boldsymbol{c}_t$ is an $m \times 1$ vector of consumption of all goods in period t,

f_0 $= 1, f_\tau = \dfrac{1}{(1+r_0)\ldots(1+r_{\tau-1})}$, $\tau = 1, \ldots, L+1$ are the discount factors,

r_t is the rate at which the consumer can borrow or lend money bewteen periods t and $t+1$,

W_0 is the consumer's wealth in period 0,

V_0 is the consumer's non-human wealth (for example, financial and non-financial) in period 0, i.e. the present value of all non-human assets less the present value of all non-human liabilities,

H_0 is the consumer's human wealth, which is measured by his current earnings from work, E_0, plus the present value of $E_1, \ldots, E_L$, his anticipated earnings (i.e. future earnings with certainty) from work in the subsequent periods.

We assume the existence of a differentiable utility function of the type (1); sufficient conditions for a utility function's existence are stated in Deaton and Muellbauer (1980, pp. 26–30); see also Green (1978, Chapters 2, 3 and 12). Thus, given

$$W_0, \boldsymbol{p}_0, \ldots, \boldsymbol{p}_{L+1}, r_0, \ldots, r_L,$$

where $\boldsymbol{p}_t$ is a $m \times 1$ vector of the corresponding prices in period t, the constrained maximization problem in eqns. (1) and (2) may be solved as in Green (1978, p. 190) to obtain the consumer's vector of demand in period 0.

$$\boldsymbol{c}_0 = \boldsymbol{c}_0(W_0, f_0\,\boldsymbol{p}_0, f_1\,\boldsymbol{p}_1, \ldots, f_{L+1}\,\boldsymbol{p}_{L+1}) \tag{3}$$

Now we follow the work of Friedman and substitute permanent income for W_0. In Green (1978, p. 190), permanent income, $\bar{y}$, is defined as that rate of receipts per period which, if maintained at a constant level over one's lifetime, would have a present value equal to that of one's total wealth. Permanent income in period 0 is determined by solving the following equation for $\bar{y}_0$,

$$\bar{y}_0(f_0 + f_1 + \ldots + f_{L+1}) = W_0 \tag{4}$$

Accordingly, we may rewrite eqn. (3) as:

$$\boldsymbol{c}_0 = \boldsymbol{c}_0\,(\theta\bar{y}_0, f_0\boldsymbol{p}_0, f_1\boldsymbol{p}_1, \ldots, f_{L+1}\,\boldsymbol{p}_{L+1}) \tag{3a}$$

where $\theta = f_0 + f_1 + \ldots + f_{L+1}$ and the function $\boldsymbol{c}_0$ is not time invariant in the presence of taste changes; i.e. the coefficients of the arguments in eqn. (3a) are time-varying if tastes change.

In eqns. (1) and (2), the choice of $\boldsymbol{c}_t$ for any $t > 0$ represents planned consumption, but only for $t = 0$ is the consumption plan given by eqn. (3a) actually implemented. The problem in eqns. (1) and (2) is handled so as to emphasize the effect upon present behavior, $\boldsymbol{c}_0$, of planning for the future. At time $t > 0$ the consumer again solves the utility maximization problem in a form analogous to eqns. (1) and (2) under a forward shift of time subscripts

$$\boldsymbol{c}_t = \boldsymbol{c}_t\,(\theta\bar{y}_t, f_0\boldsymbol{p}_t, f_1\boldsymbol{p}_{t+1}, \ldots, f_{L+1}\,\boldsymbol{p}_{t+L+1}) \tag{3b}$$

but again, the only operable $\boldsymbol{c}_t$ is that decided at time t.

The functional form for demand at time t depends on the functional form for utility at time t. In the spirit of generality, however, it is possible to proceed without specifying a particular functional form for utility, as in Theil (1975, pp. 1 and 2). The total differential of eqn. (3b) may be expressed in terms of logarithmic differentials as

$$\begin{aligned}
\mathrm{d}(\log c_{ijt}) &= \frac{\partial(\log c_{ijt})}{\partial(\log \theta\bar{y}_{it})}\,\mathrm{d}(\log \theta\bar{y}_{it}) \\
&\quad + \sum_{k=1}^{m}\sum_{\tau=0}^{L_i+1} \frac{\partial(\log c_{ijt})}{\partial(\log f_\tau p_{ik,t+\tau})}\,\mathrm{d}(\log f_\tau p_{ik,t+\tau}) \\
&= \beta^*_{ijt} + \beta^*_{1ijt}\,\mathrm{d}(\log \bar{y}_{it}) \\
&\quad + \sum_{k=1}^{m}\sum_{\tau=0}^{L_i+1} \gamma^*_{ijk,t+\tau}\mathrm{d}(\log f_\tau p_{ik,t+\tau}) \\
&= \beta^*_{0ijt} + \beta^*_{ijt}\,\mathrm{d}(\log \bar{y}_{it}) \\
&\quad + \sum_{k=1}^{m}\left(\sum_{\tau=0}^{L_i+1} \gamma^*_{ijk,t+\tau}\right)\sum_{\tau=0}^{L_i+1}\left(\frac{\gamma^*_{ijk,t+\tau}}{\sum_{\tau=0}^{L_i+1}\gamma^*_{ijk,t+\tau}}\right) \\
&\quad \times \mathrm{d}(\log f_\tau p_{ik,t+\tau}) \\
&= \beta^*_{0ijt} + \beta^*_{1ijt}\,\mathrm{d}(\log \bar{y}_{it}) \\
&\quad + \sum_{k=1}^{m} \beta^*_{2ijkt} \sum_{\tau=0}^{L_i+1} w^*_{ijk,t+\tau}\,\mathrm{d}(\log f_\tau p_{ik,t+\tau})
\end{aligned} \tag{5}$$

