A Complete System of U.S. Demand for Food

Kuo S. Huang

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Abstract

Consumer demand for food is an important component of the structure within which various agricultural policies have been formulated. To provide a model for food consumption forecasts and analyses of food program effects, a complete set of food demand relationships consisting of direct- and cross-price elasticities, and expenditure (income) elasticities was computed. This report, in addition to improving methodology, updates and revises the demand elasticity estimates for a disaggregate U.S. food demand system published in 1985.

Keywords: Ordinary demand system, constrained maximum likelihood estimation, compensated and uncompensated price elasticities.

Contents

Summary

Consumer demand for food is an important component of the structure within which various agricultural policies have been formulated. To provide a model for food consumption forecasts and analyses of food program effects, a complete set of food demand relationships consisting of direct- and cross-price elasticities, and expenditure (income) elasticities was computed. This report, in addition to improving methodology, updates and revises the demand elasticity estimates for a disaggregate U.S. food demand system published in 1985.

An ordinary (quantity dependent) demand system is derived in this report from the first-order differential approximation of conceptual demand relationships. This differential-form demand system is linearized in parameters, and the computational burden is reduced considerably, especially for estimating a large-scale demand system. The dependent variable in the demand system, defined as relative changes of quantities demanded rather than defined as expenditure shares as in other demand systems, is easily quantified by using available time series data usually expressed as index numbers. Another advantage of using this demand system is that one can directly interpret demand parameters as elasticities, which are widely used in economic analyses. Although other demand systems are capable of generating elasticities, the generating process could introduce sizable errors in measurement.

The estimation procedure developed in this report represents a unique approach for estimating a large-scale demand system with limited sample observations. The procedure, using constrained maximum likelihood with a substitution approach, is a cost-effective alternative to currently available methods for estimating a demand system. Some parametric constraints derived from the principal properties of the classical demand theory are incorporated into estimation. The constrained estimation procedure, in addition to alleviating the problem of multicollinearity, has narrowed the gap between demand theory and empirical application and provided greater statistical efficiency to demand estimates. To circumvent the problem of insufficient degrees of freedom, the estimation of a demand system is carried out by commodity group. The estimates, however, are not constrained by any particular parameters derived from specific prior assumptions about separability of the consumer preference relationships, nor are they affected by the initial ordering of commodities, by any sequential aspects of the estimation procedures.

The developed methodology was successfully applied to the estimation of a U.S. food demand system of 39 food categories and 1 nonfood sector using annual data from 1953 to 1990. The results containing 1,680 estimates of price and expenditure elasticities and time trends provide a better understanding of the interdependent nature of food demands in the United States. Among these estimates, the direct-price elasticities for major meats are beef and veal (-0.6212), pork (-0.7281), and chicken (-0.3723), and their corresponding expenditure elasticities are beef and veal (0.3923), pork (0.6593), and chicken (0.0769). In contrast with a decrease in red meat consumption, the demand for poultry meats has increased, probably because of recent consumer medical and dietary concerns and increasing use of chicken in fast-foods. The

implication of estimates for individual food categories to the general food sector indicates that the direct-price and expenditure elasticities for food as a whole are low, -0.1850 and 0.2745, respectively.

Validation of an estimated demand system was examined by means of simulation over the sample period. The simulation performance based on the calculated root-mean-square errors indicates that the errors of simulated quantities demanded are less than 5 percent in most cases. The close correspondence between simulated values and sample observations ensures that this empirical demand system is an effective instrument for use in food consumption forecasting and related policy analyses. For conducting forecasting, one may use the information on relative changes in prices and expenditures, and forecast the quantity demanded. For program analysis, one may assume various scenarios of changes in prices and expenditures, and then conduct simulation experiments for evaluation of the program effects.

The compensated price elasticities are also presented to provide a means of assessing the structure of economic interdependence among consumer demand for foods, especially for interpreting substitution and complementary relationships among food categories. Another function of the compensated price elasticities is to evaluate the food program effects on consumer welfare. Since the use of the compensated demand curves leads to the appropriate welfare measures, I developed an approximated measure of the Hicksian compensating variation as a function of all price changes and compensated price elasticities. The unique feature of this approach is that, to accommodate for multiple price changes, all potential direct- and cross-price effects are incorporated into the welfare measurement.

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Introduction

Information about demand for food is important for the economic analyses of national food programs and the assessment of changes in food consumption. Most earlier U.S. food demand studies since the 1938 work of Schultz (*31*)[1] were partial demand analyses, in which a food price and per capita income were considered as major determinant variables in a demand equation, but they did not consider the complete interdependent nature of food demands. In the consumer budgeting process, however, changes in other food prices may be equally important factors in determining food demands. A complete demand system approach should be implemented in food demand studies so that the interdependent demand relationships among all foods can be explicitly recognized.

The application of a demand system approach to modeling the U.S. food demand structure was first undertaken by Brandow (*2*), who used a synthetic method to generate a demand elasticity matrix for 24 food categories and 1 nonfood sector. George and King (*11*) later used a similar method to obtain a demand matrix for 49 food categories and 1 nonfood sector. Both studies made a significant contribution in demonstrating the feasibility and the potential practical use of a complete demand system in applied economic analyses. The major drawback in their studies is that many demand elasticities are not estimated directly from sample observations, and thus no statistical inferences can be provided for verifying the reliability of these elasticities. Their food demand estimates, consequently, may not provide an accurate representation of a food demand structure nor a reliable model for food consumption forecasts. Appendix D gives a brief review of the methodology used by Brandow and by George and King.

To improve the synthetic method, I developed an approach to estimate a demand system directly from time-series data. Two problems are often encountered in the direct estimation of a large-scale demand system. First, the number of demand parameters in each demand equation may be more than the number of available sample observations, causing insufficient degrees of freedom in estimation. Second, some price and expenditure variables in a demand system may be highly correlated, causing a multicollinearity problem. A major focus of developing estimation methodology in this report is to resolve these two problems. I applied a constrained maximum likelihood estimation procedure by

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[1]Italicized numbers in parentheses identify literature listed in the References at the end of this report.

incorporating some parametric constraints derived from the classical demand theory. The estimation procedure substantially reduces the number of demand parameters to be estimated directly and thus helps alleviate the possible multicollinearity problem. In addition, I developed a procedure to estimate the demand parameters by group to resolve the problem of insufficient degrees of freedom.

In general, the estimation methodology and the empirical food demand system in this report are similar to those in Huang (*18*), in which the results have been widely used and cited by agricultural economists in the research community at large. Major revisions in this report include: (a) improving the estimation methodology to reflect any systematic shifting of consumer tastes and preferences on the demand for foods, (b) revising data series in accordance with recently published data sources, and (c) updating the estimates with an extension of seven more recent sample observations from 1984 to 1990.

Conceptual Framework

This section explains the rationale of specifying an ordinary demand system and its parametric constraints for later use in modeling a U.S. food demand system. Some ordinary demand models are available to applied demand analysts. Each model is characterized by a tradeoff between sound theoretical property and empirical application interest. To provide information for selecting a proper model, a brief explanation of alternative ordinary demand models is given at the beginning. It is followed by exploring the comparative static properties of an ordinary demand system and identifying some constrained parametric relationships for use in empirical estimation.

Modeling Ordinary Demand Systems

Let q denote an n-coordinate column vector of quantities demanded for a "representative" consumer, p an n-coordinate vector of the corresponding prices, $m = p'q$ the consumer expenditure, and $u(q)$ the utility function, assumed nondecreasing and quasi-concave in q. The primal function for maximizing consumer utility is the following Lagrangean function with multiplier π:

$$\text{Maximize } L = u(q) - \pi (p'q - m) \qquad \qquad (1)$$
$$q, \pi$$

Defining $u_i(q)$ as the marginal utility of the ith commodity, the necessary conditions for an optimum are:

$$u_i(q) = \pi p_i \qquad i=1,2,..,n \qquad \qquad (2)$$

$$p'q = m \qquad \qquad (3)$$

In equation 2, π is known as the marginal utility of income showing the change in the maximized value of utility as income changes. Furthermore, the optimal

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conditions imply that the Hessian matrix defined as the second-order partials of $u(q)$, say $H = [u_{ij}(q) = \partial u^2/\partial q_i \partial q_j]$, is symmetric and negative definite.

A solution of equations 2 and 3 gives both the ordinary demand system and the marginal utility of income as functions of prices and income:

$$q_i = f_i(p, m) \qquad i=1,2,\ldots,n \tag{4}$$

$$\pi = g(p, m) \tag{5}$$

A typical example of deriving an ordinary demand system from an assumed functional form of utility function is given in the linear expenditure system (Klein and Rubin, *27*) and the S-branch demand system (Brown and Heien, *3*).

Within the same framework of utility maximization, one can derive an inverse demand system, in which prices are functions of quantities demanded and income. Multiplying equation 2 by q_i and summing over n to satisfy the budget constraint gives an expression of the Lagrange multiplier as

$$\pi = \sum_{j=1}^{n} q_j u_j(q)/m \tag{6}$$

Furthermore, substituting equation 6 into equation 2 yields the Hotelling-Wold identity (*16, 41*), or an inverse demand system in which the normalized prices, defined as p_i/m, are functions of quantities demanded:

$$p_i/m = u_i(q)/ \sum_{j=1}^{n} q_j u_j(q) \qquad i=1,2,\ldots,n \tag{7}$$

This inverse demand system represents another function of the Marshallian demand by showing the prices at which consumers will buy given quantities (Hicks, *15*). Since the inverse demand system is not the focus of discussion here, one may refer to Huang (*17, 19, 20, 21, 22*) for some recent developments in the inverse demand system research.

An ordinary demand system shown in equation 4 can also be derived from an indirect utility function. By substituting the equilibrium quantity q_i obtained from utility maximization into the original utility function, one can yield an indirect utility function as a function of prices and income, say $v(p,m)$, which gives the maximized utility for specified values of prices and income. Then one may apply Roy's identity (*30*) and obtain an ordinary demand system as

$$q_i = - [\partial v(p,m)/\partial p_i]/[\partial v(p,m)/\partial m] \qquad i=1,2,\ldots,n \tag{8}$$

By assuming a quadratic form of indirect utility function, Christensen, Jorgenson, and Lau (*5*) used Roy's identity to derive the well-known indirect translog demand system.

One also can derive an ordinary demand system from a cost function. Inverting an indirect utility function for the level of u that satisfies $v(p,m) = u$ gives a cost function, say $c(u,p) = m$, which is defined as the minimum cost of attaining u at a price vector p. One may first apply Shephard's lemma (32) and derive a Hicksian (compensated) demand as a function of utility level and prices:

$$\partial c(u,p)/\partial p_i = h_i(u,p) \qquad i=1,2,..,n \qquad (9)$$

Then, by substituting the indirect utility into the Hicksian demand equation, one may obtain an ordinary demand system as

$$q_i = h_i[v(p,m), p] \qquad (10)$$

This approach was used by Deaton and Muellbauer (9) to derive the almost ideal demand system (AIDS).

Thus far, all the demand systems are derived from some assumed functional form of utility, indirect utility, or cost function. Another approach of deriving a demand model is to approximate the conceptual demand model (equation 4) directly without imposing any assumption on the structure of utility function, and then incorporate parametric restrictions provided by the classical demand theory. By applying the first-order differential approximation of the conceptual demand model, one can obtain an ordinary demand system as

$$dq_i = \sum_{j=1}^{n} (\partial q_i/\partial p_j) \, dp_j + (\partial q_i/\partial m) \, dm \qquad i=1,2,..,n \qquad (11)$$

This demand system is quite general in relating to some small changes from any given point on the n-commodity demand surface.

By multiplying both sides of equation 11 with p_i/m and using expenditure share $w_i = p_i q_i/m$, one can obtain a demand system expressed in logarithmic differential form:

$$w_i d(\log q_i) = \sum_{j=1}^{n} p_i p_j/m \, \partial q_i/\partial p_j \, d(\log p_j) + p_i \, \partial q_i/\partial m \, d(\log m) \qquad (12)$$

This is the Rotterdam demand system before replacing the price slopes by the Slutsky equation (Theil, 34).

One may alternatively express the price slopes of equation 11 in terms of elasticities, and obtain the differential-form demand system:

$$dq_i/q_i = \sum_{j=1}^{n} e_{ij} \, (dp_j/p_j) + \delta_i \, (dm/m) \qquad i=1,2,..,n \qquad (13)$$

where $e_{ij} = (\partial q_i/\partial p_j)(p_j/q_i)$ is a price elasticity of the ith commodity with respect to a price change of the jth commodity, and $\delta_i = (\partial q_i/\partial m)(m/q_i)$ is an

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expenditure (or income) elasticity showing the effect of the ith quantity in response to a change in per capita expenditure. This demand model has been extensively applied in Huang (*18*) and this report.
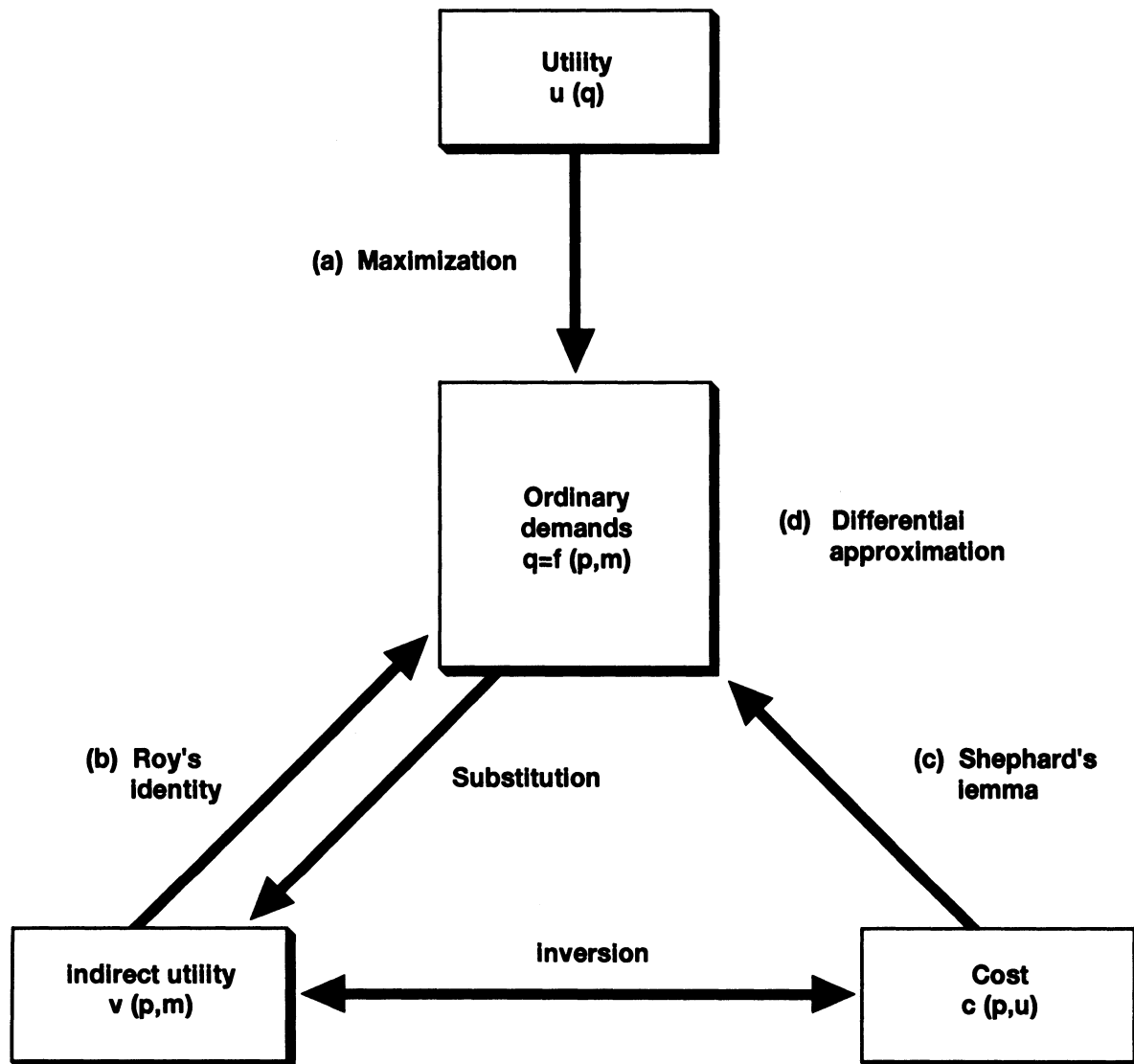
Some alternative routes of deriving an ordinary demand system are presented in figure 1 with an arrow indicating the direction of derivation. According to the figure, one can derive an ordinary demand system by applying only one of the following four approaches: (a) solving the conditions of utility maximization under an assumed utility function, such as the linear expenditure and S-branch demand systems; (b) applying Roy's identity to an assumed indirect utility function, such as the indirect translog demand system; (c) applying Shephard's lemma to an assumed cost function, such as the almost ideal demand system; and (d) approximating the conceptual demand model directly, such as the Rotterdam and differential-form demand systems.

The demand systems derived from the utility function approach, including the application of indirect utility and cost functions, are in general theoretically consistent. Conceptually, an infinite variety of functional forms for a utility function could be used to generate a demand system. Only a few demand models discussed in this report are considered to be realistic and manageable in applied demand analysis. Thus the application of a particular utility function may lose sight of some potential alternative or more general specification. In particular, the linear expenditure system is rather restrictive in the sense that both inferior goods and complementarity in the cross-price response are not permitted in the system because of additive utility structure. Besides, these demand systems, except for the simplified version of the AIDS, are nonlinear in parameters. Although some computer software packages for estimating nonlinear regressions are available, the estimation of these demand systems would require a heavy workload in computing when the number of commodities included in a demand system is large. On the other hand, the Rotterdam and differential-form demand systems are direct approximations of conceptual demand relationships and impose no rigid assumption on the functional form of utility. Also, both demand systems are linearized in parameters, and the computational burden can be reduced considerably, especially for the estimation of a large-scale demand system.

The application of the differential-form demand system has some additional advantages. The demand system is the only model that does not require consecutive time series data on expenditure shares, which were not available for this report and many other food demand analyses. All other demand systems, however, are uniformly specified by taking expenditure shares as endogenous variables. Another advantage of using the differential-form demand system is that one can directly interpret demand parameters as elasticities. Although other demand systems are capable of generating elasticities, the generating process, however, could introduce sizable measurement errors. For example, as noted in Green and Alston (*12*), price elasticity computations in the commonly used linear approximated AIDS model are theoretically incorrect. Green and Alston provide a formula for calculating price elasticities, but it involves solving n^2 complicated simultaneous equations for n goods. Besides, the generated price elasticities may be unstable inasmuch as they are functions of expenditure shares which are stochastic variables in the AIDS model. If the objective of applying an AIDS model is to obtain price

Figure 1
Modeling ordinary demand systems

```
                        ┌──────────────┐
                        │   Utility    │
                        │    u (q)     │
                        └──────────────┘
                               │
                               │
         (a) Maximization      │
                               ▼
                        ┌──────────────┐
                        │  Ordinary    │
                        │  demands     │   (d)  Differential
                        │  q=f (p,m)   │        approximation
                        └──────────────┘
        (b) Roy's        Substitution        (c) Shephard's
            identity                             lemma

   ┌──────────────┐                        ┌──────────────┐
   │Indirect utility│      Inversion       │    Cost      │
   │   v (p,m)     │◄──────────────────────►│   c (p,u)    │
   └──────────────┘                        └──────────────┘
```

Examples:

(a) The linear expenditure and S-branch demand systems

(b) The indirect translog demand system

(c) The almost ideal demand system

(d) The Rotterdam and differential-form demand systems

elasticities, the application trades too much empirical interest for model rigidity. This is another reason for preferring the application of a differential-form demand system in this report.

Parametric Constraints of Ordinary Demand Systems

To ensure theoretical consistency in applying the Rotterdam and differential-form demand systems, one needs to incorporate the parametric constraints provided by the classical demand theory as that documented in Hicks (*14*). Although the derivation of these constrained relationships can be found in the literature, it may be helpful to include a brief explanation here for completeness of discussion.

To show the effects of changes in prices and income on quantities demanded and the marginal utility of income, one can obtain the total differential of the necessary condition of equations 2 and 3 from any given point on the n-commodity demand surface as

$$\sum_{j=1}^{n} u_{ij}\, dq_j = p_i\, d\pi + \pi\, dp_i \qquad i=1,2,..,n \qquad (14)$$

$$\sum_{j=1}^{n} p_j\, dq_j + \sum_{j=1}^{n} q_j\, dp_j = dm \qquad (15)$$

or expressed in matrix form as

$$\begin{bmatrix} H & -p \\ -p' & 0 \end{bmatrix} \begin{bmatrix} dq \\ d\pi \end{bmatrix} = \begin{bmatrix} \pi I_n & 0 \\ q' & -1 \end{bmatrix} \begin{bmatrix} dp \\ dm \end{bmatrix} \qquad (16)$$

where H is defined previously as the $n \times n$ Hessian matrix $[u_{ij}(q)]$, and I_n is the $n \times n$ identity matrix. The solution of dq and $d\pi$ is obtained as

$$\begin{bmatrix} dq \\ d\pi \end{bmatrix} = \begin{bmatrix} H & -p \\ -p' & 0 \end{bmatrix}^{-1} \begin{bmatrix} \pi I_n & 0 \\ q' & -1 \end{bmatrix} \begin{bmatrix} dp \\ dm \end{bmatrix} \qquad (17)$$

One may also obtain the solution of dq and $d\pi$ by directly differentiating the equilibrium conditions of equations 4 and 5:

$$dq_i = \sum_{j=1}^{n} (\partial q_i/\partial p_j)\, dp_j + (\partial q_i/\partial m)\, dm \qquad i=1,2,...,n \qquad (18)$$

$$d\pi = \sum_{j=1}^{n} (\partial \pi/\partial p_j)\, dp_j + (\partial \pi/\partial m)\, dm \qquad (19)$$

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or expressed in matrix form as

$$
\begin{bmatrix} dq \\ d\pi \end{bmatrix} = \begin{bmatrix} Q_p & q_m \\ \pi_p{}' & \pi_m \end{bmatrix} \begin{bmatrix} dp \\ dm \end{bmatrix}
\tag{20}
$$

where $Q_p = [\partial q_i/\partial p_j]$ is the $n \times n$ matrix of price slopes, $q_m = (\partial q_i/\partial m)$ and $\pi_p = (\partial \pi/\partial p_j)$ are the $n \times 1$ vectors, and $\pi_m = \partial \pi/\partial m$ is a scalar.