$(j = 1, 2, \ldots, m)$

where

$$\beta_{0ijt} = \frac{\partial(\log c_{ijt})}{\partial(\log \theta\, \bar{y}_{it})} \mathrm{d}(\log \theta)$$

and the remaining coefficients β^*'s, γ^*'s and w^*'s are similarly defined, i indexes consumers, j and k index commodities, and L_i is the anticipated lifespan or planning horizon of the i-th consumer at time t.

We interpret the logarithmic differential formulation in eqn. (5) as an approximation in which both the intercept β^*_{0ijt} and the income coefficient β^*_{1ijt} depend on θ, and hence on anticipated future interest rates. The dependence of β^*_{1ijt} on θ is consistent with Friedman's (1957, pp. 11–14) formulation that the coefficient of permanent income depends on an interest rate variable. Eqn. (5) is the dynamic version of the logarithmic differential formulation of the static demand function given in Goldberger (1967, p. 23).

Note that we do not force the coefficients of eqn. (5) to be identical for all consumers at all points in time; rather, we conceptualize a more general approach by allowing the coefficients to vary among individuals and over time. Given the reasonableness of the assumption that individuals do indeed differ greatly in their behavior and change over time, it is questionable whether any fixed-coefficient demand models derived from a specific utility-maximization theory can compete with this variable-coefficient logarithmic differential formulation in terms of theoretical or empirical adequacy. A similar argument has been offered by Goldberger (1967, p. 107) in defense of the Rotterdam School models. The question of parameterization brought forth by Goldberger does not arise in our theoretical framework because we do not treat any feature of the demand functions, eqn. (3b), as constant parameters.

Up to this point we have been discussing consumer behavior under conditions of certainty. According to Friedman, one way of introducing uncertainty is to make the coefficient β^*_{1ijt} of $\mathrm{d}(\log \bar{y}_{it})$ in eqn. (5) a function of the ratio of non-human wealth to permanent income and other variables which change over time. More generally, the consumer's response to both permanent income and prices may depend on the degree of uncertainty. We recognize this implicitly by allowing for time-variability of coefficients in eqn. (5). The introduction of uncertainty also requires us to treat future prices as expectations. Thus, we rewrite eqn. (5) as

$$\mathrm{d}(\log c_{ijt}) = \beta^*_{0ijt} + \beta^*_{1ijt}\, \mathrm{d}(\log \bar{y}_{it}) + \sum_{k=1}^{m} \beta^*_{2ijkt} \times \sum_{\tau=0}^{L_i+1} w^*_{ijk,\, t+\tau}\, \mathrm{d}(\log {}_{t+\tau}p^{\mathrm{e}}_{ikt}) \qquad (6)$$

$(j = 1, 2, \ldots, m)$

where ${}_{t+\tau}p^{\mathrm{e}}_{ikt}$ denotes the i-th consumer's expectation, held at the end of period

t, of the discounted value of the price that will prevail for the k-th commodity at $t+\tau$. Eqn. (6) allows different individuals to have different expectations regarding future prices.

Our empirical objective is to estimate aggregate demand functions for imported and domestically produced foods based on the assumption that these two categories of foods are imperfect substitutes; see Stern et al. (1982). We now seek to justify reducing the price vector to the anticipated time paths of the prices of these two commodities relative to a general index of all prices. Following Goldberger (1967, pp. 102, 103), we define a general price index, π^{e}_{it}, such that

$$\mathrm{d}(\log \pi^{e}_{it}) = \sum_{k=1}^{m} \sum_{\tau=0}^{L_i+1} \alpha^{*}_{ik,t+\tau} \mathrm{d}(\log_{t+\tau} p^{e}_{ikt})$$

where the $\alpha^{*}_{ik,t+\tau}$ represent average budget shares in the consumer's expected lifetime budget. Then we may subtract and add $\beta^{*}_{1ijt}\mathrm{d}(\log \pi^{e}_{it})$ on the right-hand side of eqn. (6) to obtain

$$\mathrm{d}(\log c_{ijt}) = \beta^{*}_{0ijt} + \beta^{*}_{1ijt}[\mathrm{d}(\log \bar{y}_{it}) - \mathrm{d}(\log \pi^{e}_{it})] + \sum_{k=1}^{m} \sum_{\tau=0}^{L_i+1} (\beta^{*}_{2ijkt} w^{*}_{ijk,t+\tau} + \beta^{*}_{1ijt} \alpha^{*}_{ik,t+\tau}) \mathrm{d}(\log_{t+\tau} p^{e}_{ikt}) \qquad (6a)$$

$(j=1,2, \ldots, m)$

Now $\mathrm{d}(\log \bar{y}_{it}) - \mathrm{d}(\log \pi^{e}_{it})$ can be interpreted as a measure of real permanent income (i.e. nominal permanent income divided by π^{e}_{it}). Since a proportionate change in all prices (including expected prices) with no change in real permanent income will not affect consumption, the coefficients of $\mathrm{d}(\log_{t+\tau} p^{e}_{ikt})$ must sum to zero. This result is an analogue of the classical result that the Slutsky (utility-compensated) price elasticities must sum to zero, see Goldberger (1967, p. 24 (2.18f)). Accordingly,

$$\sum_{k=1}^{m} \sum_{\tau=0}^{L_i+1} (\beta^{*}_{2ijkt} w^{*}_{ijk,t+\tau} + \beta^{*}_{1ijt} \alpha^{*}_{ik,t+\tau}) = 0$$

and hence we may subtract this $\times$ $\mathrm{d}(\log \pi^{e}_{it})$ from eqn. (6a) to obtain

$$\mathrm{d}(\log c_{ijt}) = \beta^{*}_{0ijt} + \beta^{*}_{1ijt}[\mathrm{d}(\log \bar{y}_{it}) - \mathrm{d}(\log \pi^{e}_{it})] + \sum_{k=1}^{m} \sum_{\tau=0}^{L_i+1} (\beta^{*}_{2ijkt} w^{*}_{ijk,t+\tau} + \beta^{*}_{1ijt} \alpha^{*}_{ik,t+\tau}) \times [\mathrm{d}(\log_{t+\tau} p^{e}_{ikt}) - \mathrm{d}(\log \pi^{e}_{it})] \qquad (7)$$

$(j=1, 2, \ldots, m)$

Neither the Engel aggregation condition (Goldberger, 1967, p. 24, (2.15f)) nor the symmetry conditions (Goldberger, 1967, p. 24, (2.17f)) are to be imposed because we did not multiply eqn. (7) through by the average budget shares. We shall view commodities 1 and 2 as imported and domestically produced foods, respectively.

Now the subsystem for commodities 1 and 2 is

$$\begin{aligned}\mathrm{d}(\log c_{ijt}) = {} & \beta^{**}_{0ijt}+\beta^{**}_{1ijt}[\mathrm{d}(\log \bar{y}_{it})-\mathrm{d}(\log \pi^{\mathrm{e}}_{it})] \\ & +\sum_{k=1}^{2}\sum_{\tau=0}^{L_i+1}(\beta^{*}_{2ijkt}w^{*}_{ijk,t+\tau}+\beta^{*}_{1ijt}\alpha^{*}_{ik,t+\tau}) \\ & \times[\mathrm{d}(\log_{t+\tau}p^{\mathrm{e}}_{ikt})-\mathrm{d}(\log \pi^{\mathrm{e}}_{it})]\end{aligned} \tag{8}$$

$(j=1, 2)$

where β^{**}_{0ijt} represents not only β^{*}_{0ijt} but also all the relative price terms in eqn. (7) which are not written explicitly in eqn. (8).

To operationalize eqn. (8) in a context of uncertainty, we must find proxies for future expectations. Given the significant theoretical limitations of the rational expectations approach to modeling individual expectations, as demonstrated by Swamy et al. (1982) and exposited by Conway and Barth (1983), we should ideally follow an alternative approach which pays complete attention to information bases and how they differ from individual to individual in a dispersed economy. Since the informational basis of individual decision-making is usually unknown, any expectations model that economists specify will reflect their ability to model their beliefs about individual expectations. This is also true of our expectations model given below.

We let p_{1t} and p_{2t}, respectively, denote the current prices of imported foods and domestically produced foods faced by all consumers, where it is understood that henceforth these variables, along with nominal income, y_{it}, are deflated by a general price index. It is obvious that this general price index is not the same as π^{e}_{it} because the latter is unobservable. In order to simplify the nature of the estimation problems, we assume that the prices to be forecast in eqn. (8) may be written as

$$\begin{aligned}({}_{t+\tau}p^{\mathrm{e}}_{i1t}/\pi^{\mathrm{e}}_{it}) &= (1+{}_{t+\tau}\rho^{\mathrm{e}}_{i1t})p_{it} \\ ({}_{t+\tau}p^{\mathrm{e}}_{i2t}/\pi^{\mathrm{e}}_{it}) &= (1+{}_{t+\tau}\rho^{\mathrm{e}}_{i2t})p_{2t}\end{aligned} \tag{9}$$

where ${}_{t+\tau}\rho^{\mathrm{e}}_{i1t}$ and ${}_{t+\tau}\rho^{\mathrm{e}}_{i2t}$ are the τ-period rates of price increases expected by the ith consumer. To make the model tractable, we adopt the simplifying assumption that at any point of time (t), each consumer expects constant rates of inflation through the future; specifically,

$$\begin{aligned}({}_{t+\tau}p^{\mathrm{e}}_{i1t}/\pi^{\mathrm{e}}_{it}) &= (1+\rho^{\mathrm{e}}_{i1t})^{\tau}p_{1t} \\ ({}_{t+\tau}p^{\mathrm{e}}_{i2t}/\pi^{\mathrm{e}}_{it}) &= (+\rho^{\mathrm{e}}_{i2t})^{\tau}p_{2t}\end{aligned} \tag{10}$$

The ith consumer's expectations of future period-to-period rates of inflation ρ^{e}_{i1t} and ρ^{e}_{i2t}) are revised from period to period, however, and therefore carry a time subscript.