By comparing equations 17 and 20, one can obtain the "fundamental matrix equation" as follows:

$$
\begin{bmatrix} Q_p & q_m \\ \pi_p{}' & \pi_m \end{bmatrix} = \begin{bmatrix} H & -p \\ -p' & 0 \end{bmatrix}^{-1} \begin{bmatrix} \pi I_n & 0 \\ q' & -1 \end{bmatrix}
\tag{21}
$$

To find the solution, instead of following the conventional practice by inverting the matrix directly, Kuznets (*28*) set the matrix inversion as

$$
\begin{bmatrix} H & -p \\ -p' & 0 \end{bmatrix}^{-1} = \begin{bmatrix} B & b \\ b' & c \end{bmatrix}
\tag{22}
$$

in which the following conditions should be satisfied:

$$HB - pb' = I_n, \quad -p'B = 0, \quad Hb - pc = 0, \quad \text{and} \quad -p'b = 1.$$

Consequently, the solution of equation 21 may be expressed in the following functional form:

$$
\begin{bmatrix} Q_p & q_m \\ \pi_p{}' & \pi_m \end{bmatrix} = \begin{bmatrix} (\pi B + bq') & -b \\ (\pi b' + cq') & -c \end{bmatrix}
\tag{23}
$$

Based on this equation and the conditions posed in equation 22, one can derive the information of comparative static properties of an ordinary demand system in the form of partial derivatives as follows:

$$q_m = H^{-1} p \; \pi_m \tag{24}$$

$$\pi_m = (p' \; H^{-1} \; p)^{-1} \tag{25}$$

$$Q_p = \pi \; H^{-1} - (\pi/\pi_m) \; q_m \; q_m{}' - q_m \; q' \tag{26}$$

$$\pi_p = \pi \; q_m + \pi_m \; q \tag{27}$$

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In particular, a typical entry of the matrix Q_p in equation 26 is given by

$$\partial q_i/\partial p_j = \pi h^{ij} - (\pi/\pi_m)(\partial q_i/\partial m)(\partial q_j/\partial m) - (\partial q_i/\partial m)q_j \qquad i,j=1,2,..,n \qquad (28)$$

where h^{ij} is the i,j element of H^{-1}. This equation represents the well-known Slutsky equation by showing how the price effect can be separated into three components. The first term πh^{ij} is called specific substitution effect, showing the response to a marginal utility of money-compensated price change as $(\partial q_i/\partial p_j)_\pi$. The second term $(\pi/\pi_m)(\partial q_i/\partial m)(\partial q_j/\partial m)$ is called general substitution effect which is independent of utility. These first two terms represent total substitution effect, showing the response to a utility-compensated price change as $(\partial q_i/\partial p_j)_u$. Finally, the last term $(\partial q_i/\partial m)q_j$ is the income effect.

The Slutsky equation 28 also provides information in relating to what Frisch (10) called money flexibility, which is defined as $\omega = m\,(\pi_m/\pi)$. Frisch assumed that the order of magnitude ω ranging from -0.1 to -10 represents population groups from the rich to extremely poor. As shown in appendix D, Brandow (2) and George and King (11) assumed that the money flexibility of U.S. consumers is -0.86 for generating their price elasticity matrices.

The constrained relationships of an ordinary demand system can be derived from equations 24 to 27 as follows:

- *Engel aggregation*: Based on $p'b = -1$, one can obtain

$$\sum_{i=1}^{n} p_i\, \partial q_i/\partial m = 1 \qquad (29)$$

$$\text{or} \qquad \sum_{i=1}^{n} w_i\, \delta_i = 1 \qquad (30)$$

where $w_i = p_i\, q_i/m$ is the expenditure share of the ith commodity, and $\delta_i = (\partial q_i/\partial m)(m/q_i)$ is the expenditure elasticity of the ith commodity.

- *Homogeneity condition*: Based on $Q_p\, p = (\pi B + bq')\, p = -\,m\, q_m$, one can obtain

$$\sum_{j=1}^{n} (\partial q_i/\partial p_j)\, p_j = -m\, (\partial q_i/\partial m) \qquad (31)$$

$$\text{or} \qquad \sum_{j=1}^{n} e_{ij} + \delta_i = 0 \qquad i=1,2,..,n \qquad (32)$$

where $e_{ij} = (\partial q_i/\partial p_j)(p_j/q_i)$ is the price elasticity of the ith commodity, with respect to a price change of the jth commodity.

- *Symmetry condition*:   Based on $b_{ij} = b_{ji}$, one can obtain

$$\partial q_i/\partial p_j + (\partial q_i/\partial m) \ q_j = \partial q_j/\partial p_i + (\partial q_j/\partial m) \ q_i \qquad (33)$$

or $\quad e_{ij}/w_j + \delta_i = e_{ji}/w_i + \delta_j \qquad (34)$

- *Negativity condition*:   Based on $b_{ii} < 0$, one obtains

$$\partial q_i/\partial p_i + (\partial q_i/\partial m) \ q_i < 0 \qquad (35)$$

or $\quad e_{ii} + w_i\delta_i < 0 \qquad (36)$

- *Compensated linkage condition*:   Based on the Slutsky equation, one can obtain the Hicks-Allen compensated cross-price elasticity as

$$(\partial q_i/\partial p_j)_u = \partial q_i/\partial p_j + (\partial q_i/\partial m) \ q_j \qquad (37)$$

or $\quad e_{ij}^* = e_{ij} + w_j \ \delta_i \qquad (38)$

where $e_{ij}^* = (\partial q_i/\partial p_j)_u \ (p_j/q_i)$ is the compensated elasticity of the ith commodity with respect to a price change of the jth commodity.

Estimation Procedures

The methodology of estimating a large-scale disaggregate ordinary demand system by incorporating parametric constraints is developed in this section. At the beginning, a constrained maximum likelihood procedure for estimating an aggregate demand system is presented. Then, the estimation procedure is extended and modified for use in the estimation of a large-scale disaggregate demand system with limited sample observations.

Constrained Maximum Likelihood Procedure

By applying the differential-form demand model shown in equation 13, one may present an empirical demand system consisting of n commodities as a set of linear equations with $n(n+1)$ demand parameters:

$$q_1' = e_{11} \ p_1' + e_{12} \ p_2' + \ldots + e_{1n} \ p_n' + \delta_1 \ m'$$
$$\vdots$$
$$q_n' = e_{n1} \ p_1' + e_{n2} \ p_2' + \ldots + e_{nn} \ p_n' + \delta_n \ m' \qquad (39)$$

where variables q_i', p_i', and m' are the relative changes in quantity, price, and per capita expenditure. For example, the quantity variable at time t is defined as the first-order difference form $(q_t-q_{t-1})/q_{t-1}$. The parameters e_{ij} and δ_i are price and expenditure elasticities. To simplify the discussion of estimation procedure, I did not present a constant term in each demand equation throughout this section, though I added it to model estimation in the Empirical Results section.

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To ensure internal consistency with the demand structure provided by the classical demand theory, I incorporated the following parametric constraints as prior information into estimation:

$$\text{Homogeneity:} \qquad \sum_{j=1}^{n} e_{ij} + \delta_i = 0 \qquad i=1,2,..,n \qquad (40)$$

$$\text{Symmetry:} \qquad e_{ji}/w_i + \delta_j = e_{ij}/w_j + \delta_i \qquad i,j=1,2,..,n \qquad (41)$$

$$\text{Engel aggregation:} \qquad \sum_{i=1}^{n} w_i \delta_i = 1 \qquad (42)$$

where $w_i = p_i q_i/m$ is a fixed expenditure weight of the ith commodity at the base period.

Although the parametric constraints derived from individual consumer behavior may not hold exactly in a market demand analysis with the selected functional form of a demand system, the potential bias in aggregation and model specification is assumed to have negligible effects. Also, the negativity condition (that is, $e_{ii} + w_i \delta_i < 0$) of an ordinary demand system is not considered here, partly because there is no reduction in the number of parameters to be estimated and thus no gain in asymptotic efficiency of estimates, and partly to avoid introducing parametric inequality constraints that would increase the complexity of estimation.

The stochastic specification of an ordinary demand system in equation 39 for T sample observations can be represented in a Kronecker product form as

$$y = (I_n \otimes X) \alpha + u, \text{ where} \qquad (43)$$

y is the nT x 1 vector of observations, obtained by stacking the relative change in the quantity of each equation in the system,
I_n is the n x n identity matrix,
X is the T x $(n+1)$ matrix containing the observations of the relative change in prices and per capita expenditure,
α is the $n(n+1)$ x 1 vector of all parameters, obtained by stacking the parameters of each equation, and
u is the nT x 1 vector of random disturbances.

Using the Engel aggregation, one can express the expenditure elasticity of the nth commodity as a function of the expenditure elasticities of all other commodities as

$$\delta_n = 1/w_n - \sum_{i=1}^{n-1} (w_i/w_n)\delta_i \qquad (44)$$

The symmetry conditions permit the representation of $n(n-1)/2$ cross-price elasticities as

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$$e_{ji} = (w_i/w_j)e_{ij} + (\delta_i - \delta_j)w_i \qquad j=2,3,\ldots,(n-1); i=1,2,\ldots,(j-1) \qquad (45)$$

$$e_{nj} = (w_j/w_n)e_{jn} + w_j\delta_j + \sum_{i=1}^{n-1}(w_iw_j/w_n)\delta_i - (w_j/w_n) \qquad j=1,2,\ldots,(n-1) \qquad (46)$$

Finally, the homogeneity constraints with the other conditions lead to the expressions of the nth direct-price elasticities as follows:

$$e_{ii} = -\sum_{j=1}^{i-1}(w_j/w_i)e_{ji} - \sum_{j=i+1}^{n}e_{ij} - \sum_{j=1}^{i-1}w_j\delta_j - (1 - \sum_{j=1}^{i-1}w_j)\delta_i \qquad i=1,2,\ldots,(n-1) \qquad (47)$$

$$e_{nn} = -\sum_{j=1}^{n-1}(w_j/w_n)e_{jn} - 1 \qquad (48)$$

These parametric constraints can be expressed in matrix form as

$$\alpha = R\beta + h, \text{ where} \qquad (49)$$

α is the $n(n+1)$ x 1 vector of all parameters obtained by stacking the parameters of each equation,
β is the $[n(n+1)/2 - 1]$ x 1 vector of parameters appearing on the right side of equations 44 to 48,
R is the $n(n+1)$ x $[n(n+1)/2 - 1]$ matrix of constraints, and
h is the $n(n+1)$ x 1 vector of constant entries.

Two alternative approaches of the constrained maximum likelihood method are available for the estimation of an ordinary system: one is the substitution approach and the other is the Lagrange-multiplier approach. The substitution approach has been used by Huang (*18*) and Huang and Haidacher (*25*). The idea of this approach is to eliminate as many parameters as the number of imposed restrictions and to rewrite the constrained likelihood function as a function of the remaining parameters after reduction:

$$y^* = (I_n \otimes X) R \beta + u \qquad (50)$$

where $y^* = y - (I_n \otimes X) h$. Note that, of the total $n(n+1)$ demand parameters in α, only $[n(n+1)/2 - 1]$ demand parameters in β are required to be estimated directly. Thus this statistical model, which reduces by more than half the total demand parameters, not only saves much time in computing but also alleviates the potential problem of multicollinearity and improves the statistical efficiency of estimates.

Suppose that the random disturbances at time t, say $u_t = (u_{1t},\ldots, u_{nt})'$, are distributed according to a multivariate normal $N(0,\Omega)$. Then the maximization of the likelihood function for T observations is equivalent to the maximization of the following equation:

$$L(\beta) = - u' (\Omega^{-1} \otimes I_T) u \qquad (51)$$

where $u = y* - (I_n \otimes X) R \beta$. By differentiating $L(\beta)$ with respect to β and then setting it equal to zero, one can obtain a set of normal equations:

$$R'(\Omega^{-1} \otimes X') [y* - (I_n \otimes X) R \beta] = 0 \tag{52}$$

Given a prior consistent estimate of Ω, say $\hat{\Omega}$, the consistent estimate of β is then

$$\hat{\beta} = [R' (\hat{\Omega}^{-1} \otimes X'X) R]^{-1} [R' (\hat{\Omega}^{-1} \otimes X') y*] \tag{53}$$

Since the estimate of the covariance matrix for disturbances provided by ordinary least squares of the unconstrained model is consistent, one may use this estimate, say $\hat{\Omega}$, to obtain $\hat{\beta}$. The asymptotic covariance of $\hat{\beta}$ is then approximated by

$$\hat{\Omega}_\beta = [R' (\hat{\Omega}^{-1} \otimes X'X) R]^{-1} \tag{54}$$

In view of parametric constraints, one can generate the remaining unknown demand parameters and associated asymptotic covariance matrix. The consistent estimator of α is given by

$$\hat{\alpha} = R \hat{\beta} + h \tag{55}$$

and its asymptotic covariance by

$$\hat{\Omega}_\alpha = R \hat{\Omega}_\beta R' \tag{56}$$

An alternative constrained maximum likelihood method is the Lagrange-multiplier approach as employed by Court (6) and Byron (4) for estimating ordinary demand systems. The idea of this approach is to extend the maximization problem of equation 51 by adding a Lagrangean term to each concentrated likelihood function. This approach gives the same results as those obtained by applying the substitution approach. As discussed in Huang (22), however, the Lagrange-multiplier approach requires direct estimation of $n(n+2)$ parameters, including the whole set of demand parameters and a vector of Lagrange multipliers for an ordinary demand system of n commodities. By applying the substitution approach, however, one needs to directly estimate only about half the total demand parameters; that is, $[n(n+1)/2 - 1]$ parameters. If the primary objective is to obtain sustainable estimates of the set of price and expenditure elasticities, the substitution approach is computationally more efficient and more cost-effective than the Lagrange-multiplier approach. Therefore, the substitution approach was chosen for this report.

Estimation of a Large-Scale Ordinary Demand System

The estimation of a large-scale demand system is intractable if the degrees of freedom in estimation are insufficient. For example, for estimating a demand system consisting of 39 food categories and 1 nonfood sector as in this report, there are 42 parameters in each demand equation, but only 38 annual data observations for the estimation. The number of sample observations is obviously less than the number of demand parameters in each equation. Even

though the number of demand parameters required to be directly estimated can
be reduced substantially by incorporating the parametric constraints into
estimation, the covariance matrix of residuals (that is $\hat{\Omega}$ in equation 53)
required as prior information in the constrained maximum likelihood estimation
should be obtained from the unconstrained model. One might argue that the
degrees of freedom may not be a technical problem when sufficiently long
historical data series are available. The use of such lengthy time series
data, however, may introduce an additional potential problem of structural
changes in consumer demand. Instead of waiting for the availability of more
data, it is desirable to develop an estimation procedure that can be used to
estimate a large-scale demand system under the limitation of sample
observations.

Available literature indicates that the S-branch demand system of Brown and
Heien (3) and the hierarchic linear expenditure system of Deaton (7) were
designed for disaggregate demand application. They reduced the dimension of
the demand parameter space by imposing the assumption of separable utility
structure, and derived the generalized linear expenditure systems. While
their demand systems are consistent with the theory of choice, the application
of separability assumptions arbitrarily rules out possible specific
substitution effects in the Slutsky equation and thus imposes a very
restrictive pattern on the cross-price elasticities across different commodity
groups. Without a substantive theoretical or empirical justification, the
usefulness of such restrictive separability assumptions is questionable,
especially for the study of demand relationships among foods.

The estimation procedure proposed in this report is similar to that used in
Huang (18, 22). To facilitate the presentation, adapting the demand system in
equation 39 to a disaggregate demand system with N food categories and a
composite nonfood sector, I expressed the demand system as the following $N+1$
equations:

$$q_i' = \sum_{j=1}^{N} e_{ij}\, p_j' + e_{i0}\, P_0' + \delta_i\, m' \qquad i=1,2,\ldots,N$$

$$Q_0' = \sum_{j=1}^{N} e_{0j}\, p_j' + e_{00}\, P_0' + \delta_0\, m' \qquad\qquad (57)$$

where q_i' and p_j' are relative changes in quantities and prices of food
categories, and Q_0' and P_0' are relative changes in quantity and price of the
nonfood sector. Again, I did not present a constant term in each demand
equation throughout this section for simplifying the discussion of estimation
procedure, though it was added to model estimation. To make the estimation of
this large-scale demand system feasible, I carried out the estimation as
outlined in the following three steps.

In the first step, all food categories in the disaggregate demand system are
divided into groups, and an aggregate demand system for these group aggregates
is estimated directly. Suppose that the N food categories are partitioned

into G groups. Then the demand system in equation 57 can be rewritten as a set of $(G+1)$ equations:

$$Q_I' = \sum_{J=1}^{G} E_{IJ} P_J' + E_{I0} P_0' + \delta_I m' \qquad I=1,2,..,G$$

$$Q_0' = \sum_{J=1}^{G} E_{0J} P_J' + E_{00} P_0' + \delta_0 m' \qquad (58)$$

where Q_I' and P_J' are relative changes of aggregate quantities and prices for food groups. Since the number of groups in this aggregate demand system is sufficiently small, I applied directly the constrained maximum likelihood estimation procedure and obtain statistically efficient estimates of the group demand parameters.

In the second step, the demand parameters within each food group (including expenditure elasticities) are estimated by group, using the aggregate parameter estimates obtained from equation 58 as prior information to represent the price effects outside the food group under estimation. Specifically, taking group I as an example, a demand subsystem is represented as

$$q_i' = \sum_{j \in I} e_{ij} p_j' + \delta_i m'$$

$$+ \sum_{\substack{K=1 \\ (K \neq I)}}^{G} E_{IK} P_K' + E_{I0} P_0' \qquad i \in I \qquad (59)$$

Because the estimated demand parameters in any cross-group are not available at this stage, the estimates from the aggregate demand system are used as prior information. Accordingly, I subtracted the effects of these aggregate price changes from the endogenous variable q_i' and then estimated the demand parameters for this demand subsystem. Although the use of the aggregate cross-price elasticities is a crude approximation of the effects of other prices outside a particular food group under estimation, it is the only way to evaluate the price and expenditure responses solely for the food categories in that food group. Because the process of adjustment for q_i' uses the same aggregate estimates as prior information, regardless of the ordering of food groups, the adjusted quantities and thus the estimated demand parameters for the demand subsystem are not affected by the ordering of food groups.

In the third step, the demand parameters in each symmetric pair of cross-groups are estimated simultaneously, while the aggregate estimates obtained from equation 58 and the within-group demand parameters obtained from equation 59 are used as prior information to represent the price effects outside the cross-groups under estimation. Specifically, with a pair of cross-groups I and J as an example, the cross-group demand subsystems are represented as

$$q_i' = \sum_{k \in J} e_{ik}\ p_k' + \sum_{k \in I} e_{ik}\ p_k' + \delta_i\ m'$$

$$+ \sum_{\substack{K=1 \\ (K \neq I,J)}}^{G} E_{IK}\ P_K' + E_{IO}\ P_0' \qquad i \epsilon I$$

$$q_j' = \sum_{k \in I} e_{jk}\ p_k' + \sum_{k \in J} e_{jk}\ p_k' + \delta_j\ m'$$

$$+ \sum_{\substack{K=1 \\ (K \neq I,J)}}^{G} E_{JK}\ P_K' + E_{JO}\ P_0' \qquad j \epsilon J \qquad\qquad (60)$$

To estimate the demand parameters in a pair of cross-groups I and J, I adjusted the endogenous quantity variables q_i' and q_j' by excluding the price effects of those food categories and nonfood sector outside the corresponding cross-groups, and then estimate the demand parameters in these cross-groups simultaneously. Because the estimated parameters for the aggregate demand system and the within-group demand subsystems are available at this stage, these estimates can be used for the quantity adjustments. Finally, given the complete set of price and expenditure elasticities for all food categories, I obtained the price and expenditure elasticities for the nonfood sector by applying the Engel aggregation, homogeneity, and symmetry constraints.

In estimating the demand parameters of any cross-group in the same row, the quantity adjustment process uses the same set of prior information for the within-group parameters and the aggregate estimates for other cross-groups in that row. Consequently, the estimation of parameters for each pair of cross-groups is not affected by the ordering of food groups, because the adjusted quantities are the same regardless of the ordering of food groups. For convenience, I started with the first cross-group in the first row, and its symmetric pair in the first column, and completed the cross-price elasticities of food groups in that row and column. Then, I completed the remaining unknown price elasticities in the groups in the second row and their symmetric counterparts. Continuing such a row-column group operation, all the cross-price elasticities of food categories are obtained sequentially by group.

At this point, two important features inherent in the proposed estimation procedures for a large-scale demand system warrant explicit attention here. First, although the separability assumption of the consumer preference relationships is implicitly imposed in the process of grouping the food categories, the estimated demand parameters of the within-group and cross-group demand subsystems in the disaggregate model are not constrained by any particular parameters related to the assumption of separability utility structure. According to Frisch (10), for example, if additive utility assumption is imposed among food groups, any cross-price elasticity should be very restrictive as a function of income elasticities and a common factor of money flexibility as that applied in Brandow (2) and George and King (11).

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Second, although each demand subsystem is estimated sequentially by group, the estimated demand parameters for these demand subsystems are not affected by the initial ordering of food groups nor by any sequential aspects of the estimation.

Estimation of the Within-Group Demand Subsystem

To estimate the within-group demand parameters in the second step of the proposed estimation procedure, the demand subsystem for a food group, say group I, can be represented as follows:

$$q_i = \sum_{j \in I} e_{ij}\, p_j' + \delta_i\, m' \qquad i \in I \qquad (61)$$

$$\text{with } q_i = q_i' - \sum_{\substack{K=1 \\ (K \neq I)}}^{G} E_{IK}\, P_K' - E_{I0}\, P_0'$$

The endogenous variable q_i is the adjusted quantity obtained by subtracting the price effects of those food and nonfood prices outside the group from the quantity q_i'. Given a demand structure consisting of n food categories in a given food group, I expressed the stochastic demand equation system for T sample observations as follows:

$$y = (I_n \otimes X)\, \alpha + u, \text{ where} \qquad (62)$$

y is the nT x 1 vector of observations obtained, by stacking the adjusted relative change of quantity in equation 61,
I_n is the n x n identity matrix,
X is the T x $(n+1)$ matrix containing the observations of the relative change in prices and expenditures in a food group,
α is the $n(n+1)$ x 1 vector of all parameters, and
u is the nT x 1 vector of random disturbances.