Assumption (10) enables us to rewrite eqn. (8) as

$$\mathrm{d}(\log c_{ijt}) = \beta^{**}_{0ijt} + \beta^{**}_{1ijt}\,[\mathrm{d}(\log \bar{y}_{it} - \mathrm{d}(\log \pi^{e}_{it})] + \sum_{k=1}^{2} \beta^{**}_{2ijkt}\,\mathrm{d}(\log p_{kt}) + \sum_{k=1}^{2} \beta^{*}_{ijkt}\,\mathrm{d}(\log\,[1+\rho^{e}_{ikt})] \tag{11}$$

$(j=1,2)$

where

$$\beta^{**}_{2ijkt} = \sum_{\tau=0}^{L_i+1} (\beta^{*}_{2ijkt} w^{*}_{ijk,t+\tau} + \beta^{*}_{1ijt} \alpha^{*}_{ik,t+\tau})$$

$$\beta^{*}_{3ijkt} = \sum_{\tau=0}^{L_i+1} (\beta^{*}_{2ijkt} w^{*}_{ijk,t+\tau} + \beta^{*}_{1ijt} \alpha^{*}_{ik,t+\tau})$$

The preceding analysis is microeconomic in nature, and its reconciliation with macroeconomic behavior demands an explicit treatment of the aggregation problem. To provide such a treatment, we proceed as in Swamy et al. (1982, p. 134).

Rewrite the right-hand side of eqn. (11) by adding an subtracting the term

$$\begin{aligned}&\beta^{*}_{0jt} + \beta^{*}_{1j}\,[\mathrm{d}(\log \bar{y}_{it}) - \mathrm{d}(\log \pi^{e}_{it})] + \beta^{*}_{2j}\,\mathrm{d}(\log p_{1t})\\ &\quad + \beta^{*}_{3j}\,\mathrm{d}(\log p_{2t})\\ &\quad + \beta^{*}_{4j}\,\mathrm{d}(\log\,[1+\rho^{e}_{i1t}]) + \beta^{*}_{5j}\,\mathrm{d}(\log[1+\rho^{e}_{i2t}])\end{aligned}$$

$(j=1,2)$

and then average the result over i. This yields

$$\begin{aligned}\frac{1}{n_t}\sum_{i=1}^{n_t} \mathrm{d}(\log c_{ijt}) = \beta^{*}_{0jt} + \beta^{*}_{1j}\frac{1}{n_t}\sum_{i=1}^{n_t} &[\mathrm{d}(\log \bar{y}_{it})\\ &- \mathrm{d}(\log \pi^{e}_{it})] + \beta^{*}_{2j}\,\mathrm{d}(\log p_{1t})\\ &+ \beta^{*}_{3j}\,\mathrm{d}(\log p_{2t}) + \beta^{*}_{4j}\frac{1}{n_t}\sum_{i=1}^{n_t} \mathrm{d}(\log[1+\rho^{e}_{i1t}])\\ &+ \beta^{*}_{5j}\frac{1}{n_t}\sum_{i=1}^{n_t} \mathrm{d}(\log[1+\rho^{e}_{i2t}]) + \zeta_{jt}\end{aligned} \tag{12}$$

$(j=1,2)$

where n_t is the number of consumers in period t and

$$\zeta_{jt} = \frac{1}{n_t} \sum_{i=1}^{n_t} ((\beta^{**}_{0ijt} - \beta^{*}_{0jt}) + (\beta^{*}_{1ijt} - \beta^{*}_{1j}) [\mathrm{d}(\log \bar{y}_{it}) - \mathrm{d}(\log \pi^{\mathrm{e}}_{it})]$$

$$+ (\beta^{**}_{2ij1t} - \beta^{*}_{2j}) \mathrm{d}(\log p_{1t}) + (\beta^{**}_{2ij2t} - \beta^{*}_{3j}) \mathrm{d}(\log p_{2t})$$

$$+ (\beta^{*}_{3ij1t} - \beta^{*}_{4j}) \mathrm{d}(\log[1+\rho^{\mathrm{e}}_{i1t}]) + (\beta^{*}_{3ij2t} - \beta^{*}_{5j}) \mathrm{d}(\log[1+\rho^{\mathrm{e}}_{i2t}]) \quad (13)$$

$(j=1, 2)$

We assume that for $j=1, 2$, and for every $t=1, 2, \ldots, T$:

$$E\left(\frac{|\zeta_{jt}|^r}{1+|\zeta_{jt}|^r}\right) \to 0 \text{ as } n_t \to \infty \text{ for some } r>0. \quad (14)$$

Under assumption (14), we can ignore the error term ζ_{jt} $(j=1, 2)$ because n_t in our case is sufficiently large and as a result the ζ_{jt}'s are close to zero. Notice that assumption (14) can hold even when the coefficients of eqn. (11) are different for different consumers. Consequently, our aggregation procedure is more general than the one based on the assumption that the coefficients of eqn. (11) are the same for all consumers whether they are poor or rich. Indeed, our aggregation procedure would follow through even if we made the slope coefficients of eqn. (12) time dependent; however, we do not follow this general approach in this paper.

The form of the available data forces us to work with finite rather than infinitesimal changes. So, following Theil (1975, pp. 236–237), we replace logarithmic differentials in eqn. (12) by logarithmic first differences in the (quarterly) time series. Another problem associated with eqn. (12) is that, except for the price terms, each of its variables is the arithmetic mean of logarithmic values, which corresponds to the logarithm of a geometric mean. Unfortunately, available macroeconomic data are computed as arithmetic sums of microobservations, not geometric averages. If in every period the logarithms of explained and explanatory variables in eqn. (12) follow the normal distribution, however, we have a simple relation between geometric and arithmetic means. For given t, let $a_t(x)$ and $g_t(x)$ be the respective arithmetic and geometric means of a variable x_{it} (for $i=1, 2, \ldots, n_t$) and let $\sigma^2(x)$ be the variance of the logarithmic values of x_{it}. Here x_{it} represents any of the variables in eqn. (12). The variance $\sigma^2(x)$ is assumed to be constant, at least over the sample period. We then find

$$a_t(x) = g_t(x) \mathrm{e}^{\sigma^2(x)/2} \quad (15)$$

This means that the geometric means of micro variables show time movements close to arithmetic means, such that $\Delta\log g_t(x) = \Delta\log a_t(x) = \log a_t(x) - \log a_{t-1}(x)$. Using this relation we can write eqn. (12) as

$$\Delta\log a_t(c_j) = \beta_{0j} + \beta_{1j}\ \Delta\log a_t(\bar{y}_r) + \beta_{2j}\ \Delta\log p_{1t} + \beta_{3j}\ \Delta log\, p_{2t} + \beta_{4j}\ \Delta\log a_t(1+\rho_1^e) + \beta_{5j}\ \Delta\log a_t(1+\rho_2^e) + u_{jt} \tag{16}$$

$(j=1, 2)$

where $\bar{y}_r$ denotes real permanent income. The asterisk is not attached to the coefficients since these coefficients are different from the coefficients of eqn. (12), which do not remain invariant when the infinitesimal changes in variables are approximated by logarithmic finite differences and $\beta_{0j} + u_{jt} = \beta_{0jt}$. Since our typical variable is $\log(\sum_{i=1}^{nt} x_{it}) = \log(n_t a_t(x)) \equiv \log x_t$ for any x_t, we transform to

$$\Delta\log c_{jt} = \beta_{0j} + \beta_{1j}\ \Delta\log \bar{y}_{rt} + \beta_{2j}\ \Delta\log p_{1t} + \beta_{3j}\ \Delta\log p_{2t} + \beta_{4j}\ \Delta\log a_t(1+\rho_1^e) + \beta_{5j}\ \Delta\log a_t(1+\rho_2^e) + u_{jt} \tag{16a}$$

$(j=1, 2)$

where the term $(1-\beta_{1j})\ \Delta\log n_t$ is assumed to be zero.

We must now define real permanent income and the expected rates of inflation in terms of variables that can be observed. Let y_t denote personal disposable income in period t in constant dollars and note that the changes in historic logarithmic prices, $\Delta\log \rho_{1t}$ and $\Delta\log \rho_{2t}$, reflect historic values of the inflation rates ρ_{1t} and ρ_{2t}. We adopt the following assumptions

$$\log \bar{y}_{rt} = (1-\lambda_{1j}) \sum_{s=0}^{\infty} \lambda_{1j}^s \log y_{t-s}$$

$$\log a_t(1+\rho_1) = (1-\lambda_{2j}) \sum_{s=0}^{\infty} \lambda_{2j}^s \log(p_{1t-s}/p_{1t-s-1}) \tag{17}$$

and

$$\log a_t(1+\rho_2) = (1-\lambda_{3j}) \sum_{s=0}^{\infty} \lambda_{3j}^s \log(p_{2t-s}/p_{2t-s-1})$$

$(j=1, 2)$

We also add the term $\beta_{6j}\Delta DSD_t$ to the right hand side of eqn. (16a), where DSD_t is a dummy variable constructed to capture the influence of dock strikes on imports. Substitution of eqn. (17) into eqn. (16a) gives

$$\Delta\log c_{jt} = \beta_{0j} + \beta_{1j}(1-\lambda_{1j}) \sum_{s=0}^{\infty} \lambda_{1j}^{s}\, \Delta\log y_{t-s} + \beta_{2j}\Delta\log p_{1t}$$

$$+\beta_{3j}\Delta\log p_{2j} + \beta_{4j}(1-\lambda_{2j}) \sum_{s=0}^{\infty} \lambda_{2j}^{s}\, \Delta\log\,(p_{1t-1}/p_{1t-s-1})$$

$$+\beta_{5j}(1-\lambda_{3j}) \sum_{s=0}^{\infty} \lambda_{3j}^{s}\, \Delta\log\,(p_{2t-s}/p_{2t-s-1}) + \Delta DSD_t + u_{jt} \qquad (18)$$

$(j=1, 2)$

Our estimation form is a rather lengthy expression (not spelled out here) that is obtained by applying to eqn. (18) a series of Koyck transformations (Theil, 1971, p. 260) represented by the following steps:

(I) $\Delta\log c_{jt} - \lambda_{1j}\,\Delta\log c_{jt-1}$

(II) $(\Delta\log c_{jt} - \lambda_{1j}\,\Delta\log c_{jt-1}) - \lambda_{2j}\,(\Delta\log c_{jt-1} - \lambda_{1j}\,\Delta\log c_{jt-2})$

(III) $(\Delta\log c_{jt} - \lambda_{1j}\,\Delta\log c_{jt-1}) - \lambda_{2j}\,(\Delta\log c_{jt-1} - \lambda_{1j}\,\Delta\log c_{jt-2})$
$-\lambda_{3j}\,[(\Delta\log c_{jt-1} - \lambda_{1j}\,\Delta\log c_{jt-2})$
$-\lambda_{2j}(\Delta\log c_{jt-2} - \lambda_{1j}\,\Delta\log c_{jt-3})]$

Each of the two consumer demand equations obtained from these transformations is overidentified, with a total of nineteen coefficients determined by ten basic parameters. Consequently, we must estimate the ten parameters under nine nonlinear constraints. For this purpose we have used a nonlinear estimation program that incorporates Marquardt's (1963) iterative procedure. In estimating each equation separately we make the simplifying assumption that the u_{jt} follow the appropriate third-order auto-regressive processes, such that the combined stochastic terms in the estimating equations have the convenient properties of being independently distributed with zero means and constant variances. This assumption may be appropriate if the disturbances of the first-differenced equations are stationary. The method of differencing time series data to make them stationary is employed by Box and Jenkins (1970). We also fit regressions to logarithms of the levels of variables. A comparison of results before and after first-differencing the logarithms of variables indicates the effects of first-differencing.

Before closing this section, a few remarks about the single equation approach followed in this paper are in order. As is well-known, the classical theory of consumer demand provides a good number of restrictions which will be satisfied by any complete set of demand functions that is derivable from maximation of a consumer utility function (see Goldberger, 1967). If the use of such restrictions results in efficiency gains, then it is desirable to estimate the complete set of demand functions imposing those restrictions. For the case that concerns us, however, tastes differ from individual to individual and change over time, and it cannot be presumed, as noted earlier, that the consumer sector behaves as if it were maximizing a single community utility function. Again, as we noted earlier, since we do not multiply both sides of eqn. (7) by the average budget share of the j-th commodity, the income and price coefficients do not satisfy the Engel aggregation condition and symmetry conditions, respectively. Accordingly, it is not necessarily desirable to estimate a complete set of aggregate demand functions subject to the restrictions that apply to a single utility-maximizing agent.

On an empirical level, it has also been shown that joint estimation of a complete set of demand functions does not always lead to more efficient estimates than equation-by-equation estimation; see Revankar (1976) and Mehta and Swamy (1976). This is a second justification for abstracting from the allocation of total consumer expenditure and confining attention to individual categories of consumer demand.

Empirical results

We have estimated equations derived from eqn. (18) through the indicated Koyck transformations, both in terms of logarithmic changes of variables and in terms of logarithms of the levels of variables, using quarterly data for the period 1959-I through 1978-IV. Lagged variables are observed as early as 1958-I in some cases. To measure consumption of imported foods, we used seasonally adjusted data on end-use imports of foods, feeds and beverages, as published by the U.S. Department of Commerce, Bureau of the Census. Even though the theory of consumer behavior developed in the previous section is not applicable to feeds, we had to consider them here because we could not separate the data on feeds from the data on foods and beverages. During our data period imports of (a) meats, (b) fish, (c) coffee, and (d) sugar each represented roughly 15% of total food imports, while imports of (e) fruits, nuts and vegetables, and (f) alcoholic beverages each represented roughly 10%. For consumption of domestically produced foods, we used seasonally adjusted data on manufacturer's shipments of food and kindred products, also published by the Bureau of the Census (see the Survey of Current Business). These choices of our dependent variables reflect the fact that data on the food purchases of consumers are not available. The final quantities purchased of imported and domestically produced foods (the dependent variables in theoretical demand functions) can differ substantially from the measures we have adopted, due to changes in inventories, 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.

For y_t we used seasonally adjusted personal income, as published by the U.S.

Department of Commerce, Bureau of Economic Analysis. For the price of imported foods 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 food import, with the moving weights appropriately reflecting changes in the composition of imports. For the price of domestically produced foods 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 consumption of domestic foods. Our choice of a wholesale price index for domestic foods, 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 the prices of imported foods and domestic foods at similar stages of marketing.

To conform to our definition of variables in the previous section, we expressed our income and food price variables 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".

Tables 1 and 2 present our empirical results for imported and domestically produced foods under the two model specifications. In each table unconstrained estimates of the ten free parameters are shown as case 1, and three sets of constrained estimates are shown as cases 2–4. Constraints are described in the left-most columns of the Tables. The parameters for each model are defined at the top of the Tables; subscripts m and d, which denote imported and domestically-produced foods, respectively, have been substituted for subscripts 1 and 2 of eqn. (16a). The parameters λ_y, λ_m and λ_d correspond, respectively, to λ_1, λ_2 and λ_3 of eqn. (17).