Under this within-group demand subsystem, the only applicable parametric constraint is the symmetric condition, which provides $n(n-1)/2$ independent linear constraints on the parameters of the system:

$$e_{ji} = (w_i/w_j)\, e_{ij} + (\delta_i - \delta_j)w_i \qquad j=2,3,\ldots,(n-1);\ i=1,2,\ldots,j \qquad (63)$$

These constraints can be expressed in matrix form as

$$\alpha = R\, \beta, \text{ where} \qquad (64)$$

α is the $n(n+1)$ x 1 vector of all parameters,
β is the $n(n+3)/2$ x 1 vector of parameters in the right side of equation 63, and
R is the $n(n+1)$ x $n(n+3)/2$ matrix of constraints.

By substituting equation 64 into equation 62, I obtained a demand system represented by

$$y = (I_n \otimes X)\ R\ \beta + u \tag{65}$$

Assuming that the random disturbances at time t are distributed according to a multivariate normal $N(0,\Omega)$, I obtained the consistent estimates of β as

$$\hat{\beta} = [R'(\hat{\Omega}^{-1} \otimes X'X)\ R]^{-1}\ [R'(\hat{\Omega}^{-1} \otimes X')\ y] \tag{66}$$

where $\hat{\Omega}^{-1}$ is the estimate of disturbance covariance provided by ordinary least squares of the unconstrained model. The asymptotic covariance of $\hat{\beta}$ is then estimated by

$$\hat{\Omega}_\beta = [R'(\hat{\Omega}^{-1} \otimes X'X)\ R]^{-1} \tag{67}$$

Given the parametric constraints in equation 64, I obtained consistent estimates for α and the corresponding standard errors.

Estimation of the Cross-Group Demand Subsystem

After the estimation of all within-group demand subsystems, I estimated the demand parameters in a pair of systemwide cross-groups by imposing the implied restrictions of symmetry and homogeneity on the parameters. On the basis of the homogeneity condition, a particular cross-price elasticity, say the price change of nonfood, can be represented as the negative of the sum of remaining price and expenditure elasticities in that equation. Accordingly, a convenient way to introduce the homogeneity condition into the cross-group estimation is to adjust the relative changes of all prices and expenditures, by subtracting the relative change of the nonfood price and deleting the cross-price elasticities of nonfood from the estimation.

I simultaneously estimated the cross-price elasticities in each pair of cross-groups, say groups I and J, by applying the symmetry restriction:

$$[q_I,\ q_J] = [p_I,\ p_J] \begin{bmatrix} O & Z_{JI} \\ Z_{IJ} & O \end{bmatrix}, \text{ where} \tag{68}$$

Z_{IJ} and Z_{JI} are matrices of cross-price elasticities for the pair of cross-
   groups with element e_{ij} in Z_{IJ} and e_{ji} in Z_{JI}; $i \epsilon I$, $j \epsilon J$,
p_I and p_J are adjusted price vectors with components defined by
   $p_i = p_i' - P_o'$, $i \epsilon I$; $p_j = p_j' - P_o'$, $j \epsilon J$, and
q_I and q_J are adjusted quantity vectors with components defined as

$$q_i = q_i' - \sum_{k \epsilon I} e_{ik}(p_k' - P_o') - \delta_i\ m' - \sum_{\substack{K=1 \\ (K \neq I)}}^{G} E_{IK}(P_K' - P_o') \quad \text{for } i \epsilon I$$

$$q_j = q_j' - \sum_{k \epsilon J} e_{jk}(p_k' - P_o') - \delta_j\ m' - \sum_{\substack{K=1 \\ (K \neq J)}}^{G} E_{JK}(P_K' - P_o') \quad \text{for } j \epsilon J$$

The endogenous variables q_i and q_j are adjusted quantities of q_i' and q_j' by excluding the price effects of those foods and nonfoods outside the corresponding cross-group.

For programming the estimation procedure, it is useful to make the demand structure in equation 68 more explicit. Given the Ith group with m food categories, ordered in $1,2,..,m$, and the Jth group with n food categories ordered in $m+1,m+2,..,m+n$, the demand subsystem can be expressed as follows:

$$q_1 = e_{1,m+1}\, p_{m+1} + e_{1,m+2}\, p_{m+2} + \ldots + e_{1,m+n}\, p_{m+n}$$
$$\vdots$$
$$q_m = e_{m,m+1}\, p_{m+1} + e_{m,m+2}\, p_{m+2} + \ldots + e_{m,m+n}\, p_{m+n} \tag{69}$$

$$q_{m+1} = e_{m+1,1}\, p_1 + e_{m+1,2}\, p_2 + \ldots + e_{m+1,m}\, p_m$$
$$\vdots$$
$$q_{m+n} = e_{m+n,1}\, p_1 + e_{m+n,2}\, p_2 + \ldots + e_{m+n,m}\, p_m \tag{70}$$

I estimated the pair of cross-group price elasticities for foods in the Ith and the Jth groups by incorporating the symmetry constraints, which can be expressed as a set of $m \times n$ independent linear restrictions on the parameters of the system:

$$e_{m+j,i} = (e_{i,m+j}/w_{m+j} + \delta_i - \delta_{m+j})\, w_i \qquad i=1,2,..,m;\ j=1,2,\ldots,n \tag{71}$$

By substituting the symmetry conditions in equation 71 into equation 70, I transformed the demand subsystem for the Jth food group as follows:

$$q^*_{m+1} = e_{1,m+1}\, p^*_{1,(m+1)} + e_{2,m+1}\, p^*_{2,(m+1)} + \ldots + e_{m,m+1}\, p^*_{n,(m+1)}$$
$$\vdots$$
$$q^*_{m+n} = e_{1,m+n}\, p^*_{1,(m+n)} + e_{2,m+n}\, p^*_{2,(m+n)} + \ldots + e_{m,m+n}\, p^*_{n,(m+n)} \tag{72}$$

in which the variables are redefined as

$$q^*_{m+j} = q_{m+j} - \sum_{k=1}^{m} (\delta_k - \delta_{m+j})\, w_j\, p_j \qquad j=1,2,\ldots,n \tag{73}$$

$$p^*_{i,(m+j)} = (w_i/w_{m+j})\, p_i \qquad i=1,2,\ldots,m;\ j=1,2,\ldots,n \tag{74}$$

This demand subsystem for the Jth food group shown in equation 72, along with the demand subsystem in equation 69 specified for the Ith food group, completes the economic model for estimating the set of cross-group price elasticities. Again, it is worth noting that although a food grouping is used, the demand parameters in each cross-group are not constrained by any particular parameter, such as a money flexibility measure derived from a prior assumption about the separable utility structure.

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The demand subsystems consisting of equations 69 and 72 with stochastic specifications can be expressed in an abbreviated form as

$$y = X \beta + u, \text{ where} \tag{75}$$

y is the $(m+n)T \times 1$ vector of observations, obtained by stacking the adjusted relative change in quantities in a pair-wise food group as defined in equations 69 and 72,

X is the $(m+n)T \times mn$ matrix containing the observations of the adjusted relative change in prices in a pair-wise food group,

β is the $mn \times 1$ vector of parameters, and

u is the $(m+n)T \times 1$ vector of random disturbances.

Suppose that the random disturbances at time t are distributed according to a multivariate normal $N(0,\Omega)$ with $(m+n)$ dimensions. The constrained maximum likelihood estimates of β are obtained by

$$\hat{\beta} = [X'(\hat{\Omega}^{-1} \otimes I_T) X]^{-1} [X' (\hat{\Omega}^{-1} \otimes I_T) y] \tag{76}$$

where I_T is the $T \times T$ identity matrix, and $\hat{\Omega}^{-1}$ is the estimate of disturbance covariance provided by ordinary least squares of the unconstrained model. The asymptotic covariance of $\hat{\beta}$ can be estimated by

$$\hat{\Omega}_\beta = [X'(\hat{\Omega}^{-1} \otimes I_T) X]^{-1} \tag{77}$$

Finally, I derived the parameters and standard errors in the demand subsystem for the Jth food group by applying the symmetric relationships in equation 71.

Empirical Results

The methodology developed in this report is applied to the estimation of a large-scale U.S. food demand system. As discussed in the estimation procedures, it is possible to estimate a large-scale demand system with limited sample observations by first estimating an aggregate demand system for food groups, and then using the aggregate model as a framework for sequentially estimating a disaggregate food demand system by group. In the following sections, a discussion of data sources and an aggregate food demand system is presented first. The empirical results of both the uncompensated and compensated disaggregate food demand systems are then presented. Finally, potential applications of the estimated demand systems to the food consumption forecasts and consumer welfare are discussed.

Data Sources and Aggregate Food Demand System

In estimation of a food demand system, the basic data required are the time series data of food prices, quantities, and per capita total expenditure, and a set of fixed values of expenditure weights represented for the sample period. The extent of detailed food classification for the demand system depends mainly on the practical use of food categories and the availability of consistent time series data on food prices and quantities. After an extensive

search for data sources, I obtained annual data covering 1953-90 for 39 food categories and 1 nonfood sector. All food categories are further divided into seven food groups along with one nonfood sector for use in the estimation of an aggregate food demand system. Each food group consists of closely related food categories as follows:

(1) *Meats and other animal proteins*, consisting of beef and veal, pork, other meats, chicken, turkey, fresh and frozen fish, canned and cured fish, eggs, and cheese;

(2) *Staple foods*, containing fluid milk, evaporated and dry milk, wheat flour, rice, and potatoes;

(3) *Fats and oils*, consisting of butter, margarine, and other fats and oils;

(4) *Fresh fruits*, consisting of apples, oranges, bananas, grapes, grapefruits, and other fresh fruits;

(5) *Fresh vegetables*, containing lettuce, tomatoes, celery, onions, carrots, and other fresh vegetables;

(6) *Processed fruits and vegetables*, containing fruit juice, canned tomatoes, canned peas, canned fruit cocktail, peanuts and tree nuts, and other processed fruits and vegetables; and

(7) *Desserts, sweeteners, and coffee*, consisting of coffee and tea, ice cream and other frozen dairy products, sugar, and sweeteners.

Most food category price indexes are components of the consumer price index (CPI) obtained from the U.S. Department of Labor (*38*). The CPI did not report retail price indexes for grapes, grapefruits, celery, onions, carrots, and canned tomatoes in 1979. I used the estimates from Huang (*18*), in which a set of price linkage equations between retail and farm prices for 1959-78 was estimated first, and then I used the 1979 farm prices to compute the retail prices of that year. Since the CPI does not have price data for peanuts and tree nuts, I used the relative change in the farm price of peanuts to represent the relative category price. In fact, peanuts are the major part, accounting for 74 percent (6.4 pounds) in 1987, of per capita consumption of the peanuts and tree nuts category. As to the price of cheese, the CPI did not report consistent data over the years. Before 1977, only the retail price of American processed cheese slices was reported, and thereafter both processed cheese and cheddar cheese were included. American cheddar cheese accounted for 44 percent (10.58 pounds) of the cheese category in 1987. To better represent the aggregate cheese price, the relative wholesale price change of Wisconsin cheddar cheese (assembly point, 40-pound block) obtained from the U.S. Department of Agriculture's Agricultural Marketing Service (*36*) was used as a proxy for the relative retail cheese price.

Per capita total expenditure is computed by dividing the personal consumption expenditures (obtained from the U.S. Department of Commerce (*37*)) by the civilian population of 50 States on July 1 of each year. The quantity index for the nonfood sector is calculated from the current value of per capita

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expenditure on nonfood divided by the CPI of all items less food. To calculate the food expenditure weights for representing the mean values of the sample period, I used the value aggregates of food items for 1967-69 compiled from table 3 of the 1979 issue of *Food Consumption, Prices, and Expenditures* (*29*). The expenditure weights between food and nonfood categories for 1967-69 are calculated from the personal consumption expenditures (*37*). Given the expenditure weight for total food, this weight is proportionally allocated to each individual food item in accordance with its value in 1967-69. The expenditure weights of 1967-69, about the middle of the sample period, could be quite representative, especially for those food categories having expenditure weights on a steady trend over the years.

The food quantity data are compiled from *Food Consumption, Prices, and Expenditures* (*29*) by using the expenditure weights of 1967-69 to calculate the Laspeyres quantity indexes for each food category. These quantity indexes are consistent with the recently published CPI indexes for composite food and nonfood categories, which are measured with a base of 1967=100. The food quantity data are compiled in two steps. First, to match the available expenditure weight data for 101 food items in the base period 1967-69, I aggregated a set of original per capita food consumption data series, consisting of 161 individual food items, into 101 items by summing their food weights in a particular food category. The aggregation process is a convenient and reasonable measure because of the homogeneous nature of commodities inside a particular food category. Second, by using the available expenditure weights, I then aggregated the quantity data of 101 items into a set of 39 food categories expressed in Laspeyres quantity indexes.

The quantity data used in this report differ slightly from those used in Huang (*18*) for a disaggregate food demand system. The number of food categories in this demand system has been reduced from the previous 40 to 39 categories because of a deletion in the cabbage data series. The data for pork have been revised in accordance with recently published data series, which are compiled using the revised conversion factors by adjusting carcass-weight pork consumption to retail equivalent weights to reflect changes in amounts of fat, bone, and skin sold at the retail market. The data for fluid milk have been significantly revised in accordance with recently revised published data series. Also, fluid milk is redefined as the total weight of whole milk, lowfat milk, and skim milk. A set of original data series for 23 individual food items, mostly fresh vegetables, and the processed fruits and vegetables, is deleted from data compilation because the data were discontinued after 1985. The quantity data for 28 other missing items of processed fruits and vegetables, however, are estimated from available scanner data on the basis of an assumption that the consecutive yearly changes of per capita consumption are highly correlated with changes in foodstore quantity sales of the same item.

As with many other food demand studies, the available price and quantity data series do not always correspond as closely as one would like. The quantity data are defined as the retail-weight equivalent of civilian food disappearance. Many food commodities, however, are sold to manufacturers as raw materials for processing and through wholesale channels to restaurants, institutions, and fast-food stores. Thus, the quantity data are not direct

Figure 2
Beef and veal: quantity change
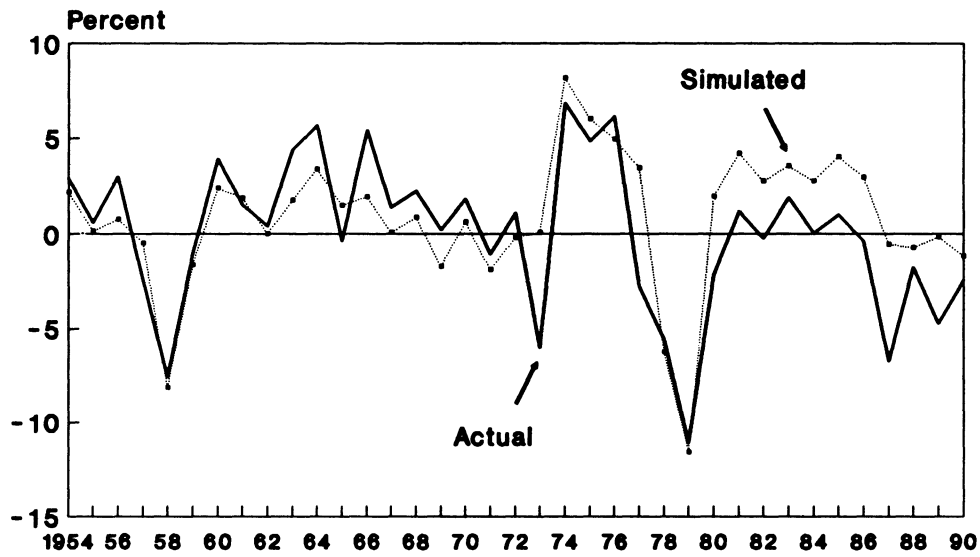
Figure 3
Beef and veal: quantity level

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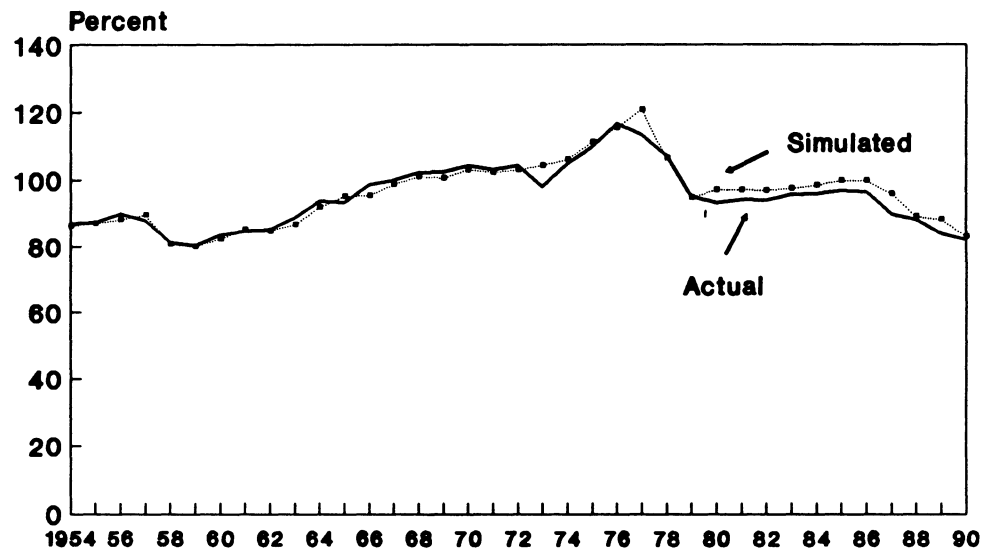
Watson (*DW*) statistics, because these diagnostic statistics do not directly apply to the demand system, in which variables are expressed in the first-order differences, and all demand equations are simultaneously estimated by incorporating parametric constraints across equations.

The empirical measurements of *RMS* and *MAE* for the simulation over the period 1954-90 are presented in the last two columns of table 3. Among a total of 40 equations, 31 cases of *RMS* and 26 cases of *MAE* had average errors of less than 5 percent. One can reasonably conclude that the conformity of the simulated quantities demanded with the sample observations appears reasonably good. These results provide evidence that the estimated demand parameters adequately reflect consumer responses to changes in prices and income over the sample period.

Graphic presentation of the actual and simulated results often provides a better comprehension of simulation performance and helps to ascertain the consistency of the error measurements. To save space, I presented examples of the beef and veal category in figure 2. The figure depicts the relative changes of actual and simulated quantity demanded in the beef and veal category; its *MAE* error is 2.11 percent. The direction of simulated changes is generally quite consistent with actual changes. The number of turning point errors is only 9 out of 37 observations. In addition, the simulation results in terms of the level of quantity demanded in the beef and veal category are depicted in figure 3. The conformity of simulated and actual values for the beef and veal category is reflected by an *RMS* error of only 2.77 percent. All other graphic comparisons of actual and simulated results in terms of the level of quantity demanded are presented in appendix A.

Another potential application of the estimated demand system is to evaluate the food program effects on consumer welfare. Marshall's concept of consumer surplus, defined as the area under an uncompensated demand curve over a price change, has been widely used as a welfare measure to analyze agricultural policy, such as in Tolley, Thomas, and Wong (*35*). Deaton and Muellbauer (*8*, p. 185) argued, however, that the use of consumer surplus as an analytical tool frequently seems to lead to errors and confusion. They proposed that taking the area under a compensated or Hicksian demand curve over a price change would be an appropriate welfare measure. The rationale of using this welfare measure is that the Hicksian demand functions are the derivatives of the cost function, and the integration of the demand functions gives the differences in costs of reaching the same indifference curve at two different price vectors.

Since the use of the compensated demand curves has been recognized leading to the appropriate welfare measures, Willig (*40*), Shonkwiler (*33*), and Just, Hueth, and Schmitz (*26*) had proposed some approximated Hicksian welfare measures to correct the Marshallian consumer surplus. Also, Hausman (*13*) derived a measure of the Hicksian compensating variation from an indirect utility function, which is retrieved from an observed market demand equation. These approaches, however, are useful for the welfare analysis with only a single price change. Given the interdependent nature of demands in consumer budgeting, such a welfare analysis is obviously not practical for empirical application. To improve the welfare measurement reflecting multiple price

model are expressed in terms of relative changes in quantities demanded, say $\hat{q}_{it}'$ at year t. These forecasting results for a demand system of n food categories can be represented by

$$\hat{q}_{it}' = \sum_{j=1}^{n} e_{ij} \, p_{jt}' + \delta_i \, m_t' + c_i \qquad i=1,2,..,n; \ t=1,2,..,T \qquad (85)$$

where the exogenous variables p_{jt}' and m_t' are the relative changes in price and expenditure, and the parameters e_{ij}, δ_i, and c_i are price elasticity, expenditure elasticity, and constant term. In practice, it is desirable to present the forecasting results expressed in terms of quantity levels, say $\hat{q}_{it}$, by transforming the projected relative changes into quantity levels on the basis of quantity level available in the previous year, q_{t-1}, as

$$\hat{q}_{it} = (1 + \hat{q}_{it}') \, q_{t-1} \qquad i=1,2,..,n; \ t=1,2,..,T \qquad (86)$$

To understand the potential analytic and forecasting capability of the demand system, I conducted an *ex post* simulation over the sample period. The simulation uses the actual relative changes of prices and expenditures as input information to generate the simulated quantities demanded for a given year. The procedure is then repeated to cover the whole sample period. The error between actual and simulated values gives information about the accuracy of the simulation for that year. Another possible approach, not used here, is to compare the forecasts outside the sample period with available actual data. The problem with the latter approach is that, in addition to the difficulty of obtaining sufficient actual data beyond the sample period, the assessment of forecasting performance on the basis of only a few available observations could be misleading. Because the dependent variable is stochastic, we might erroneously conclude that forecasting performance is poor if one or more of a very few observations are far away from the mean value, even though the model accurately predicts the mean value over a large sample.

To assess the performance of the demand system, I computed the average errors of the *ex post* simulation represented by the following two measurements expressed in percentage terms: (a) one labeled *RMS* to represent the ratio of root-mean-square error of the simulated level of quantity demanded to its sample mean of actual observations over the sample period, and (b) another labeled *MAE* to represent the mean absolute error of the simulated relative change of quantity demanded as

$$RMS = [\sum_{t=1}^{T} (q_t - \hat{q}_t)^2/T \,]^{\frac{1}{2}}/\bar{q} \times 100 \qquad (87)$$

$$MAE = \sum_{t=1}^{T} |q_t' - \hat{q}_t'|/T \times 100 \qquad (88)$$

where q_t, $\hat{q}_t$, and $\bar{q}$ are respectively the levels of actual, simulated, and sample mean of per capita consumption for a sample period T years, and q_t' and $\hat{q}_t'$ are respectively the relative changes of actual and simulated per capita consumption. I did not, however, compute the conventional R^2 and the Durbin-

Table 4--Demand elasticities for general food and nonfood

Sector	Price Food	Nonfood	Expenditure
Uncompensated elasticity			
Food	-0.1850	-0.0895	0.2745
Nonfood	-.1866	-.9795	1.1661
Compensated elasticity			
Food	-.1338	.1338	NA
Nonfood	.0306	-.0306	NA
Allen's elasticity of substitution			
Food	NA	.1645	NA
Nonfood	.1645	NA	NA
Weight	.1863	.8137	NA

Note: Computed on the basis of direct-price and expenditure
elasticities of the nonfood sector and its expenditure share.
The notations are Weight (expenditure weight), and NA (not
applicable).

Table 5--Compensated demand elasticities for meats and other animal proteins

Food category	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE
BEEF.V	-0.6088	0.1214	0.1089	0.0207	0.0048	-0.0057	0.0012	0.0262	-0.0243
PORK	.2130	-.7162	.0823	.0167	.0139	.0264	.0111	.0078	-.0037
O.MEAT	.7999	.3447	-1.8764	.2764	-.0570	-.0251	.0222	-.1741	.3555
CHICKN	.1054	.0484	.1917	-.3718	-.0225	-.0134	.0179	.0797	-.0386
TURKEY	.0847	.1387	-.1363	-.0775	-.5347	.0378	.1352	-.0738	.2213
FISH	-.0996	.2636	-.0601	-.0458	.0378	.1220	.0152	.0040	.0128
C.FISH	.0218	.1108	.0529	.0617	.1352	.0152	-.3708	-.2352	.1305
EGGS	.1009	.0172	-.0913	.0603	-.0162	.0009	-.0516	-.1080	.0098
CHEESE	-.2136	-.0184	.4246	-.0664	.1107	.0065	.0653	.0223	-.2457

Price (spanning header over BEEF.V through CHEESE)

Note: Computed on the basis of estimated uncompensated price and expenditure elasticities.
The notations are BEEF.V (beef and veal), PORK (pork), O.MEAT (other meats), CHICKN (chicken),
TURKEY (turkey), FISH (fresh and frozen fish), C.FISH (canned and cured fish), EGGS (eggs),
and CHEESE (cheese).

The results of the compensated food demand system are compiled in appendix C. For convenient illustration, only the compensated demand subsystem for meats and other animal proteins is presented in table 5. In the table, for example, the compensated cross-price elasticities of beef and veal in response to the change of pork and chicken prices are 0.1214 and 0.0207, respectively. These elasticities imply that, while maintaining the same level of utility (satisfaction), the quantity demanded of beef and veal could increase by 0.1214 percent in response to a 1-percent increase in the pork price, and increase by 0.0207 percent in response to a 1-percent increase in the chicken price, because of their substitution relationships. The cross-price elasticity of beef and veal with respect to the price of cheese, however, is negative (-0.0243), a complementary relationship that may, in part, reflect such popular complementary preparations as cheeseburgers. Similar explanations can be extended to other entries of the table. In general, the magnitudes of compensated price elasticities for food categories are quite close to the uncompensated price elasticities, mainly because the expenditure share of each food category is rather small (less than 3 percent in each case). Thus the effects of income elasticity component ($\delta_i \, w_j$) in computing the compensated price elasticities are rather small.

Forecasting and Welfare Applications

The disaggregate food demand system estimated in this report can serve at least two major functions. The first function is to give a quantitative representation of the economic structure of food demands, in which the demand elasticity estimates provide information for policymakers about the program effects of direct- and cross-price changes. The second function is to provide an instrumental model for food consumption forecasts and evaluate the food program effects on consumer welfare. Since all these potential applications depend on the purpose and issue that one needs to address, there is no intent here to focus on any particular forecast or any specific policy analysis.

For empirical application, one might question whether inverting a matrix of directly estimated elasticities as in this report can represent flexibilities. As discussed in Huang (24), inverting a matrix of elasticities (or flexibilities) to obtain measures of flexibilities (or elasticities) could cause sizable errors in measurement. Therefore, the common practice of taking the reciprocal of a directly estimated price elasticity or inverting a price elasticity matrix as flexibility measures is not proper in applying a demand matrix for agricultural policy and program analyses. Consistent with Waugh's (39) view, the flexibilities from a directly estimated inverse demand system should be used to assess the price effects in response to quantity changes. To evaluate the quantity effects in response to price changes, however, the elasticities from a directly estimated ordinary demand system should be used.

The application of the estimated demand system for food consumption forecasts is rather straightforward. For conducting outlook, one may use the information on relative changes in prices and expenditures, and forecast the quantity demanded. For program analysis, one may assume various scenarios of changes in prices and expenditures, and conduct simulation experiments for evaluation of the program effects. The immediate forecasting results from the

The direct-price elasticity of food can be obtained by applying the homogeneity condition as

$$e_{ff} = - \delta_f - e_{fn} = -0.1850 \qquad (81)$$

Then, I computed the compensated cross-price elasticity of food in response to the change of nonfood price by applying the compensated linkage condition as

$$e_{fn}{}^* = e_{fn} + w_n \, \delta_f = 0.1338 \qquad (82)$$

By applying a similar formula, all other compensated price elasticities can be obtained. In particular, the compensated cross-price elasticity of nonfood in response to the change of food price is obtained as $e_{nf}{}^* = 0.0306$. The positive sign of $e_{fn}{}^*$ and $e_{nf}{}^*$ implies the substitution relationship between food and nonfood as expected.

Finally, Allen's elasticity of substitution (1, p. 508) between food and nonfood can be obtained as

$$\sigma_{fn} = e_{fn}{}^*/w_n = 0.1645, \text{ and}$$

$$\sigma_{nf} = e_{nf}{}^*/w_f = 0.1645 \qquad (83)$$

The elasticity of substitution between food and nonfood is positive indicating substitution between food and nonfood. The direct-price and expenditure elasticities for food as a whole are low, -0.1850 and 0.2745, respectively. These results are consistent with Waugh's (39) estimates of direct-price and expenditure elasticities for food, which are low, respectively, -0.24 and 0.14. Waugh's results are obtained by fitting an aggregate demand equation for per capita food consumption as a function of deflated food price and per capita deflated income for 1948-62.

Compensated Food Demand System

The compensated price elasticities can be computed from the available uncompensated price and expenditure elasticities on the basis of the Slutsky equation as

$$e_{ij}{}^* = e_{ij} + \delta_i \, w_j \qquad i,j=1,2,..,n \qquad (84)$$

where $e_{ij}{}^*$ is the compensated price elasticity of the ith food category in response to the price change of the jth food category, e_{ij} is the corresponding uncompensated price elasticity, δ_i is the expenditure elasticity of the ith food category, and w_j is the expenditure weight of the jth food category. These compensated price elasticities are useful in the following two ways: (a) to explain the Hicksian substitution or complementary relationships by showing the effect of quantity change in response to a price change given that the consumer stays on the same indifference curve, and (b) to provide input information for measuring consumer welfare that will be discussed later.

categories in such food groups as meat and other animal proteins, fresh fruits, fresh vegetables, and processed fruits and vegetables have statistically significant estimates with an expected negative sign. The estimates for rice and fresh and frozen fish, however, are positive but not statistically significant. Regarding the expenditure elasticities, in addition to those food categories in meats and other animal proteins discussed previously, other statistically significant estimates are evaporated and dry milk (0.5151), tomatoes (0.9184), celery (0.7250), canned tomatoes (0.8684), and coffee and tea (0.8176). The estimated constants indicate that there are trends of decreasing per capita consumption for pork, eggs, fluid milk, celery, other fresh vegetables, and coffee and tea, while chicken, turkey, margarine, and other processed fruits and vegetables have trends of increasing consumption. In the table, some "other" categories are defined to include those other foods in a particular food group. Their estimates, however, can hardly be accurate because available aggregate group-price indexes are used to represent the prices for these categories. For example, the aggregate price of fresh fruits is used to represent the other fresh fruits category.

Implications for the Food Sector

Given the estimates of the disaggregate food demand system, one issue frequently raised concerns the implications of these demand estimates for the food sector. In other words, what is the demand for food as a sector in response to changes in food prices and expenditures? What is the implied Allen's elasticity of substitution between food and nonfood, a measure widely used as input information in the Computable General Equilibrium model? Based on the information of the direct-price and expenditure elasticities of nonfood, I computed the elasticity measures for the food sector and compiled the results in table 4. Following is an explanation of the sequential procedure to obtain this information. The subscripts f denote food and n nonfood. The prior information required for the calculation is: (a) direct-price and expenditure elasticities for nonfood, respectively, $e_{nn} = -0.9795$ and $\delta_n = 1.1661$, and (b) expenditure shares of nonfood and food, respectively, $w_n = 0.8137$, and $w_f = 0.1863$.

At the beginning, I computed the uncompensated elasticity measures. The expenditure elasticity of the food sector can be obtained by applying the Engel aggregation as

$$\delta_f = (1 - w_n\, \delta_n)/w_f = 0.2745 \tag{78}$$

The cross-price elasticity of nonfood in response to the change of food price can be obtained by applying the homogeneity condition as

$$e_{nf} = -\, \delta_n - e_{nn} = -0.1866 \tag{79}$$

The cross-price elasticity of food in response to the change of nonfood price can be obtained by applying the symmetry constraint as

$$e_{fn} = (e_{nf}/w_f + \delta_n - \delta_f)/w_n = -0.0895 \tag{80}$$

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Table 3--Summary of major estimated demand parameters and model verification

Food category	Price elasticity	Expenditure elasticity	Trend (constant)	Errors RMS	Errors MAE
				Percent	
(1) Beef and veal	-0.6212(0.0572)	0.3923(0.1240)	-0.0001(0.0083)	2.77	2.11
(2) Pork	-.7281 (.0424)	.6593 (.1461)	-.0231 (.0098)	3.28	2.53
(3) Other meats	-1.8739 (.5480)	-.5737 (.4802)	.0321 (.0296)	8.00	5.20
(4) Chicken	-.3723 (.0560)	.0769 (.1884)	.0286 (.0123)	3.88	3.07
(5) Turkey	-.5345 (.1217)	-.1267 (.3449)	.0437 (.0218)	6.23	4.02
(6) Fresh and frozen fish	.1212 (.1606)	.4290 (.3076)	-.0187 (.0188)	4.50	3.27
(7) Canned and cured fish	-.3715 (.1486)	.3942 (.3621)	-.0113 (.0219)	4.28	3.46
(8) Eggs	-.1103 (.0172)	.2865 (.0816)	-.0223 (.0053)	2.53	2.18
(9) Cheese	-.2472 (.0833)	.4181 (.1934)	.0119 (.0118)	3.75	3.16
(10) Fluid milk	-.0431 (.1259)	.1193 (.0718)	-.0150 (.0044)	1.38	1.15
(11) Evaporated and dry milk	-.2764 (.5383)	.5151 (.2584)	-.0149 (.0151)	2.61	2.01
(12) Wheat flour	-.0777 (.1037)	.1314 (.1172)	-.0054 (.0076)	1.54	1.33
(13) Rice	.0661 (.1232)	.1475 (.4537)	.0144 (.0295)	7.21	5.41
(14) Potatoes	-.0983 (.0531)	.1100 (.3235)	-.0135 (.0209)	5.34	3.88
(15) Butter	-.2428 (.1613)	.5386 (.3659)	-.0342 (.0207)	4.12	3.28
(16) Margarine	-.0087 (.1470)	-.3355 (.2494)	.0349 (.0148)	3.05	2.57
(17) Other fats and oils	-.1393 (.0650)	.4938 (.1713)	-.0051 (.0110)	2.53	1.89
(18) Apples	-.1902 (.1295)	-.3617 (.4206)	-.0111 (.0284)	7.38	5.89
(19) Oranges	-.8486 (.1154)	-.1646 (.4765)	.0137 (.0326)	7.34	5.93
(20) Bananas	-.4985 (.1337)	.0940 (.3658)	-.0119 (.0230)	4.68	3.29
(21) Grapes	-1.1795 (.1591)	.5613 (.5710)	-.0198 (.0358)	7.99	6.03
(22) Grapefruits	-.4546 (.1246)	-.4896 (.5712)	.0486 (.0375)	9.06	7.60
(23) Other fresh fruits	-.4159 (.5166)	.1234 (.5278)	-.0350 (.0328)	7.83	6.10
(24) Lettuce	-.0904 (.0873)	.3720 (.2803)	.0051 (.0184)	4.46	3.58
(25) Tomatoes	-.6220 (.0845)	.9184 (.1906)	-.0131 (.0116)	3.26	2.48
(26) Celery	-.0775 (.0638)	.7250 (.2283)	-.0389 (.0135)	2.85	2.37
(27) Onions	-.2066 (.0474)	.0783 (.3184)	.0030 (.0209)	4.53	3.59
(28) Carrots	-.5339 (.2014)	.6750 (.5309)	-.0220 (.0322)	7.15	5.72
(29) Other fresh vegetables	-.2152 (.2407)	1.2917 (.4331)	-.0656 (.0262)	6.11	4.83
(30) Fruit juice	-.5575 (.1081)	.3664 (.5539)	.0373 (.0377)	8.05	6.29
(31) Canned tomatoes	-.1688 (.0885)	.8684 (.2654)	-.0205 (.0161)	3.71	3.23
(32) Canned peas	-.5335 (.1580)	.6282 (.3599)	-.0305 (.0217)	5.16	4.27
(33) Canned fruit cocktail	-.7400 (.3536)	.7172 (.5848)	-.0025 (.0350)	6.03	4.90
(34) Peanuts and tree nuts	-.1685 (.0778)	.0992 (.2551)	.0213 (.0165)	3.56	3.12
(35) Other processed fruits and vegetables	-.1509 (.0752)	.0216 (.1541)	.0398 (.0096)	3.12	2.94
(36) Sugar	-.0368 (.0220)	.0059 (.1761)	.0023 (.0120)	2.68	2.16
(37) Sweeteners	-.0522 (.0938)	.4190 (.2659)	-.0170 (.0168)	4.28	2.98
(38) Coffee and tea	-.1761 (.0289)	.8176 (.2153)	-.0349 (.0142)	4.02	3.18
(39) Ice cream and other frozen dairy products	-.0784 (.0955)	.2534 (.1366)	-.0000 (.0077)	1.39	1.08
(40) Nonfood	-.9795 (.0198)	1.1661 (.0093)	-.0015 (.0005)	.71	.52

Note: The figures in parentheses are the standard errors of estimates. The simulated errors are measured in two forms for the compensated demand systems over the sample period 1954-90: RMS = [$\Sigma_t(y_t - \hat{y}_t)^2/T$]$^{1/2}$ / $\bar{y}$ x 100, and MAE = $\Sigma_t|y_t' - \hat{y}_t'|/T$, t=1,2,..,T, where y_t, $\hat{y}_t$, and $\bar{y}$ are actual, simulated, and sample mean of per capita consumption, and y_t' and $\hat{y}_t'$ are actual and simulated relative change of per capita consumption.

Table 2--Demand elasticities for meats and other animal proteins

Food category	Price										
	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	EXPEND	CONST
BEEF.V	-0.6212	0.1143	0.1072	0.0183	0.0041	-0.0064	0.0005	0.0230	-0.0257	0.3923	-0.0001
	(.0572)	(.0275)	(.0460)	(.0171)	(.0114)	(.0112)	(.0117)	(.0101)	(.0125)	(.1240)	(.0083)
PORK	.1922	-.7281	.0795	.0126	.0127	.0252	.0099	.0024	-.0061	.6593	-.0231
	(.0488)	(.0424)	(.0482)	(.0206)	(.0122)	(.0124)	(.0131)	(.0114)	(.0139)	(.1461)	(.0098)
O.MEAT	.8180	.3550	-1.8739	.2800	-.0560	-.0241	.0232	-.1694	.3576	-.5737	.0321
	(.3350)	(.1991)	(.5480)	(.1366)	(.1191)	(.1397)	(.1314)	(.0956)	(.1409)	(.4802)	(.0296)
CHICKN	.1030	.0470	.1914	-.3723	-.0226	-.0135	.0178	.0791	-.0389	.0769	.0286
	(.0863)	(.0585)	(.0944)	(.0560)	(.0294)	(.0287)	(.0316)	(.0258)	(.0327)	(.1884)	(.0123)
TURKEY	.0887	.1410	-.1358	-.0767	-.5345	.0380	.1354	-.0728	.2218	-.1267	.0437
	(.1988)	(.1203)	(.2845)	(.1017)	(.1217)	(.0978)	(.0955)	(.0672)	(.1002)	(.3449)	(.0218)
FISH	-.1132	.2559	-.0619	-.0485	.0370	.1212	.0144	.0005	.0113	.4290	-.0187
	(.1955)	(.1225)	(.3335)	(.0990)	(.0977)	(.1606)	(.1168)	(.0727)	(.1196)	(.3076)	(.0188)
C.FISH	.0093	.1037	.0512	.0593	.1345	.0145	-.3715	-.2384	.1291	.3942	-.0113
	(.2033)	(.1290)	(.3136)	(.1090)	(.0954)	(.1167)	(.1486)	(.0764)	(.1163)	(.3621)	(.0219)
EGGS	.0918	.0120	-.0925	.0585	-.0167	.0004	-.0521	-.1103	.0088	.2865	-.0223
	(.0387)	(.0246)	(.0504)	(.0196)	(.0148)	(.0161)	(.0169)	(.0172)	(.0183)	(.0816)	(.0053)
CHEESE	-.2268	-.0259	.4228	-.0690	.1099	.0057	.0645	.0189	-.2472	.4181	.0119
	(.1090)	(.0686)	(.1679)	(.0563)	(.0500)	(.0597)	(.0581)	(.0415)	(.0833)	(.1934)	(.0118)
WEIGHT	.0316	.0180	.0043	.0062	.0018	.0018	.0018	.0082	.0036	NA	NA

Note: For each pair of estimates in the tables, the upper part is the estimated elasticity, and the lower part (in parentheses) is the standard error. The notations are BEEF.V (beef and veal), PORK (pork), O.MEAT (other meats), CHICKN (chicken), TURKEY (turkey), FISH (fresh and frozen fish), C.FISH (canned and cured fish), EGGS (eggs), CHEESE (cheese), EXPEND (expenditure), CONST (constant term), WEIGHT (expenditure weight), and NA (not applicable).

Among the expenditure elasticities in table 2, those of statistically significant estimates are beef and veal (0.3923), pork (0.6593), eggs (0.2865), and cheese (0.4181). Although the expenditure elasticities of other meats and turkey are negative, they may not imply that the goods are inferior, because the estimates are not statistically significant. The previous estimates of expenditure elasticities in Huang (18) are beef and veal (0.4549), pork (0.4427), cheese (0.5927), and a statistically insignificant estimate for eggs. The different results in Huang (18) probably arise because the time trend effects were excluded. Finally, the estimated constants indicate increasing consumption trends for chicken and turkey, and decreasing consumption trends for pork and eggs. These trends may relate to medical and dietary concerns of a perceived linkage between heart disease and cholesterol levels. Also, there is increasing use of chicken in fast-food outlets, while turkey is often used as processed foods and sold as parts throughout the year, not just at holidays.

Table 3 summarizes the estimated direct-price and expenditure elasticities, trends, and the errors of simulation over the sample period, which will be discussed later. In general, most direct-price elasticities of major food

elasticities for the food groups in the second row related to the categories
of staple foods and their symmetric counterparts are completed. Thus,
continuing such a row-column group operation, I obtained all the cross-price
elasticities for food groups sequentially by group. Given the complete set of
price and expenditure elasticities for all food categories, I obtained the
price elasticities for nonfood by applying the Engel aggregation, homogeneity,
and symmetry constraints.

Uncompensated Food Demand System

The empirical estimates of a disaggregate food demand system for 39 food
categories and 1 nonfood sector are presented in appendix B. This table
contains 1,680 estimates of the demand elasticities of the food categories and
nonfood sector listed in the left column with respect to their prices,
expenditures, and constant term listed at the top of the table. The
expenditure weight of each food category is listed at the bottom of the table.
Using the estimates of price and expenditure elasticities for food categories,
I obtained the direct-price and expenditure elasticities of nonfood as
-0.9795 and 1.1661, respectively. These estimates are quite accurate because
they are almost the same as the direct estimation results of an aggregate food
system (table 1), in which the direct-price and expenditure elasticities of
nonfood are -0.9794 and 1.1500.

We can easily verify that all estimated elasticities in the appendix table
satisfy the theoretical constraints of symmetry, homogeneity, and Engel
aggregation. The numerous estimates of the demand system make it difficult to
perform a detailed examination of all estimation results. For a convenient
illustration, the demand subsystem for the food group of meats and other
animal proteins is presented in table 2. This food group accounts for about
42 percent of the consumer food budget, and its importance in food consumption
has long been recognized. This demand subsystem consists of nine food
categories: beef and veal, pork, other meats (including lamb, mutton, and
edible offal), chicken, turkey, fresh and frozen fish, canned and cured fish,
eggs, and cheese.

In table 2, most estimated direct-price elasticities are statistically
significant with an expected negative sign. They are beef and veal (-0.6212),
pork (-0.7281), other meats (-1.8739), chicken (-0.3723), turkey (-0.5345),
canned and cured fish (-0.3715), eggs (-0.1103), and cheese (-0.2472). The
price elasticity of the fresh and frozen fish category, however, is not
statistically significant. This poor estimate is partly because of difficulty
in defining prices and quantities for such a wide variety of fish species, and
partly because of much fish consumed away from home and influenced by menu
prices instead of the price of raw fish. The previous estimates in Huang (18)
indicate that the direct-price elasticities are beef and veal (-0.6166), pork
(-0.7297), other meats (-1.3712), chicken (-0.5308), turkey (-0.6797), eggs
(-0.1452), and cheese (-0.3319), while the elasticities for both fresh and
canned fishes are not statistically significant. Obviously, the estimates for
red meats in this report are almost the same as previous estimates, but the
estimates for poultry, eggs, and cheese are slightly less elastic than
previous estimates.

elasticities for any pair of cross-groups is not affected by the ordering of food groups, I started with the estimation of the cross-group between meats and staple foods. At the beginning of the estimation, the relative changes of quantities for all food categories were adjusted by subtracting the relative change of nonfood prices from them. Then, the quantities of individual food categories in the meats or staple foods were adjusted by subtracting the price and expenditure effects caused by the food categories outside the corresponding cross-group. The prior information for the quantity adjustment comes from two sources: one is the estimated price elasticities for within-group demand subsystems (in this case, the estimated price and expenditure elasticities within the meats and staple food groups), and the other is the estimates from the aggregate food demand system. Then, the cross-price elasticities in each pair of cross-groups are estimated simultaneously by incorporating the symmetry constraints into the estimation.