For each category of foods and each model, the results suggest that: (i) the data do not specify λ_y as being within the theoretically plausible interval between 0 and 1; and (ii) the data do not reject 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 constrained to equal 0.33 and 0.67 (under the additional constraint that $\lambda_m = \lambda_d = 0$). Although the estimates of λ_y are significantly different from zero in some cases, the reported and unreported regressions fail to confirm that permanent income — as defined by the general form of eqn. (17) — has significantly more explanatory power than current income (i.e. the case $\lambda_y = 0$). We attribute this failure to the low variance of seasonally adjusted personal disposable income about its exponential trend during our sample period, which implies that our construction of permanent income is fairly insensitive to the choice of λ_y. The results do not indicate that zero is the best estimate of λ_y and hence do not refute the general

TABLE 1

Demand for imported foods

Model 1: $\Delta \log c_{mt} = \beta_0 + \beta_1 \Delta \log \bar{y}_{rt} + \beta_2 \Delta \log p_{mt} + \beta_3 \Delta \log p_{dt} + \beta_4 \Delta \log a_t(1+\rho^e_m) + \beta_5 \Delta \log a_t(1+\rho^e_d) + \beta_6 \Delta DSD_t$

Model 2: $\log c_{mt} = \beta_0 + \beta_1 \log \bar{y}_{rt} + \beta_2 \log p_{mt} + \beta_3 \log p_{dt} + \beta_4 \log a_t(1+\rho^e_m) + \beta_5 \log a_t(1+\rho^e_d) + \beta_6 DSD_t$

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	λ_y	λ_m	λ_d	Standard error of estimate
Model 1											
Case 1: 10 free	0.000122	0.818	−0.839	1.06	0.536	−0.880	1.15	1.00	0.147	−0.300	0.0731
parameters	(0.0016)	(0.923)	(0.395)	(0.567)	(0.630)	(0.403)	(0.137)	(0.500)	(0.464)	(0.189)	
Case 2: 9 free	0.00689	0.248	−0.984	1.78	0.629	−2.08	1.00	−1.00	0.0738	λ_m	0.0778
$\lambda_m = \lambda_d$	(0.0133)	(0.913)	(0.483)	(0.736)	(0.696)	(0.537)	(0.132)	(0.432)	(0.459)		
Case 3: 8 free	0.00309	0.517	−0.809	1.22	0.446	−1.40	1.14	0.352	0	0	0.0749
$\lambda_m = \lambda_d = 0$	(0.0117)	(0.889)	(0.294)	(0.615)	(0.222)	(0.426)	(0.131)	(0.109)			
Case 4: 7 free	0.00236	0.642	0.859	1.29	0.493	−1.44	1.07	0	0	0	0.0742
$\lambda_y = \lambda_m = \lambda_d = 0$	(0.0116)	(0.866)	(0.284)	(0.602)	(0.212)	(0.420)	(0.104)				
Model 2											
Case 1: 10 free	3.14	0.799	−0.544	0.314	0.592	−0.465	1.03	1.00	0.0666	−0.0627	0.0768
parameters	(0.909)	(0.0807)	(0.138)	(0.282)	(0.329)	(0.569)	(0.183)	(0.706)	(0.333)	(0.503)	
Case 2: 9 free	2.92	0.816	−0.481	0.272	0.520	−0.453	1.02	0.999	−0.00910	λ_m	0.0752
$\lambda_m = \lambda_d$	(0.849)	(0.0671)	(0.131)	(0.261)	(0.306)	(0.460)	(0.178)	(0.405)	(0.408)		
Case 3: 8 free	3.41	0.799	−0.356	0.0641	0.461	−0.338	1.03	0.587	0	0	0.0741
$\lambda_m = \lambda_d = 0$	(0.826)	(0.0663)	(0.125)	(0.247)	(0.217)	(0.442)	(0.175)	(0.0323)			
Case 4: 7 free	3.41	0.799	−0.356	0.0641	0.461	−0.339	1.03	0	0	0	0.0736
$\lambda_y = \lambda_m = \lambda_d = 0$	(0.808)	(0.0502)	(0.121)	(0.246)	(0.215)	(0.438)	(0.167)				

Numbers in parentheses are standard errors. Means of the dependent variables are approximately 0.007 and 7.0 for models 1 and 2, respectively.

TABLE 2

Demand for domestically-produced foods

Model 1: $\Delta\log c_{mt}=\beta_0+\beta_1\Delta\log \bar{y}_{rt}+\beta_2\Delta\log p_{mt}+\beta_3\Delta\log p_{dt}+\beta_4\Delta\log a_t(1+\rho_m^e)+\beta_5\Delta\log a_t(1+\rho_d^e)+\beta_6\Delta DSD_t$

Model 2: $\log c_{mt}=\beta_0+\beta_1\log \bar{y}_{rt}+\beta_2\log p_{mt}+\beta_3\log p_{dt}+\beta_4\log a_t(1+\rho_m^e)+\beta_5\log a_t(1+\rho_d^e)+\beta_6 DSD_t$