Following the similar estimation procedures for computing the cross-price elasticities between food groups of meats and staple foods, I estimated the cross-price elasticities of food categories for the other cross-groups in the row and column related to the meat group. Then, the remaining unknown price

Table 1--Demand elasticities for food groups and nonfood

Food group	Price								EXPEND	CONST
	MEAT	STAPLE	FATS	FRUITS	VEGETA	PRO.FV	DESERT	N.FOOD		
MEAT	-0.3611	-0.0004	0.0059	0.0107	-0.0060	-0.0097	-0.0333	-0.1219	0.5157	-0.0109
	(.0328)	(.0206)	(.0090)	(.0107)	(.0064)	(.0083)	(.0115)	(.0749)	(.0819)	(.0026)
STAPLE	.0300	-.1508	-.0330	-.0411	.0241	.0314	.0007	.0202	.1186	-.0045
	(.0383)	(.0649)	(.0259)	(.0266)	(.0191)	(.0261)	(.0226)	(.0901)	(.0918)	(.0028)
FATS	.0632	-.1311	-.0674	-.0239	-.0710	.1090	-.0098	-.1081	.2391	.0014
	(.0640)	(.0997)	(.0820)	(.0536)	(.0493)	(.0603)	(.0484)	(.1506)	(.1556)	(.0048)
FRUITS	.1773	-.2016	-.0270	-.1954	.1694	-.1571	.2276	.3908	-.3840	.0064
	(.1083)	(.1452)	(.0759)	(.1069)	(.0567)	(.0780)	(.0632)	(.2649)	(.2680)	(.0083)
VEGETA	-.0660	.1502	-.1267	.2043	-.1348	-.0811	.0062	-.3599	.4079	-.0036
	(.0781)	(.1292)	(.0863)	(.0701)	(.0989)	(.0877)	(.0545)	(.1776)	(.1932)	(.0057)
PRO.FV	-.0506	.0859	.0879	-.0979	-.0383	-.2876	-.0514	-.0821	.4341	.0091
	(.0485)	(.0832)	(.0499)	(.0456)	(.0414)	(.0744)	(.0338)	(.1112)	(.1148)	(.0035)
DESERT	-.0784	-.0106	-.0053	.0538	.0014	-.0227	-.1049	-.2281	.3947	-.0168
	(.0317)	(.0335)	(.0184)	(.0171)	(.0118)	(.0156)	(.0225)	(.0937)	(.0995)	(.0031)
N.FOOD	-.0606	-.0420	-.0114	-.0081	-.0073	-.0108	-.0303	-.9794	1.1500	-.0015
	(.0035)	(.0029)	(.0013)	(.0016)	(.0009)	(.0012)	(.0016)	(.0101)	(.0102)	(.0005)
WEIGHT	.0773	.0417	.0109	.0077	.0062	.0132	.0293	.8137	NA	NA

Note: For each pair of estimates in the table, the upper part is the estimated elasticity, and the lower part (in parentheses) is the standard error. The notations are MEAT (meats and other animal proteins), STAPLE (staple foods), FATS (fats and oils), FRUITS (fresh fruits), VEGETA (fresh vegetables), PRO.FV (processed fruits and vegetables), DESERT (desserts, sweeteners, and coffee), N.FOOD (nonfood), EXPEND (expenditure), CONST (constant term), WEIGHT (expenditure weight), and NA (not applicable).

estimates of actual consumption at the retail level. The correspondence between the price and quantity variables is certainly not ideal as assumed by the conceptual demand theory. Given the limitations of the available data sources, however, the data compiled in this report are about as close a correspondence as one can achieve.

To estimate an aggregate demand system for seven food groups and one nonfood sector, I computed a set of Laspeyres quantity and price indexes for each food group as variables defined in the demand system. The estimation results are contained in table 1. These estimates are obtained by applying the constrained maximum likelihood method, while the parametric constraints of homogeneity, symmetry, and Engel aggregation are incorporated. As discussed in the estimation procedures, the main purpose of estimating this aggregate food demand system is to provide a framework for estimating a disaggregate food demand system.

The results in the table give information regarding the demand elasticities of the food groups in the left column with respect to their prices and expenditure at the top of the table. The direct-price elasticities for the food groups, shown in the diagonal entries of table 1, are all negative as expected, with magnitudes ranging between -0.07 and -0.98. The expenditure elasticities, shown in the next to last column of the table, indicate that the elasticities for all food groups are less than 1. Although the expenditure elasticity of the fresh fruits group is negative, one cannot conclude that fresh fruits are inferior goods as a group, because the estimate is statistically insignificant. A constant term in the demand system may show the potential time trends of demand in response to changes in consumer tastes and preferences, because the variables in the demand system are expressed in first-order differences. Among the statistically significant estimates of constants, meats and desserts have negative signs, indicating that the per capita consumption of these food groups is decreasing over the years, while processed fruits and vegetables have positive signs, showing an increase in consumption.

Disaggregate Food Demand Systems

After the estimation of an aggregate food demand system, I carried out the estimation of a disaggregate food demand system by first sequentially estimating the within-group demand parameters in each diagonal block of the demand system. The quantity variable in each demand subsystem is adjusted by excluding the price effects of other food categories and the nonfood sector outside a given food group under estimation. These price effects are approximated by using cross-group price elasticities from an aggregate food demand system. Then, the parameters within each food group, including expenditure elasticities and constant terms, are estimated by incorporating the symmetry constraints.

Following the estimation of demand parameters within each food group, the cross-price elasticities across different groups are obtained sequentially for two groups at a time, subject to symmetry and homogeneity constraints. As discussed in the estimation procedures, because the estimation of price

23

changes, I propose the following approximated Hicksian compensating variation measure, with the required information of compensated direct- and cross-price elasticities obtained from this report.

The Hicksian compensating variation (*CV*) is defined as the minimum amount by which a consumer would have to be compensated after a price change to be as well off as before. In other words, let us consider a change in the price vector from p^0 to p^1 and the initial equilibrium utility level u^0. The *CV* can be represented as the difference of expenditures between price changes as

$$CV = E(p^1, u^0) - E(p^0, u^0) \qquad (89)$$

where the expenditure functions $E(p^1, u^0)$ and $E(p^0, u^0)$ are the minimum expenditures necessary to maintain the level of utility u^0 given prices p^1 and p^0. This welfare measure reflects additional expenditures being required to achieve the same level of utility as before the change in price. I regarded p^0 as the initial price level and p^1 as the price level after change, and then computed the change in expenditures to represent the level of gain or loss in consumer welfare. If the compensating variation is positive (or negative), the consumer welfare is decreasing (or increasing).

In equation 89, I expressed $E(p^0, u^0) = p^{0\prime} q^0$ under the equilibrium in the initial period, and $E(p^1, u^0) = p^{1\prime} q^h(p^1, u^0)$, where $q^h(p^1, u^0)$ is the Hicksian compensated quantities demanded in response to a price p^1 to maintain the same initial utility u^0. Furthermore, I defined the changes of prices and compensated quantities as $dp = p^1 - p^0$ and $dq^h = q^h - q^0$, and rewrote the measurement of *CV* as

$$CV = p^{1\prime} dq^h + q^{0\prime} dp \qquad (90)$$

Given the initial quantity vector q^0 and the projected price vectors p^1 and dp under various scenarios of commodity program effects, the key question for computing the compensating variation is to find a vector of changes in compensated quantities demanded dq^h. I approximated the *i*th element of dq^h, say dq_i^h, by applying the first-order differential form as

$$dq_i^h = \Sigma_j \; \partial q_i^h / \partial p_j \; dp_j \qquad i=1,2,\ldots,n \qquad (91)$$

or $\qquad dq_i^h / q_i = \Sigma_j \; e_{ij}{}^* \; (dp_j / p_j) \qquad i=1,2,\ldots,n \qquad (92)$

where $e_{ij}{}^* = (\partial q_i^h / \partial p_j)(p_j / q_i)$ is a compensated price elasticity of the *i*th food category with respect to a price change of the *j*th food category. These compensated price elasticity estimates are available in appendix C. The unique feature of this approach is that all potential direct- and cross-price effects are incorporated into the welfare measurement. An example of applying this approach is given in Huang (*23*), in which the effects of U.S. meat trade on consumer welfare are measured.

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Appendix A:

Graphic Comparison of Actual and Simulated Consumptions

Figure A1--Beef and veal
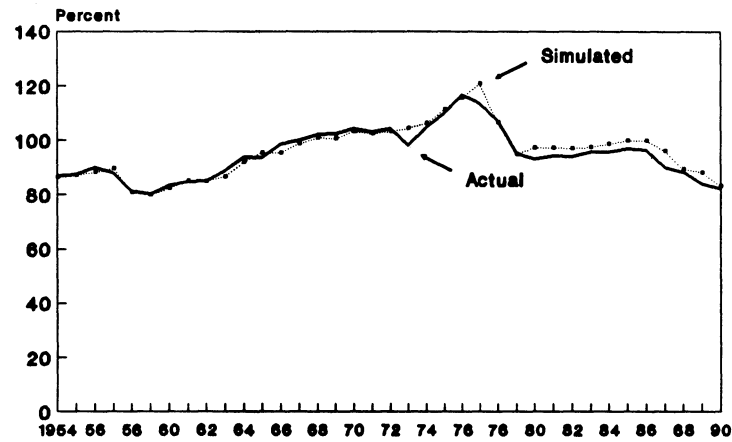
Figure A2--Pork
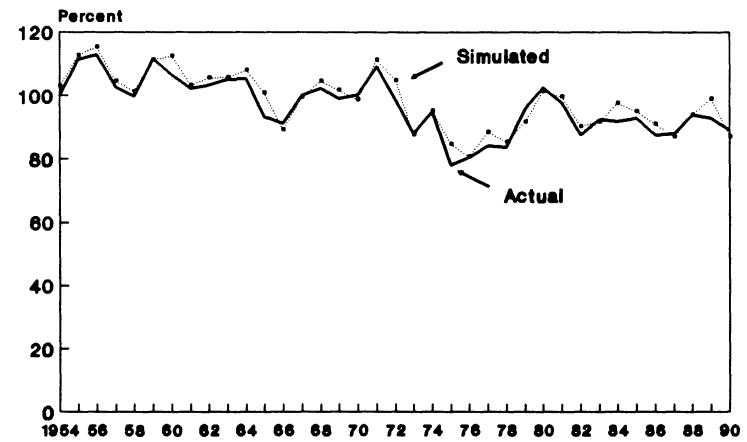
Figure A3--Other meats
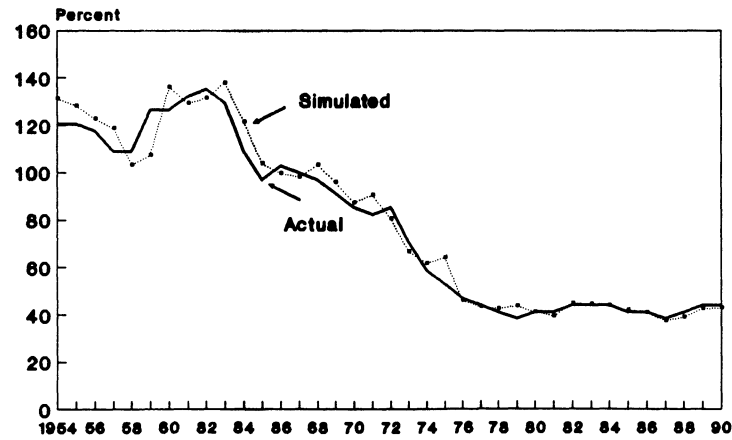
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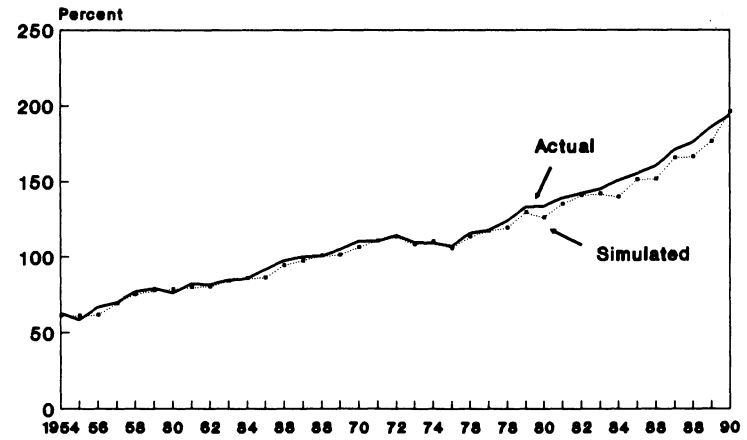
Figure A5--Turkey
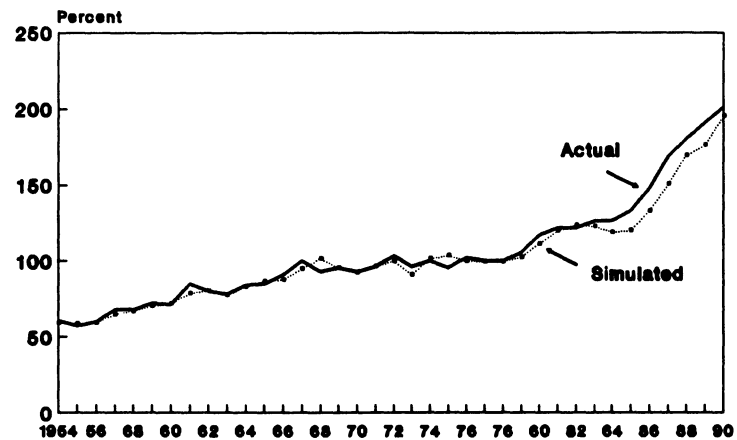
Figure A6--Fresh and frozen fish
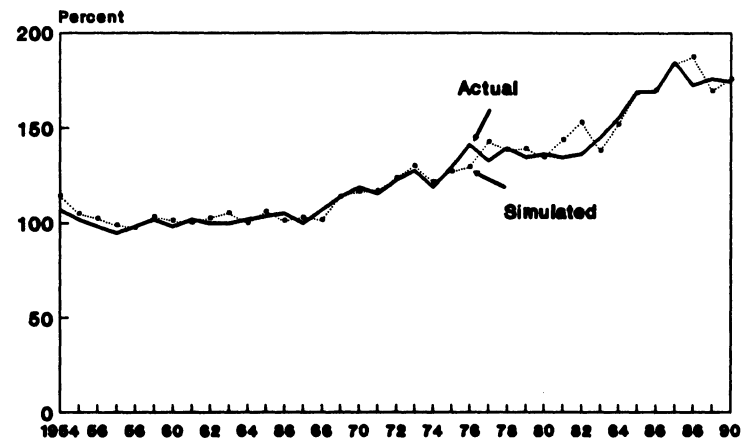
Figure A7--Canned and cured fish
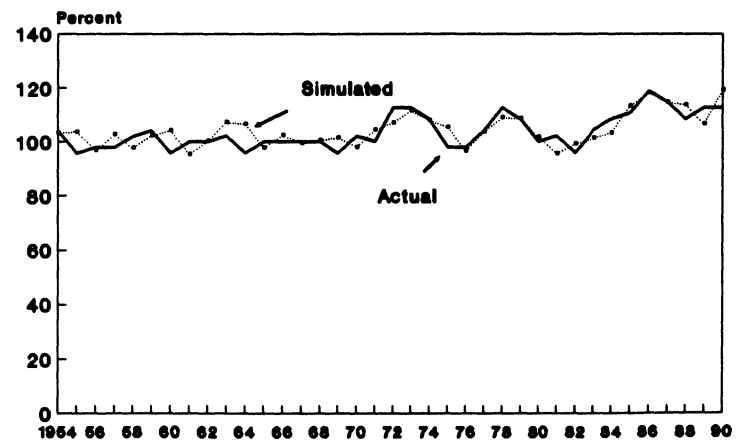
Figure A8--Eggs

Figure A9--Cheese

Percent
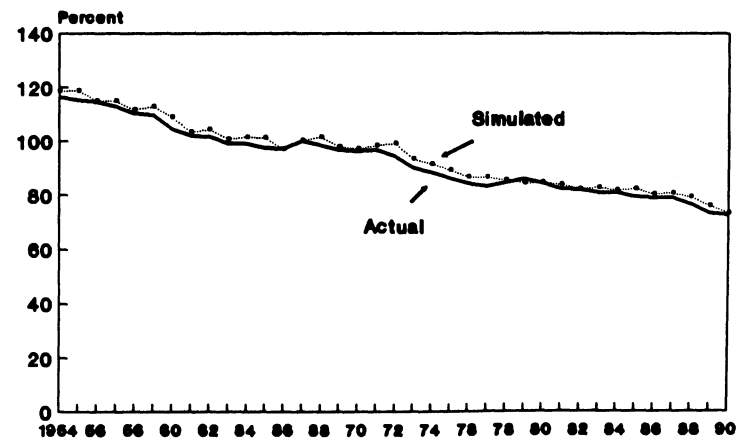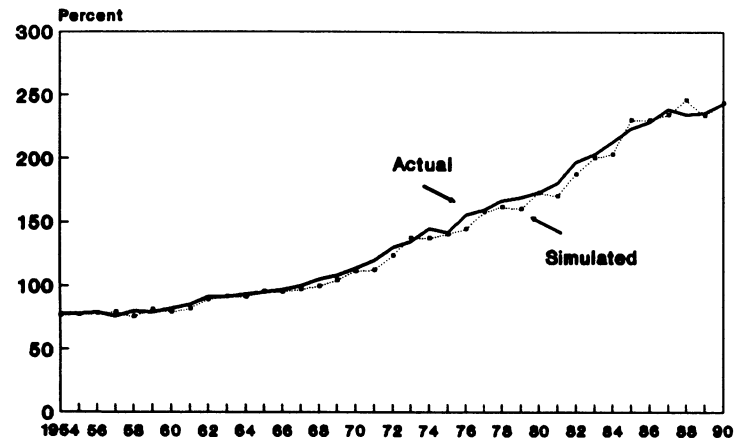
Figure A10--Fluid milk

Percent
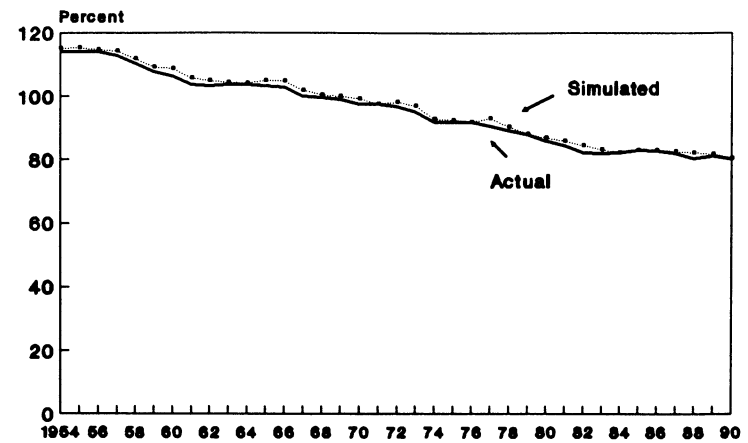
Figure A11--Evaporated and dry milk

Percent
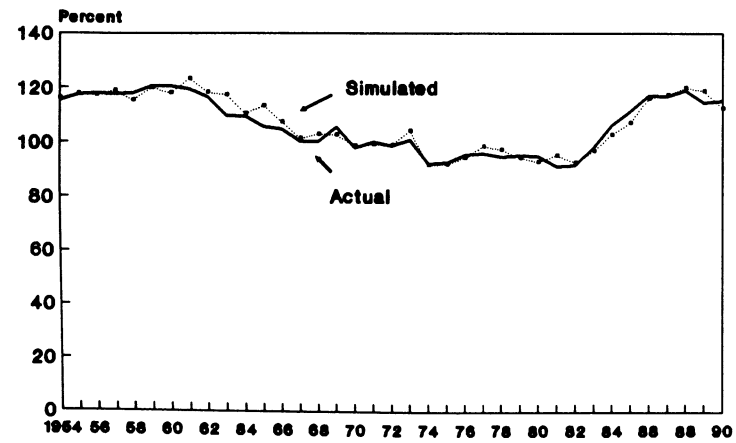
Figure A12--Wheat flour

Percent

41

Figure A13—Rice

Percent

Figure A14—Potatoes

Percent

Figure A15—Butter

Percent
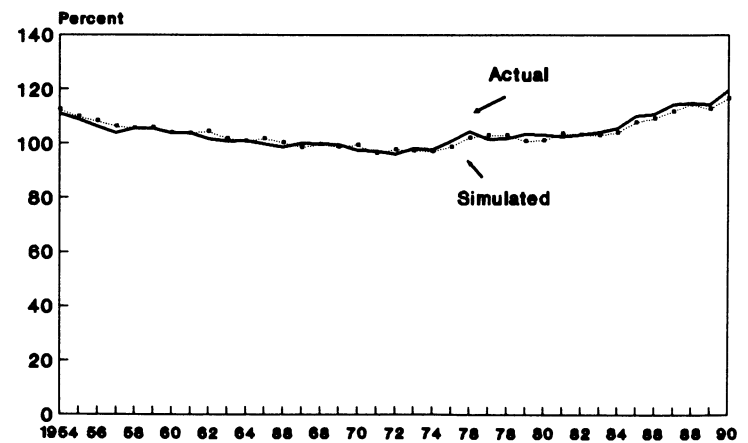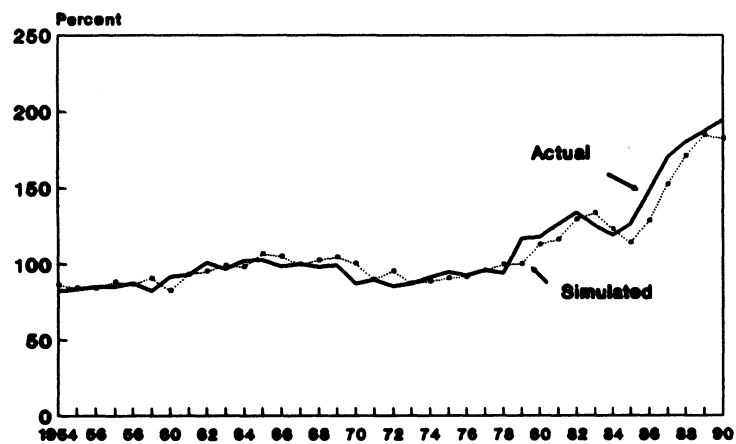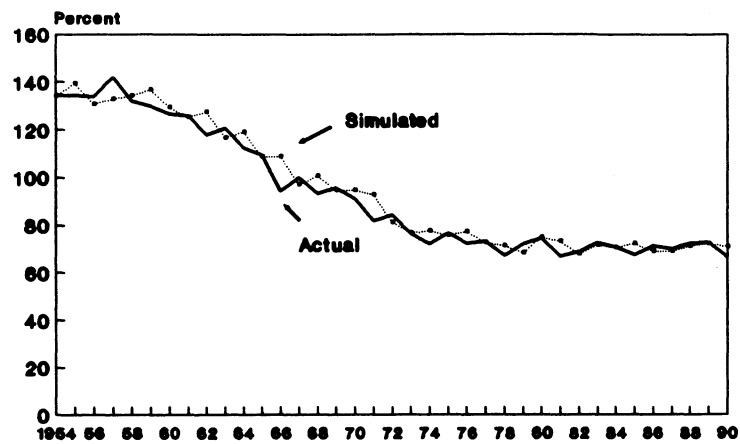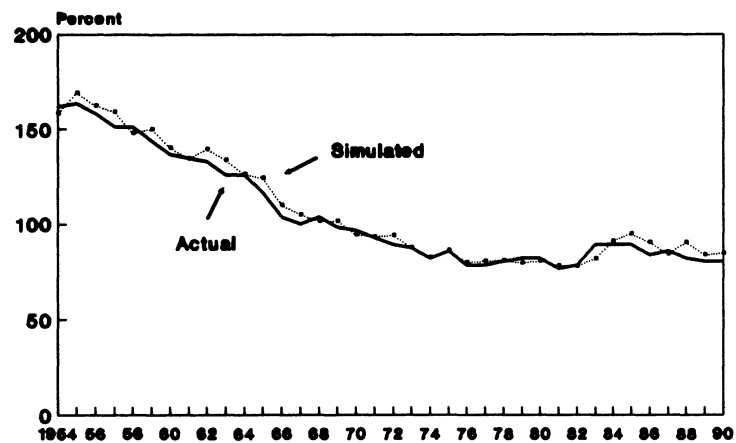
Figure A16—Margarine

Percent
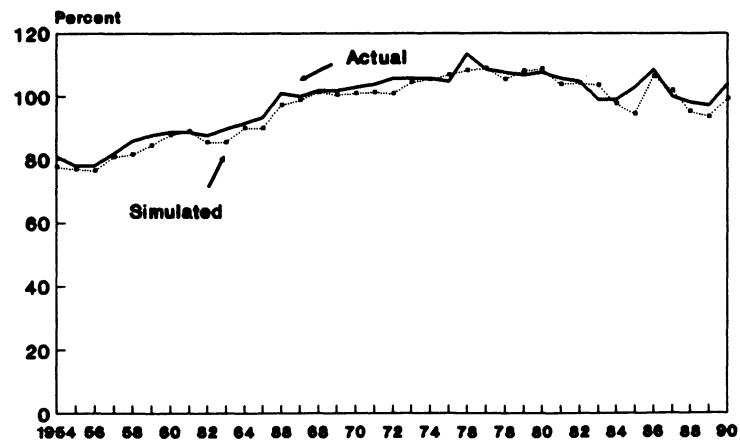
Figure A17—Other fats and oils
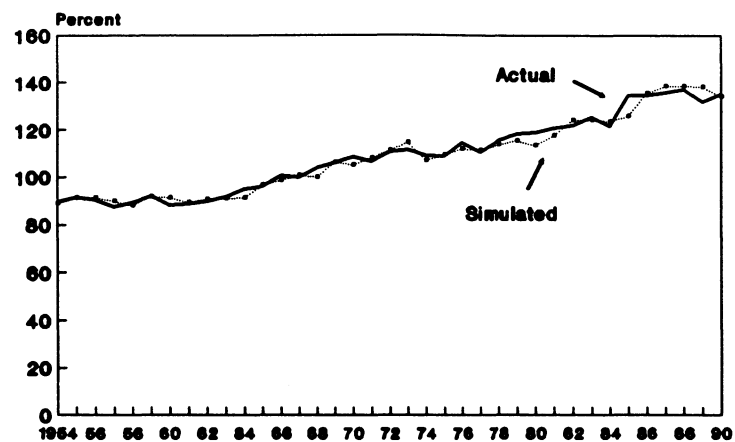
Percent

Actual

Simulated

160
140
120
100
80
60
40
20
0

1954 56 58 60 62 84 66 68 70 72 74 76 78 80 82 84 86 88 90

Figure A18—Apples

Percent

Actual

Simulated

160
140
120
100
80
60
40
20
0

1954 56 58 60 62 84 66 68 70 72 74 76 78 80 82 84 86 88 90

Figure A19—Oranges

Percent

Actual

Simulated

140
120
100
80
60
40
20
0

1954 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

Figure A20—Bananas

Percent

Actual

Simulated

160
140
120
100
80
60
40
20
0

1954 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

43

Figure A21--Grapes

Percent
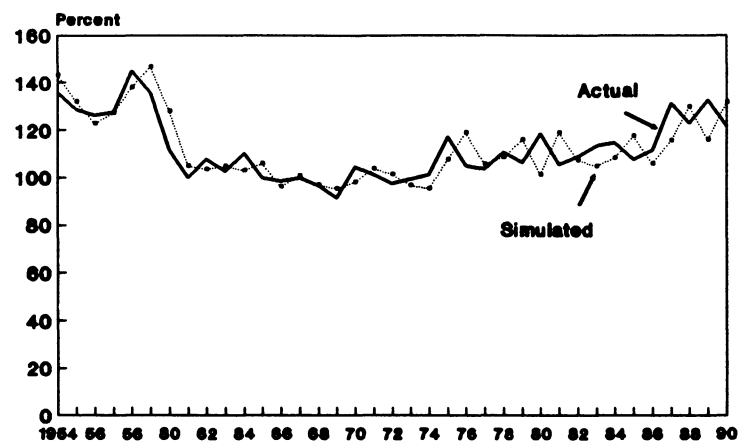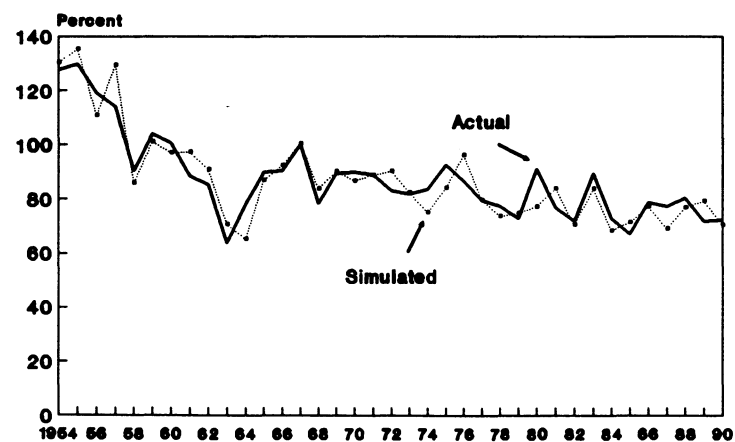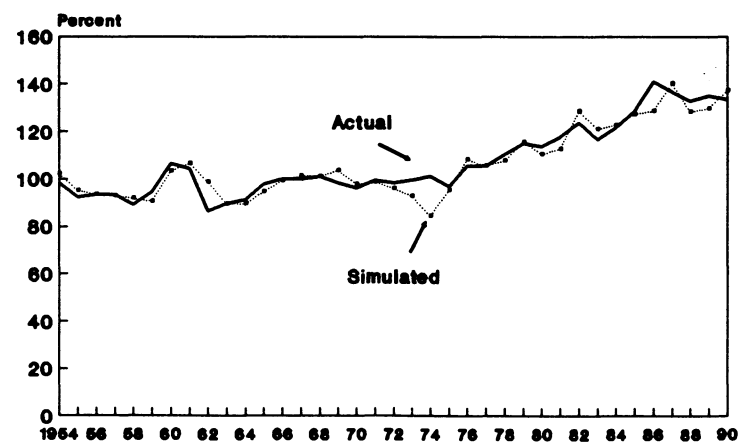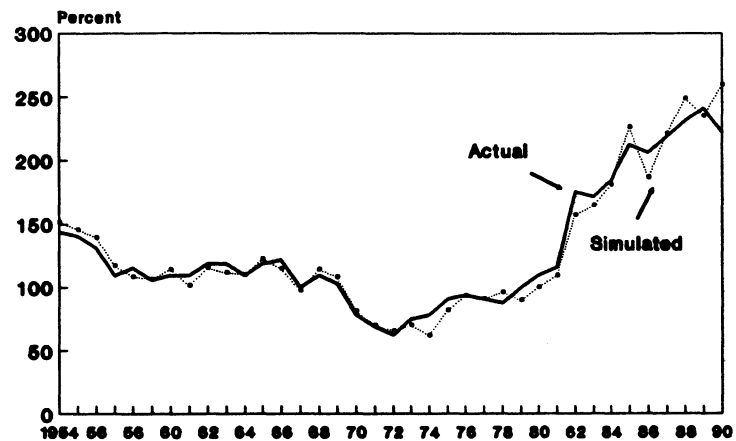
Figure A22--Grapefruits

Percent
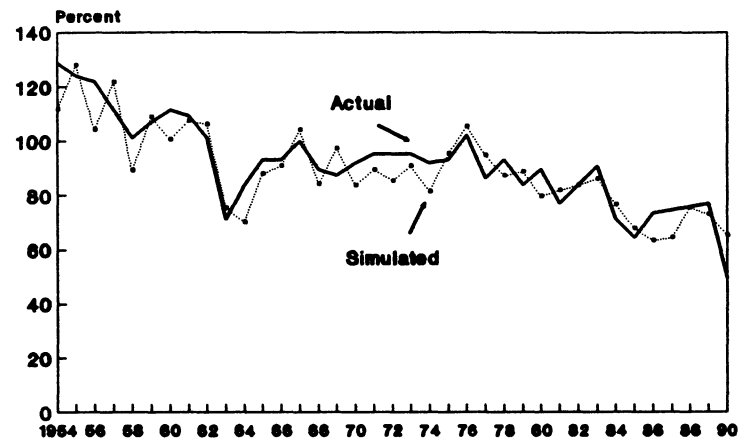
Figure A23--Other fresh fruits
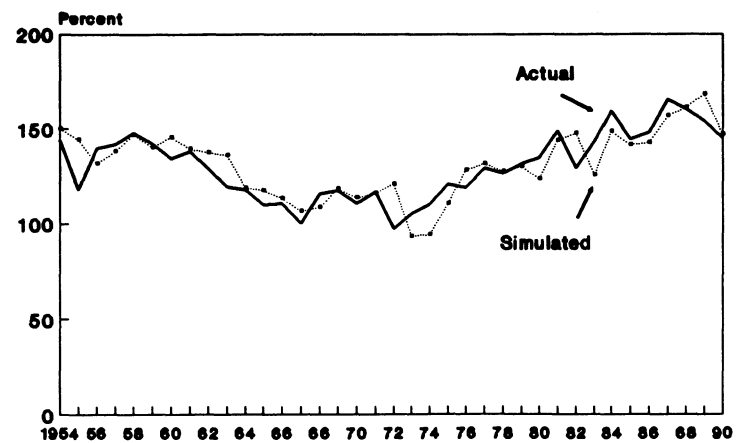
Percent

Figure A24--Lettuce

Percent

44

Figure A25--Tomatoes

Percent

Figure A26--Celery

Percent

Figure A27--Onions

Percent
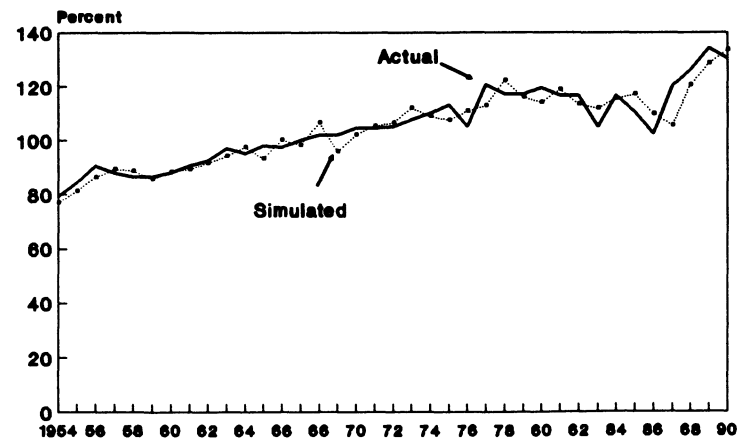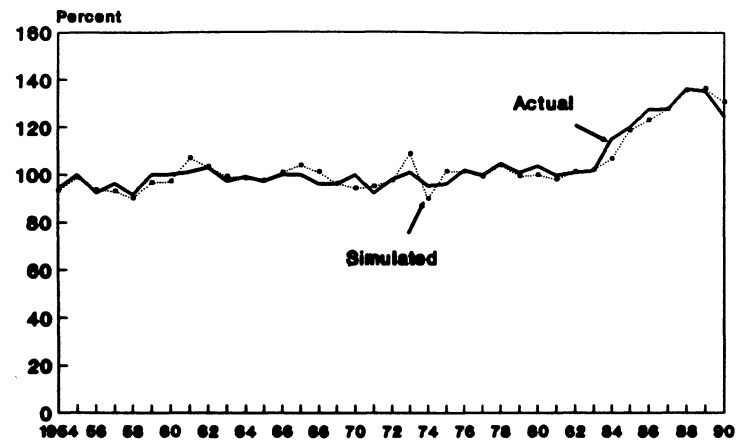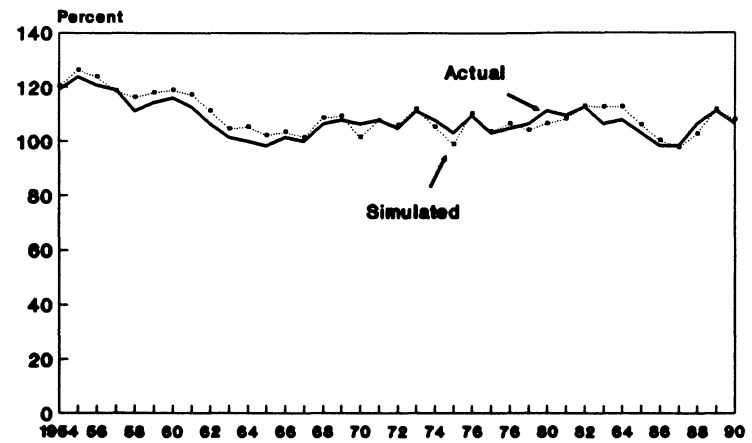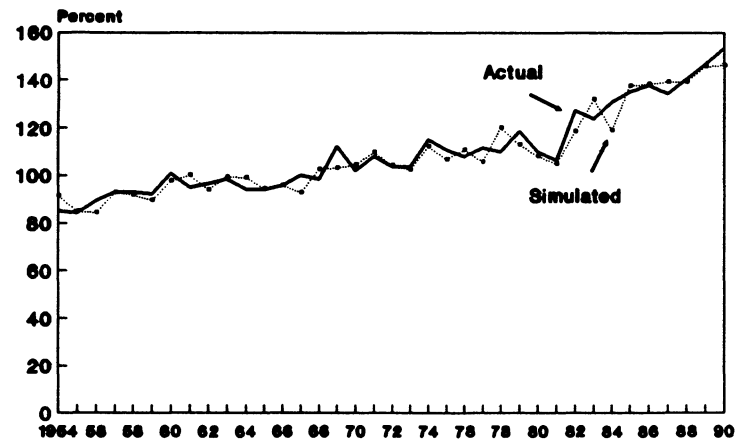
Figure A28--Carrots

Percent

45
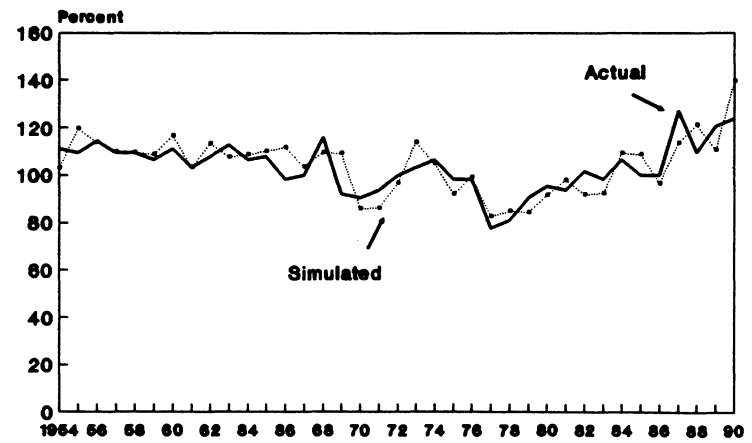
Figure A29--Other fresh vegetables

Percent
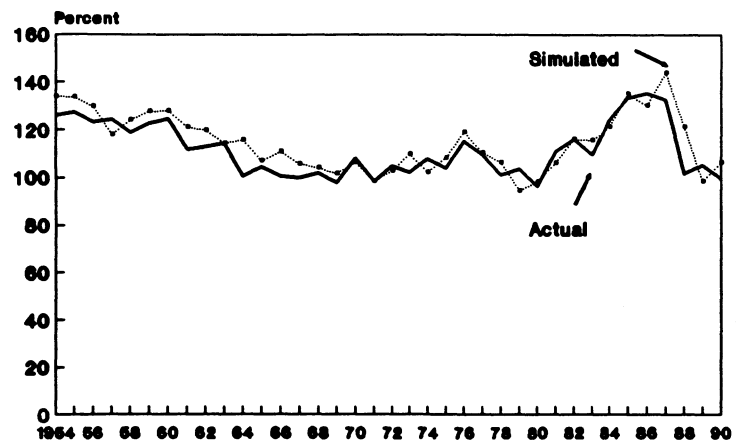
Figure A30--Fruit juices

Percent
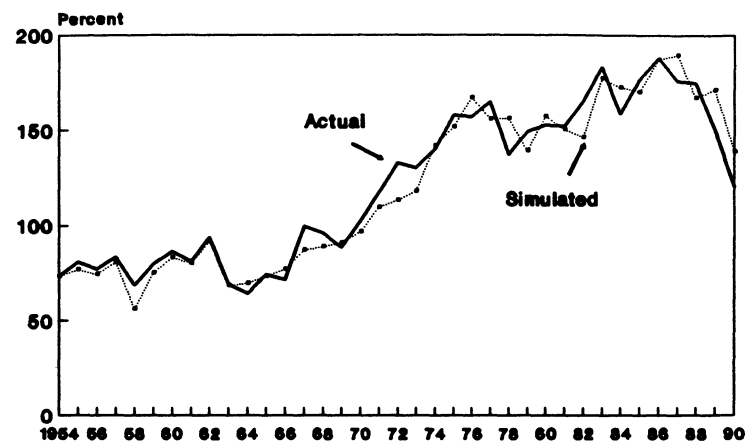
Figure A31--Canned tomatoes

Percent
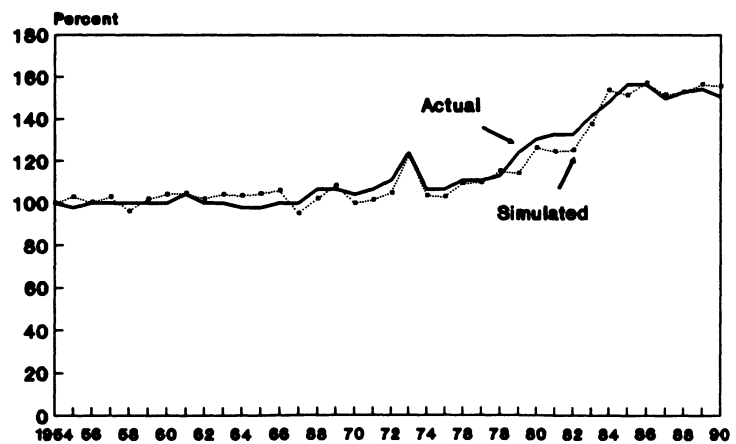
Figure A32--Canned peas

Percent
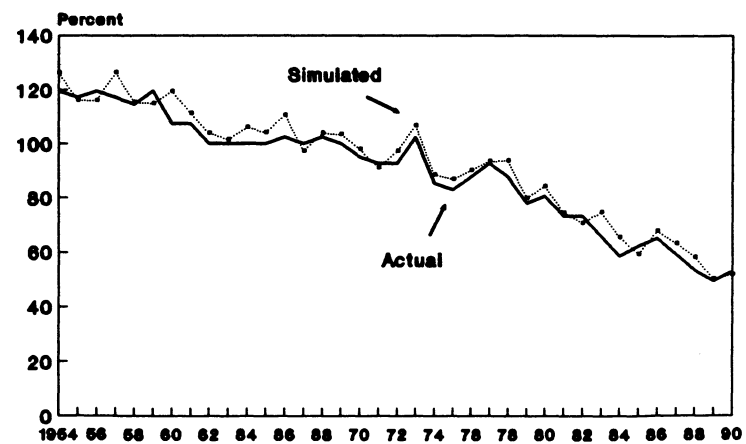
Figure A33--Canned fruit cocktail

Percent

Simulated

Actual

1954 56 58 60 62 84 66 68 70 72 74 76 78 80 82 84 66 88 90
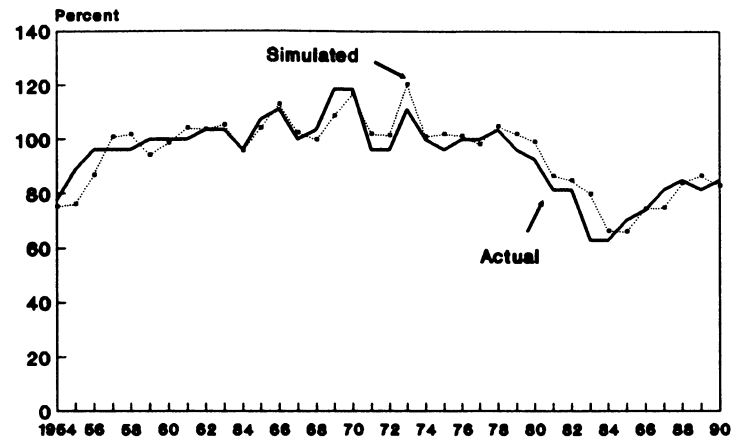
Figure A34--Peanuts and tree nuts