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	λ_y	λ_m	λ_d	Standard error of estimate
Model 1											
Case 1: 10 free	0.00921	0.250	−0.00593	−1.08	0.0733	0.420	−0.000504	−1.00	0.454	0.0349	0.0177
parameters	(0.0108)	(0.245)	(0.142)	(0.924)	(0.237)	(1.30)	(0.0188)	(0.589)	(0.341)	(0.801)	
Case 2: 9 free	0.00964	0.270	0.00294	−1.20	0.0288	0.812	−0.00536	−0.900	0.286	λ_m	0.0177
$\lambda_m=\lambda_d$	(0.00629)	(0.367)	(0.119)	(0.578)	(0.134)	(0.737)	(0.0181)	((0.107)	(0.592)		
Case 3: 8 free	0.00430	0.485	0.0121	−1.00	0.0270	0.312	0.00942	1.00	0	0	0.0186
$\lambda_m=\lambda_d=0$	(0.00331)	(0.267)	(0.0722)	(0.309)	(0.0533)	(0.264)	(0.0262)	(0.345)			
Case 4: 7 free	0.00304	0.350	0.00125	−0.735	0.0284	0.0764	0.00696	0	0	0	0.0176
$\lambda_y=\lambda_m=\lambda_d=0$	(0.00274)	(0.205)	(0.0674)	(0.143)	(0.0502)	(0.0995)	(0.0246)				
Model 2											
Case 1: 10 free	13.18	0.590	0.0601	−0.209	0.0751	−0.266	0.0102	0.179	−0.0105	0.0313	0.0208
parameters	(0.252)	(0.0157)	(0.0528)	(0.0825)	(0.0721)	(0.154)	(0.0469)	(0.417)	(0.408)	(0.233)	
Case 2: 9 free	13.8	0.593	0.0439	−0.197	0.0842	0.269	0.0101	−0.137	−0.0118	λ_m	0.0206
$\lambda_m=\lambda_d$	(0.240)	(0.0152)	(0.0519)	(0.0803)	(0.0761)	(0.131)	(0.0465)	(0.333)	(0.334)		
Case 3: 8 free	13.7	0.591	0.0514	0.184	0.0778	−0.251	0.0126	1.00	0	0	0.0224
$\lambda_m=\lambda_d=0$	(0.248)	(0.0161)	(0.0491)	(0.0777)	(0.0675)	(0.138)	(0.0510)	(0.0115)			
Case 4: 7.free	13.8	0.583	0.117	0.256	0.0462	−0.190	0.0128	0	0	0	0.0210
$\lambda_y=\lambda_m=\lambda_d=0$	(0.231)	(0.0143)	(0.0346)	(0.0701)	(0.0613)	(0.125)	(0.0478)				

Numbers in parentheses are standard errors. Means of the dependent variables are approximately 0.007 and 17.0 for models 1 and 2, respectively.

hypothesis that consumers view part of any increase in current income as transitory and refrain from allocating that transitory income to current consumption. The standard error of the estimates suggest that the models fit the data well. For model 2 the standard errors of the estimates are roughly 1.1% of the sample mean for imported foods and 0.12% of the sample mean for domestically produced foods. For model 1 the standard errors of the estimates are comparable in size, although quite large relative to the small mean *changes* in the logarithms of consumption.

The estimates of β_1 confirm that both imported foods and domestically produced foods are necessities. In particular, the model 2 estimates of the income elasticity are significantly greater than zero and significantly less than one for both categories of foods, while the insignificant model 1 estimates also lie between zero and one. For both models the estimates suggest that as income grows, ceteris paribus, consumption of imported foods increases relative to consumption of domestically produced foods. This result is consistent with the view that imported foods contain relatively more luxury items like coffee, sugar, beverages, etc., than domestic foods. The estimates of β_6 are also consistent with our prior expectations. The dock strike dummy, *DSD*, has been constructed by Isard (1975) as the logarithm of the ratio of observed imports of foods to an estimate of the level of food imports that would have been recorded in the absence of dock strikes. Thus, by definition, we expect β_6 to equal one in both models of the demand for imported foods, and in fact our estimates do not differ significantly from one. For domestically produced foods the estimates of β_6 suggest that consumption of domestic foods does not during dock strikes, ceteris paribus. The estimates in Table 1 confirm that imports of foods are affected significantly by dock strikes, but do not necessarily imply that consumption of imported foods is affected significantly, since inventories of imported foods can provide a buffer stock for consumers.

Estimates of β_2 and β_3 — the intratemporal income-compensated (Slutsky) own-price and cross-price elasticities — have the expected signs for both categories of foods in all cases of both models except case 1 of model 1 for domestic foods. With the exception of that cae, all estimates of intratemporal own-price elasticities are significantly less than zero. All estimates of intratemporal cross-price elasticities are positive, and they are significantly greater than zero in model 1 of the demand for imported foods.

The most distinguishing feature of our models is the assumption that expected future prices play an explicit role in determining current demands. This assumption is supported by the estimates for imported foods, but not by the estimates for domestic foods. Current demand for imported foods is positively related to the expected future rate of own-price inflation, and significantly so in cases 3 and 4 of both models. In addition, the elasticity of import demand with respect to the expected future rate of domestic-food-price inflation is estimated to be significantly less than zero. The fact that the (negative) current response of imports to expected cross-price inflation is more elastic than the (positive) current response to expected own-price inflation is consistent with the fact that domestic foods were roughly 20 times larger than imported foods as a share of consumption during our sample period.

Summary and conclusions

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 framework 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 1959 through 1978, 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 of imported foods do depend on expected future prices. Stronger confirmation should be pursued in other empirical investigations (for example, our hypothesis should ideally be compared and/or integrated with a model of order-delivery lags) — 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 consistent with the underlying theory.

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