Percent

Actual

Simulated

1954 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90
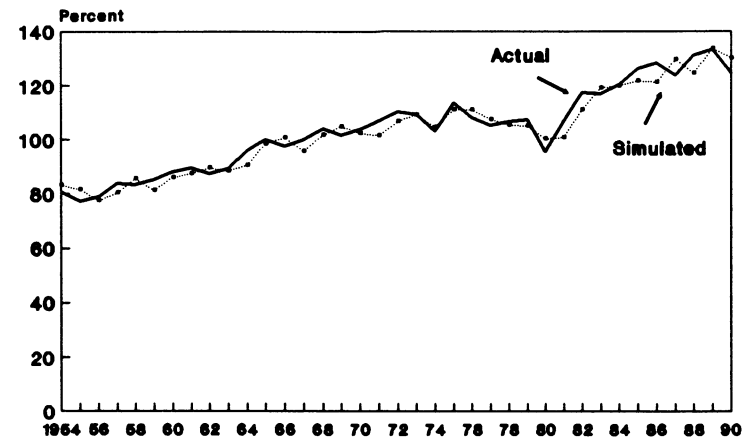
Figure A35--Proc. fruits and vegetables

Percent

Actual

Simulated

1954 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

Figure A36--Sugar

Percent

Simulated

Actual

1954 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

47
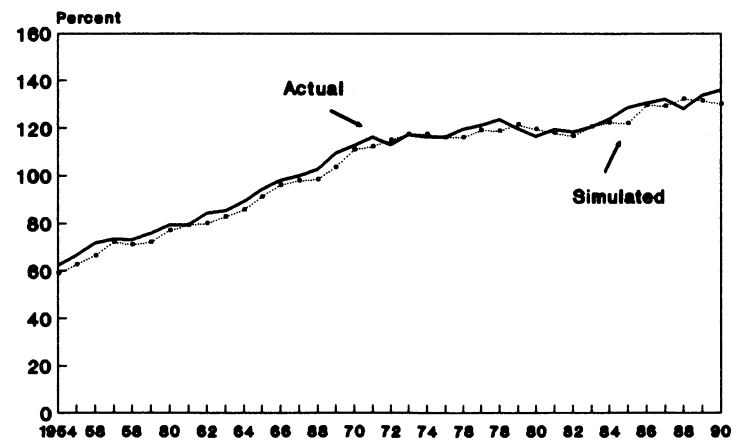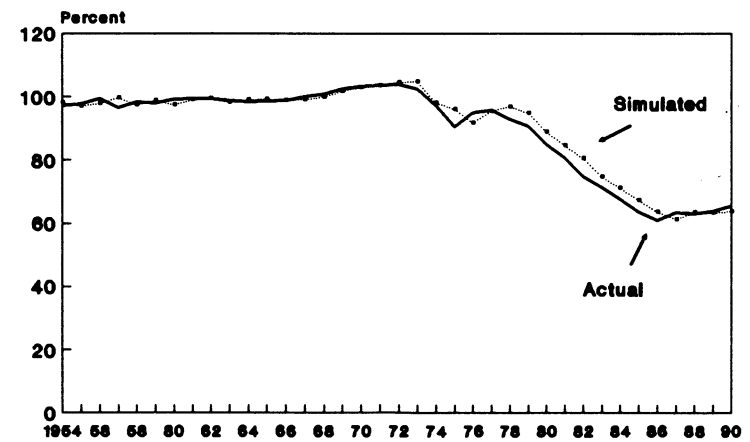
Figure A37--Sweeteners

Percent
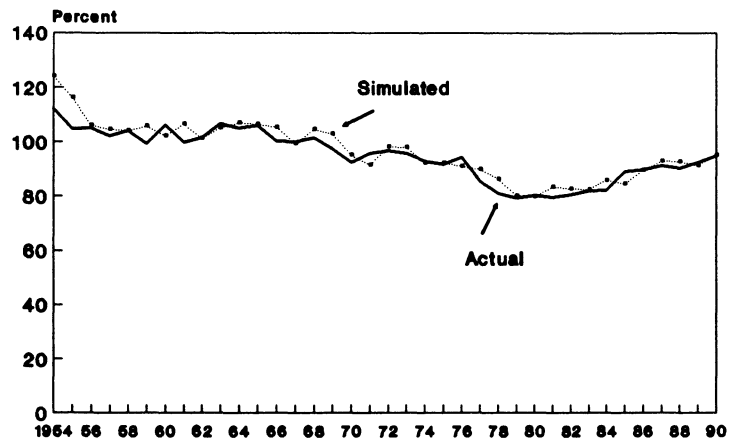
Figure A38--Coffee and tea

Percent

48
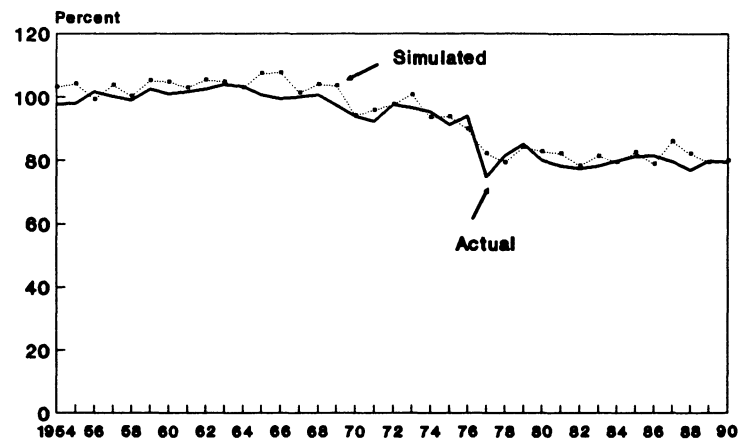
Figure A39--Ice cream and frozen dairy

Percent
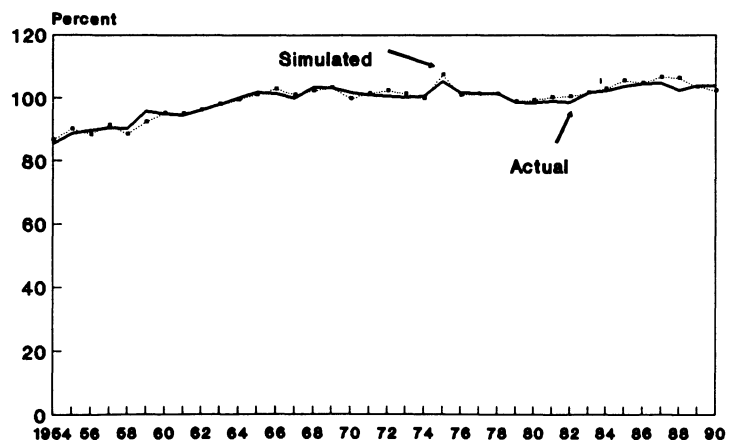
Figure A40--Nonfood

Percent
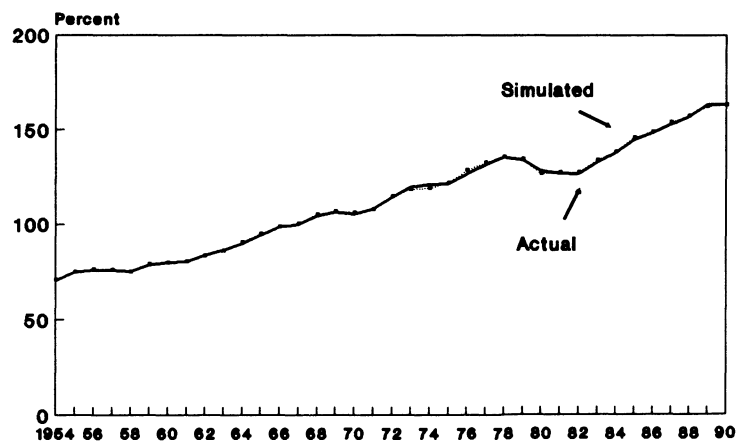
Appendix B:

Uncompensated Food Demand System

The estimated uncompensated demand system is represented as

$$q_i' = \sum_{j=1}^{n} e_{ij} \, p_j' + \delta_i \, m' + \alpha_i \qquad i=1,2,..,n$$

where variables q_i', p_i', and m' are the relative changes in per capita quantity, price, and per capita expenditure. The parameters e_{ij}, δ_i, and α_i are price, expenditure elasticities, and constant. These estimates are presented in a matrix form of order n x $(n+2)$ for n commodity case as

Food category	p_1'	Price p_2' . . . . p_n'	m'	1
q_1'	e_{11}	e_{12} . . . . e_{1n}	δ_1	α_1
q_2'	e_{21}	e_{22} . . . . e_{2n}	δ_2	α_2
.				
.				
q_n'	e_{n1}	e_{n2} . . . . e_{nn}	δ_n	α_n

To illustrate the estimation results, the matrix of parameter estimates is partitioned into nine blocks and presented in a sequential table ordering as B11, B21, B31, B12, B22, B32, B13, B23, and B33.

Partition of uncompensated elasticity matrix

B11	B12	B13
B21	B22	B23
B31	B32	B33

For each pair of estimates in the tables, the upper part is the estimated elasticity, and the lower part (in parentheses) is the standard error. The notations in the tables are BEEF.V (beef and veal), PORK (pork), O.MEAT (other meats), CHICKN (chicken), TURKEY (turkey), FISH (fresh and frozen fish), C.FISH (canned and cured fish), EGGS (eggs), CHEESE (cheese), F.MILK (fluid milk), O.MILK (evaporated and dry milk), FLOUR (wheat flour), RICE (rice), POTATO (potatoes), BUTTER (butter), MARGAR (margarine), O.FATS (other fats and oils), APPLES (apples), ORANGE (oranges), BANANA (bananas), GRAPES (grapes), GRAFRU (grapefruits), O.FRUT (other fresh fruits), LETTUC (lettuce), TOMATO (tomatoes), CELERY (celery), ONIONS (onions), CARROT (carrots), O.VEGE (other fresh vegetables), JUICE (fruit juice), C.TOMA (canned tomatoes), C.PEAS (canned peas), COCKTL (canned fruit cocktail), NUTS (peanuts and tree nuts), O.PRFV (other processed fruits and vegetables), SUGAR (sugar), SWEET (sweeteners), COFFEE (coffee and tea), FRZN.D (ice cream and other frozen dairy products), N.FOOD (nonfood), EXPEND (expenditure), CONST (constant term), WEIGHT (expenditure weight), and NA (not applicable).

Appendix table--U.S. uncompensated food demand system   (Matrix partition B11)

Food category	Price BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
BEEF.V	-0.6212 (0.0572)	0.1143 (0.0275)	0.1072 (0.0460)	0.0183 (0.0171)	0.0041 (0.0114)	-0.0064 (0.0112)	0.0005 (0.0117)	0.0230 (0.0101)	-0.0257 (0.0125)	-0.0113 (0.0167)	-0.0088 (0.0178)	-0.0744 (0.0222)	0.0506 (0.0116)	0.0040 (0.0078)
PORK	0.1922 (0.0488)	-0.7281 (0.0424)	0.0795 (0.0482)	0.0126 (0.0206)	0.0127 (0.0122)	0.0252 (0.0124)	0.0099 (0.0131)	0.0024 (0.0114)	-0.0061 (0.0139)	0.0018 (0.0180)	-0.0165 (0.0195)	-0.0031 (0.0242)	0.0233 (0.0123)	-0.0086 (0.0084)
O.MEAT	0.8180 (0.3350)	0.3550 (0.1991)	-1.8739 (0.5480)	0.2800 (0.1366)	-0.0560 (0.1191)	-0.0241 (0.1397)	0.0232 (0.1314)	-0.1694 (0.0956)	0.3576 (0.1409)	-0.0713 (0.1821)	0.2468 (0.2142)	1.0234 (0.2261)	-0.3909 (0.0921)	-0.1328 (0.0522)
CHICKN	0.1030 (0.0863)	0.0470 (0.0585)	0.1914 (0.0944)	-0.3723 (0.0560)	-0.0226 (0.0294)	-0.0135 (0.0287)	0.0178 (0.0316)	0.0791 (0.0258)	-0.0389 (0.0327)	-0.0584 (0.0439)	0.1164 (0.0493)	0.0382 (0.0586)	-0.0645 (0.0268)	0.0172 (0.0177)
TURKEY	0.0887 (0.1988)	0.1410 (0.1203)	-0.1358 (0.2845)	-0.0767 (0.1017)	-0.5345 (0.1217)	0.0380 (0.0978)	0.1354 (0.0955)	-0.0728 (0.0672)	0.2218 (0.1002)	0.4315 (0.1319)	-0.2252 (0.1480)	0.1808 (0.1652)	-0.0692 (0.0646)	0.0084 (0.0367)
FISH	-0.1132 (0.1955)	0.2559 (0.1225)	-0.0619 (0.3335)	-0.0485 (0.0990)	0.0370 (0.0977)	0.1212 (0.1606)	0.0144 (0.1168)	0.0005 (0.0727)	0.0113 (0.1196)	-0.4308 (0.1460)	-0.1669 (0.1669)	-0.3008 (0.1668)	0.0256 (0.0612)	0.0278 (0.0315)
C.FISH	0.0093 (0.2033)	0.1037 (0.1290)	0.0512 (0.3136)	0.0593 (0.1090)	0.1345 (0.0954)	0.0145 (0.1167)	-0.3715 (0.1486)	-0.2384 (0.0764)	0.1291 (0.1163)	0.1981 (0.1808)	-0.2302 (0.1941)	-0.0635 (0.2113)	0.0465 (0.0790)	-0.0166 (0.0433)
EGGS	0.0918 (0.0387)	0.0120 (0.0246)	-0.0925 (0.0504)	0.0585 (0.0196)	-0.0167 (0.0148)	0.0004 (0.0161)	-0.0521 (0.0169)	-0.1103 (0.0172)	0.0088 (0.0183)	0.0424 (0.0258)	0.0392 (0.0271)	-0.0907 (0.0312)	0.0099 (0.0139)	0.0056 (0.0088)
CHEESE	-0.2268 (0.1090)	-0.0259 (0.0686)	0.4228 (0.1679)	-0.0690 (0.0563)	0.1099 (0.0500)	0.0057 (0.0597)	0.0645 (0.0581)	0.0189 (0.0415)	-0.2472 (0.0833)	0.0320 (0.0880)	-0.1803 (0.1000)	-0.2387 (0.1055)	0.1241 (0.0420)	-0.0036 (0.0239)
F.MILK	-0.0130 (0.0320)	0.0117 (0.0196)	-0.0216 (0.0474)	-0.0222 (0.0165)	0.0466 (0.0144)	-0.0464 (0.0159)	0.0221 (0.0197)	0.0224 (0.0128)	0.0081 (0.0192)	-0.0431 (0.1259)	-0.0603 (0.1199)	0.0238 (0.0668)	-0.0280 (0.0229)	0.0021 (0.0103)
O.MILK	-0.0737 (0.1410)	-0.0718 (0.0876)	0.2606 (0.2303)	0.1777 (0.0764)	-0.1025 (0.0666)	-0.0753 (0.0751)	-0.1038 (0.0874)	0.0785 (0.0555)	-0.1626 (0.0900)	-0.2551 (0.4924)	-0.2764 (0.5383)	0.0304 (0.2180)	-0.0089 (0.0775)	-0.0175 (0.0326)
FLOUR	-0.1316 (0.0418)	0.0062 (0.0260)	0.2589 (0.0579)	0.0137 (0.0216)	0.0189 (0.0177)	-0.0317 (0.0179)	-0.0063 (0.0226)	-0.0430 (0.0153)	-0.0501 (0.0226)	0.0232 (0.0658)	0.0088 (0.0520)	-0.0777 (0.1037)	0.0191 (0.0350)	-0.0094 (0.0151)
RICE	0.6739 (0.1526)	0.1837 (0.0926)	-0.7035 (0.1650)	-0.1670 (0.0692)	-0.0524 (0.0485)	0.0197 (0.0459)	0.0353 (0.0592)	0.0349 (0.0476)	0.1871 (0.0630)	-0.1931 (0.1585)	-0.0133 (0.1296)	0.1332 (0.2463)	0.0661 (0.1232)	-0.0259 (0.0495)
POTATO	0.0720 (0.1237)	-0.0671 (0.0759)	-0.2885 (0.1121)	0.0531 (0.0548)	0.0071 (0.0330)	0.0256 (0.0284)	-0.0144 (0.0390)	0.0243 (0.0361)	-0.0054 (0.0430)	0.0175 (0.0853)	-0.0333 (0.0653)	-0.0785 (0.1274)	-0.0310 (0.0594)	-0.0983 (0.0531)

Appendix table--U.S. uncompensated food demand system--Continued   (Matrix partition B21)

Food category	Price BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
BUTTER	0.0997	0.0284	-0.0943	0.2541	0.0454	-0.2681	-0.1378	-0.0710	-0.3878	0.1761	0.2003	-0.0521	-0.1227	-0.0254
	(0.1306)	(0.0829)	(0.2054)	(0.0754)	(0.0706)	(0.0743)	(0.0900)	(0.0545)	(0.0925)	(0.1887)	(0.1964)	(0.2295)	(0.0844)	(0.0410)
MARGAR	-0.2022	-0.0210	0.4162	-0.0048	-0.1212	0.0392	-0.0394	0.0319	0.0725	0.4333	-0.3796	-0.0838	0.0245	-0.0498
	(0.1340)	(0.0843)	(0.2344)	(0.0735)	(0.0696)	(0.0797)	(0.0927)	(0.0556)	(0.0908)	(0.2757)	(0.3074)	(0.1754)	(0.0592)	(0.0261)
O.FATS	0.0933	0.1205	-0.1376	0.0107	0.0374	-0.0195	0.0354	-0.0201	-0.0603	0.0170	0.1121	0.0021	-0.0230	-0.0230
	(0.0641)	(0.0405)	(0.0808)	(0.0304)	(0.0234)	(0.0250)	(0.0298)	(0.0209)	(0.0303)	(0.0782)	(0.0804)	(0.0725)	(0.0304)	(0.0204)
APPLES	0.0138	-0.0205	0.3274	-0.0366	0.0963	0.0860	-0.0104	-0.0976	-0.0158	-0.1290	0.1193	-0.1273	0.0361	-0.0528
	(0.2006)	(0.1205)	(0.2625)	(0.0839)	(0.0607)	(0.0767)	(0.0703)	(0.0602)	(0.0799)	(0.1580)	(0.1595)	(0.2039)	(0.0917)	(0.0529)
ORANGE	0.0250	-0.2251	0.5352	0.0035	-0.0627	-0.0138	-0.1232	0.0255	-0.1241	-0.1820	-0.1355	0.1895	-0.0227	-0.0971
	(0.2044)	(0.1209)	(0.2356)	(0.0817)	(0.0562)	(0.0706)	(0.0663)	(0.0543)	(0.0746)	(0.1649)	(0.1589)	(0.1984)	(0.0893)	(0.0509)
BANANA	-0.0695	0.0065	0.1706	-0.1216	0.0711	-0.1090	-0.0464	-0.0200	0.0496	-0.3242	-0.1548	0.1310	-0.1061	0.0673
	(0.1791)	(0.1103)	(0.3026)	(0.0876)	(0.0748)	(0.0972)	(0.0917)	(0.0656)	(0.1060)	(0.2301)	(0.2380)	(0.2611)	(0.0948)	(0.0459)
GRAPES	0.0597	0.4489	-0.5154	-0.1092	-0.0108	-0.2646	0.5577	0.3373	-0.4753	-0.0590	-0.1490	-0.8389	0.1224	-0.0574
	(0.3163)	(0.1932)	(0.5218)	(0.1510)	(0.1331)	(0.1640)	(0.1461)	(0.1113)	(0.1803)	(0.3290)	(0.3257)	(0.4034)	(0.1527)	(0.0734)
GRAFRU	-0.5842	-0.3946	1.1654	0.1318	0.0247	-0.2710	0.1990	-0.0815	-0.0121	0.5525	-0.4746	-0.0599	-0.1200	-0.0316
	(0.2859)	(0.1708)	(0.4018)	(0.1265)	(0.0980)	(0.1278)	(0.1098)	(0.0892)	(0.1293)	(0.2787)	(0.2577)	(0.3727)	(0.1551)	(0.0818)
O.FRUT	0.5623	0.3459	-1.3271	0.0202	-0.1462	0.0481	0.0718	0.0303	0.3372	0.3599	-0.0597	-0.1947	-0.0649	0.0852
	(0.2512)	(0.1527)	(0.4048)	(0.1200)	(0.0986)	(0.1305)	(0.1201)	(0.0876)	(0.1368)	(0.2980)	(0.3097)	(0.3683)	(0.1450)	(0.0743)
LETTUC	0.0380	-0.0913	-0.1192	0.1135	-0.0062	-0.0038	-0.0238	-0.0010	0.0125	0.1529	0.0821	-0.0895	0.0575	0.0041
	(0.1564)	(0.0944)	(0.1822)	(0.0714)	(0.0436)	(0.0557)	(0.0494)	(0.0470)	(0.0699)	(0.1036)	(0.0987)	(0.1367)	(0.0684)	(0.0428)
TOMATO	-0.2331	-0.0511	0.1567	0.3299	-0.1007	-0.1422	0.0589	0.0119	-0.1415	0.2776	0.1474	0.1041	-0.0281	-0.0595
	(0.1612)	(0.0977)	(0.2431)	(0.0781)	(0.0608)	(0.0771)	(0.0668)	(0.0569)	(0.0888)	(0.1471)	(0.1548)	(0.1859)	(0.0788)	(0.0442)
CELERY	-0.2103	-0.2531	0.5477	0.0909	-0.1871	-0.3401	0.2377	0.1680	-0.0197	0.6846	-0.7508	0.0539	-0.0395	0.0185
	(0.1323)	(0.0829)	(0.2371)	(0.0700)	(0.0665)	(0.0810)	(0.0823)	(0.0533)	(0.0891)	(0.2297)	(0.2558)	(0.1829)	(0.0626)	(0.0276)
ONIONS	0.1816	0.1568	-0.4313	-0.0959	-0.0800	0.1344	-0.1032	0.0953	-0.0108	-0.0736	-0.0977	0.0041	0.1098	-0.0354
	(0.1528)	(0.0898)	(0.2317)	(0.0744)	(0.0573)	(0.0731)	(0.0657)	(0.0547)	(0.0855)	(0.1549)	(0.1541)	(0.1957)	(0.0845)	(0.0492)
CARROT	0.4844	0.0425	-0.4579	0.2584	-0.1292	-0.3544	0.0393	-0.0079	-0.1780	0.2247	0.6981	-0.5540	0.1812	0.0915
	(0.3448)	(0.2128)	(0.5853)	(0.1699)	(0.1537)	(0.1982)	(0.1757)	(0.1314)	(0.2203)	(0.3768)	(0.3993)	(0.4702)	(0.1747)	(0.0836)

Continued--

Appendix table--U.S. uncompensated food demand system--Continued   (Matrix partition B31)

Food category	Price													
	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
O.VEGE	-0.5567	0.0898	0.2922	-0.2582	0.3711	-0.1121	0.0411	0.0669	-0.1262	0.0450	0.1501	-0.2650	0.1717	-0.0230
	(0.2152)	(0.1324)	(0.3663)	(0.1068)	(0.1000)	(0.1250)	(0.1256)	(0.0878)	(0.1364)	(0.3772)	(0.4222)	(0.3128)	(0.1168)	(0.0596)
JUICE	-0.2120	-0.2185	0.0805	0.1478	-0.0031	0.1463	0.0866	-0.2072	-0.1002	0.0620	0.0819	0.0642	-0.0331	-0.0743
	(0.2201)	(0.1364)	(0.1902)	(0.0913)	(0.0492)	(0.0615)	(0.0588)	(0.0573)	(0.0739)	(0.0992)	(0.0943)	(0.1505)	(0.0848)	(0.0513)
C.TOMA	-0.2920	-0.2185	0.7210	0.2628	-0.1077	-0.2483	-0.2132	-0.0379	0.0815	0.2567	-0.3228	0.4038	-0.0889	0.0251
	(0.1491)	(0.0962)	(0.2722)	(0.0823)	(0.0785)	(0.0939)	(0.1071)	(0.0634)	(0.1054)	(0.3998)	(0.4539)	(0.2583)	(0.0872)	(0.0379)
C.PEAS	-0.5289	0.0189	0.7099	0.1436	-0.2534	0.0130	-0.0260	-0.0861	0.2834	1.1036	-1.2282	0.1575	-0.0349	-0.0232
	(0.2274)	(0.1426)	(0.3790)	(0.1198)	(0.1093)	(0.1327)	(0.1432)	(0.0898)	(0.1481)	(0.4198)	(0.4797)	(0.3142)	(0.1094)	(0.0505)
COCKTL	0.3613	0.3974	-0.4252	0.0839	-0.0575	0.1498	0.1440	0.2090	-0.2775	-0.2123	0.2560	-0.0506	0.1146	-0.0513
	(0.3589)	(0.2264)	(0.6285)	(0.1938)	(0.1800)	(0.2166)	(0.2356)	(0.1473)	(0.2436)	(0.7355)	(0.8335)	(0.4911)	(0.1722)	(0.0770)
NUTS	-0.2086	0.1419	0.0447	0.0251	0.0508	-0.1016	-0.0068	0.0163	0.0252	-0.1833	0.0117	0.0814	-0.0302	0.0095
	(0.1310)	(0.0788)	(0.1574)	(0.0612)	(0.0408)	(0.0517)	(0.0483)	(0.0415)	(0.0594)	(0.0836)	(0.0826)	(0.1231)	(0.0612)	(0.0354)
O.PRFV	-0.1450	-0.0454	0.1138	0.0489	0.0095	0.0066	0.0093	0.0496	0.0215	-0.1102	0.0353	0.1463	-0.0197	0.0262
	(0.0731)	(0.0450)	(0.0762)	(0.0333)	(0.0200)	(0.0252)	(0.0244)	(0.0219)	(0.0298)	(0.0471)	(0.0475)	(0.0572)	(0.0315)	(0.0182)
SUGAR	0.1082	-0.0071	-0.0129	-0.0043	-0.0101	0.0051	-0.0041	-0.0030	0.0140	0.0095	-0.0012	-0.0150	-0.0039	0.0057
	(0.0331)	(0.0185)	(0.0164)	(0.0079)	(0.0039)	(0.0045)	(0.0043)	(0.0053)	(0.0058)	(0.0076)	(0.0073)	(0.0123)	(0.0072)	(0.0052)
SWEET	-0.0435	0.0673	-0.1088	-0.0478	0.0275	-0.0090	-0.0249	0.0709	-0.1179	-0.0840	-0.0730	-0.0692	0.0463	0.0174
	(0.1013)	(0.0617)	(0.1047)	(0.0403)	(0.0220)	(0.0302)	(0.0270)	(0.0271)	(0.0360)	(0.0476)	(0.0467)	(0.0732)	(0.0395)	(0.0252)
COFFEE	0.0325	-0.0124	-0.0171	0.0108	-0.0207	-0.0080	0.0157	0.0137	0.0404	0.0099	-0.0002	-0.0222	0.0113	-0.0051
	(0.0665)	(0.0408)	(0.0466)	(0.0221)	(0.0109)	(0.0129)	(0.0125)	(0.0137)	(0.0163)	(0.0213)	(0.0202)	(0.0353)	(0.0208)	(0.0147)
FRZN.D	-0.0018	0.1056	-0.2998	0.1169	-0.0304	0.0024	-0.0474	-0.0215	-0.0442	-0.1434	0.1630	0.2505	-0.0789	-0.0110
	(0.0790)	(0.0483)	(0.1408)	(0.0391)	(0.0364)	(0.0481)	(0.0476)	(0.0290)	(0.0492)	(0.1170)	(0.1304)	(0.1164)	(0.0407)	(0.0176)
N.FOOD	-0.0232	-0.0159	-0.0043	-0.0104	-0.0020	0.0009	-0.0021	-0.0098	-0.0018	-0.0190	-0.0028	-0.0210	-0.0027	-0.0012
	(0.0074)	(0.0048)	(0.0060)	(0.0025)	(0.0016)	(0.0017)	(0.0018)	(0.0016)	(0.0020)	(0.0048)	(0.0048)	(0.0051)	(0.0023)	(0.0013)
WEIGHT	0.0316	0.0180	0.0043	0.0062	0.0018	0.0018	0.0018	0.0082	0.0036	0.0165	0.0040	0.0168	0.0024	0.0020

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Continued--

Appendix table--U.S. uncompensated food demand system--Continued   (Matrix partition B12)

Food category	Price													
	BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
BEEF.V	0.0063	-0.0100	0.0232	-0.0005	0.0004	-0.0030	0.0010	-0.0116	0.0386	0.0024	-0.0123	-0.0032	0.0038	0.0078
	(0.0079)	(0.0059)	(0.0154)	(0.0102)	(0.0103)	(0.0068)	(0.0050)	(0.0054)	(0.0175)	(0.0099)	(0.0092)	(0.0021)	(0.0034)	(0.0055)
PORK	0.0028	-0.0030	0.0496	-0.0035	-0.0213	-0.0002	0.0124	-0.0138	0.0411	-0.0107	-0.0046	-0.0070	0.0057	0.0012
	(0.0088)	(0.0066)	(0.0171)	(0.0107)	(0.0107)	(0.0074)	(0.0054)	(0.0057)	(0.0187)	(0.0105)	(0.0098)	(0.0023)	(0.0035)	(0.0059)
O.MEAT	-0.0396	0.1358	-0.2350	0.1222	0.1998	0.0484	-0.0594	0.1627	-0.6775	-0.0535	0.0683	0.0643	-0.0698	-0.0526
	(0.0907)	(0.0763)	(0.1428)	(0.0977)	(0.0877)	(0.0844)	(0.0607)	(0.0561)	(0.2071)	(0.0848)	(0.1018)	(0.0276)	(0.0377)	(0.0681)
CHICKN	0.0788	-0.0017	0.0163	-0.0102	0.0005	-0.0235	-0.0086	0.0124	0.0073	0.0372	0.0973	0.0077	-0.0108	0.0211
	(0.0231)	(0.0166)	(0.0372)	(0.0216)	(0.0211)	(0.0169)	(0.0122)	(0.0122)	(0.0426)	(0.0230)	(0.0227)	(0.0056)	(0.0084)	(0.0137)
TURKEY	0.0491	-0.0945	0.1626	0.0852	-0.0558	0.0477	-0.0027	0.0080	-0.1781	-0.0059	-0.0988	-0.0515	-0.0310	-0.0355
	(0.0745)	(0.0542)	(0.0990)	(0.0539)	(0.0499)	(0.0498)	(0.0370)	(0.0327)	(0.1206)	(0.0485)	(0.0608)	(0.0185)	(0.0223)	(0.0427)
FISH	-0.2828	0.0294	-0.0818	0.0752	-0.0132	-0.0731	-0.0734	-0.0909	0.0581	-0.0043	-0.1414	-0.0943	0.0520	-0.0983
	(0.0784)	(0.0620)	(0.1055)	(0.0681)	(0.0627)	(0.0648)	(0.0455)	(0.0426)	(0.1595)	(0.0619)	(0.0771)	(0.0225)	(0.0284)	(0.0551)
C.FISH	-0.1452	-0.0317	0.1503	-0.0105	-0.1104	-0.0313	0.1550	0.0658	0.0872	-0.0265	0.0598	0.0662	-0.0403	0.0110
	(0.0950)	(0.0721)	(0.1259)	(0.0625)	(0.0589)	(0.0611)	(0.0406)	(0.0366)	(0.1467)	(0.0549)	(0.0668)	(0.0229)	(0.0255)	(0.0488)
EGGS	-0.0160	0.0046	-0.0171	-0.0201	0.0042	-0.0032	0.0207	-0.0064	0.0078	-0.0001	0.0038	0.0105	0.0080	-0.0003
	(0.0126)	(0.0095)	(0.0194)	(0.0117)	(0.0106)	(0.0096)	(0.0068)	(0.0065)	(0.0235)	(0.0115)	(0.0125)	(0.0033)	(0.0047)	(0.0080)
CHEESE	-0.2044	0.0271	-0.1268	-0.0083	-0.0561	0.0161	-0.0659	-0.0026	0.2054	0.0069	-0.0698	-0.0026	-0.0023	-0.0246
	(0.0488)	(0.0353)	(0.0639)	(0.0355)	(0.0332)	(0.0353)	(0.0250)	(0.0216)	(0.0836)	(0.0388)	(0.0444)	(0.0124)	(0.0166)	(0.0306)
F.MILK	0.0211	0.0361	0.0107	-0.0133	-0.0181	-0.0236	-0.0016	0.0197	0.0480	0.0190	0.0317	0.0210	-0.0032	0.0071
	(0.0217)	(0.0234)	(0.0360)	(0.0153)	(0.0160)	(0.0167)	(0.0100)	(0.0101)	(0.0397)	(0.0126)	(0.0160)	(0.0070)	(0.0066)	(0.0114)
O.MILK	0.0952	-0.1340	0.2128	0.0463	-0.0553	-0.0469	-0.0186	-0.0718	-0.0337	0.0407	0.0670	-0.0937	-0.0174	0.0873
	(0.0933)	(0.1076)	(0.1528)	(0.0638)	(0.0636)	(0.0714)	(0.0407)	(0.0387)	(0.1703)	(0.0494)	(0.0697)	(0.0320)	(0.0270)	(0.0499)
FLOUR	-0.0051	-0.0076	0.0037	-0.0129	0.0176	0.0093	-0.0248	-0.0025	-0.0255	-0.0102	0.0126	0.0019	0.0001	-0.0162
	(0.0260)	(0.0146)	(0.0328)	(0.0194)	(0.0189)	(0.0187)	(0.0120)	(0.0133)	(0.0482)	(0.0163)	(0.0199)	(0.0054)	(0.0082)	(0.0140)
RICE	-0.0964	0.0136	-0.0702	0.0233	-0.0157	-0.0531	0.0257	-0.0304	-0.0596	0.0483	-0.0197	-0.0079	0.0320	0.0380
	(0.0668)	(0.0345)	(0.0962)	(0.0612)	(0.0595)	(0.0474)	(0.0318)	(0.0388)	(0.1329)	(0.0570)	(0.0591)	(0.0130)	(0.0246)	(0.0364)
POTATO	-0.0233	-0.0355	-0.0845	-0.0430	-0.0781	0.0404	-0.0141	-0.0098	0.0938	0.0046	-0.0521	0.0049	-0.0124	0.0232
	(0.0389)	(0.0182)	(0.0776)	(0.0423)	(0.0407)	(0.0276)	(0.0183)	(0.0245)	(0.0818)	(0.0428)	(0.0398)	(0.0069)	(0.0172)	(0.0209)

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Continued--

Appendix table--U.S. uncompensated food demand system--Continued   (Matrix partition B22)

Food category	Price BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
BUTTER	-0.2428	0.1092	-0.1612	-0.0957	-0.0279	0.1417	0.0417	-0.0419	0.2263	-0.0170	-0.1213	-0.0102	-0.0122	0.0199
	(0.1613)	(0.0738)	(0.1298)	(0.0595)	(0.0562)	(0.0609)	(0.0416)	(0.0407)	(0.1474)	(0.0548)	(0.0740)	(0.0198)	(0.0277)	(0.0531)
MARGAR	0.1499	-0.0087	0.0068	0.1294	0.1185	0.0195	-0.0188	0.1067	-0.4879	-0.0137	0.1373	0.0284	-0.0161	-0.0317
	(0.1006)	(0.1470)	(0.1818)	(0.0475)	(0.0486)	(0.0593)	(0.0353)	(0.0302)	(0.1306)	(0.0366)	(0.0558)	(0.0267)	(0.0212)	(0.0419)
O.FATS	-0.0402	0.0001	-0.1393	-0.0540	-0.0484	-0.0156	-0.0130	-0.0439	0.0997	0.0228	-0.0782	-0.0195	-0.0021	-0.0068
	(0.0322)	(0.0335)	(0.0650)	(0.0263)	(0.0250)	(0.0197)	(0.0129)	(0.0141)	(0.0512)	(0.0238)	(0.0260)	(0.0073)	(0.0097)	(0.0148)
APPLES	-0.1119	0.1133	-0.2499	-0.1902	0.1233	0.1021	0.0554	0.0687	-0.0429	0.0475	-0.1073	0.0310	0.0065	0.0249
	(0.0707)	(0.0416)	(0.1250)	(0.1295)	(0.0877)	(0.0801)	(0.0519)	(0.0551)	(0.2182)	(0.0654)	(0.0775)	(0.0138)	(0.0270)	(0.0395)
ORANGE	-0.0319	0.1034	-0.2251	0.1229	-0.8486	-0.0635	-0.0021	-0.1035	0.4066	0.1672	-0.0376	0.0230	-0.0091	0.0307
	(0.0667)	(0.0425)	(0.1189)	(0.0878)	(0.1154)	(0.0765)	(0.0508)	(0.0523)	(0.2456)	(0.0578)	(0.0676)	(0.0147)	(0.0250)	(0.0362)
BANANA	0.2252	0.0221	-0.0955	0.1354	-0.0851	-0.4985	-0.0178	-0.0546	0.1612	-0.0342	0.1106	-0.0717	-0.0685	-0.1229
	(0.0965)	(0.0692)	(0.1247)	(0.1068)	(0.1019)	(0.1337)	(0.0655)	(0.0640)	(0.2668)	(0.0620)	(0.0832)	(0.0243)	(0.0312)	(0.0550)
GRAPES	0.1584	-0.0538	-0.1983	0.1759	-0.0078	-0.0433	-1.1795	-0.1464	0.5884	0.1554	0.2556	-0.0668	-0.0186	-0.0652
	(0.1581)	(0.0988)	(0.1956)	(0.1660)	(0.1624)	(0.1573)	(0.1591)	(0.1061)	(0.4266)	(0.1013)	(0.1333)	(0.0320)	(0.0499)	(0.0852)
GRAFRU	-0.1306	0.2493	-0.5492	0.1835	-0.2754	-0.1085	-0.1215	-0.4546	-0.1640	0.1013	-0.2617	-0.0143	-0.0631	0.1166
	(0.1288)	(0.0705)	(0.1783)	(0.1469)	(0.1392)	(0.1281)	(0.0884)	(0.1246)	(0.3606)	(0.0849)	(0.1112)	(0.0228)	(0.0389)	(0.0611)
O.FRUT	0.1962	-0.3111	0.3471	-0.0320	0.2953	0.0879	0.1339	-0.0451	-0.4159	0.0807	0.2598	-0.0474	0.0526	0.0328
	(0.1273)	(0.0831)	(0.1769)	(0.1584)	(0.1782)	(0.1456)	(0.0969)	(0.0982)	(0.5166)	(0.0795)	(0.1127)	(0.0289)	(0.0411)	(0.0720)
LETTUC	-0.0159	-0.0106	0.0877	0.0368	0.1329	-0.0208	0.0389	0.0299	0.0882	-0.0904	-0.0577	0.0127	0.0732	0.0159
	(0.0520)	(0.0256)	(0.0906)	(0.0524)	(0.0462)	(0.0372)	(0.0253)	(0.0255)	(0.0874)	(0.0873)	(0.0487)	(0.0169)	(0.0272)	(0.0384)
TOMATO	-0.1287	0.1050	-0.3334	-0.0974	-0.0352	0.0727	0.0708	-0.0881	0.3158	-0.0652	-0.6220	-0.0406	0.0544	0.0913
	(0.0781)	(0.0434)	(0.1100)	(0.0689)	(0.0601)	(0.0555)	(0.0370)	(0.0371)	(0.1377)	(0.0541)	(0.0845)	(0.0259)	(0.0260)	(0.0501)
CELERY	-0.0390	0.0782	-0.2980	0.0974	0.0721	-0.1727	-0.0668	-0.0179	-0.2097	0.0503	-0.1458	-0.0775	-0.0335	0.0736
	(0.0754)	(0.0748)	(0.1108)	(0.0442)	(0.0471)	(0.0583)	(0.0320)	(0.0274)	(0.1271)	(0.0677)	(0.0934)	(0.0638)	(0.0358)	(0.0757)
ONIONS	-0.0322	-0.0328	-0.0198	0.0142	-0.0212	-0.1174	-0.0131	-0.0544	0.1655	0.2097	0.1413	-0.0236	-0.2066	0.1141
	(0.0753)	(0.0425)	(0.1056)	(0.0618)	(0.0570)	(0.0535)	(0.0356)	(0.0333)	(0.1292)	(0.0778)	(0.0669)	(0.0256)	(0.0474)	(0.0549)
CARROT	0.0753	-0.0902	-0.1051	0.0781	0.0967	-0.2956	-0.0652	0.1392	0.1429	0.0630	0.3291	0.0736	0.1593	-0.5339
	(0.2017)	(0.1172)	(0.2249)	(0.1263)	(0.1158)	(0.1319)	(0.0852)	(0.0733)	(0.3168)	(0.1539)	(0.1805)	(0.0757)	(0.0768)	(0.2014)

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Continued--

Appendix table--U.S. uncompensated food demand system--Continued   (Matrix partition B32)

Food category	BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	Price GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
O.VEGE	0.1495	-0.1217	0.0332	0.0883	0.2179	-0.1944	-0.0543	0.0442	-0.4422	-0.1204	0.0230	0.0652	0.1431	-0.2799
	(0.1384)	(0.1208)	(0.1962)	(0.0870)	(0.0907)	(0.1001)	(0.0586)	(0.0528)	(0.2281)	(0.1234)	(0.1674)	(0.0762)	(0.0702)	(0.1282)
JUICE	0.0357	-0.0558	0.1523	-0.0786	-0.2001	0.0380	0.0203	-0.0256	0.1768	-0.0182	-0.0025	-0.0149	-0.0074	-0.0666
	(0.0484)	(0.0250)	(0.1161)	(0.0647)	(0.0607)	(0.0372)	(0.0277)	(0.0347)	(0.1097)	(0.0522)	(0.0544)	(0.0070)	(0.0250)	(0.0264)
C.TOMA	0.1267	-0.3257	0.4961	0.0036	-0.0704	-0.2047	-0.0949	0.0005	0.1189	-0.0291	-0.1998	-0.0840	-0.0184	0.1023
	(0.0968)	(0.1148)	(0.1588)	(0.0602)	(0.0605)	(0.0716)	(0.0452)	(0.0403)	(0.1624)	(0.0422)	(0.0658)	(0.0327)	(0.0255)	(0.0494)
C.PEAS	0.1614	0.0304	0.0403	0.0789	-0.0474	0.1587	-0.1481	0.0509	-0.0218	0.0274	-0.2093	-0.0832	0.0156	0.0972
	(0.1272)	(0.1345)	(0.1961)	(0.0891)	(0.0917)	(0.1100)	(0.0646)	(0.0569)	(0.2376)	(0.0636)	(0.0968)	(0.0432)	(0.0377)	(0.0719)
COCKTL	0.3537	0.4559	-0.4663	0.2407	0.2045	0.2753	-0.1712	0.1227	-0.5540	-0.0756	-0.1106	-0.0819	0.0483	-0.0846
	(0.1930)	(0.2312)	(0.3329)	(0.1414)	(0.1475)	(0.1750)	(0.1027)	(0.0877)	(0.3853)	(0.0764)	(0.1182)	(0.0572)	(0.0459)	(0.0817)
NUTS	-0.0326	0.0559	0.0791	-0.0432	0.1048	0.0323	0.0246	0.0101	-0.1191	-0.0386	0.0571	0.0095	-0.0156	0.0277
	(0.0435)	(0.0220)	(0.0768)	(0.0452)	(0.0402)	(0.0319)	(0.0232)	(0.0290)	(0.0884)	(0.0409)	(0.0456)	(0.0064)	(0.0197)	(0.0233)
O.PRFV	-0.0026	-0.0055	0.1132	-0.0080	-0.0033	-0.0024	0.0256	-0.0063	-0.0335	-0.0076	0.0037	0.0122	-0.0074	0.0182
	(0.0229)	(0.0121)	(0.0539)	(0.0257)	(0.0233)	(0.0159)	(0.0114)	(0.0144)	(0.0447)	(0.0212)	(0.0234)	(0.0035)	(0.0102)	(0.0113)
SUGAR	0.0061	-0.0013	0.0041	-0.0048	-0.0083	-0.0067	0.0021	-0.0054	0.0003	-0.0034	-0.0055	-0.0006	0.0015	0.0002
	(0.0044)	(0.0020)	(0.0103)	(0.0061)	(0.0059)	(0.0029)	(0.0018)	(0.0027)	(0.0086)	(0.0047)	(0.0043)	(0.0006)	(0.0019)	(0.0021)
SWEET	-0.0336	0.0084	-0.0787	0.0616	0.0403	-0.0047	-0.0280	0.0213	-0.0413	-0.0030	0.0213	0.0012	-0.0112	-0.0130
	(0.0300)	(0.0128)	(0.0535)	(0.0323)	(0.0258)	(0.0196)	(0.0124)	(0.0168)	(0.0498)	(0.0296)	(0.0285)	(0.0039)	(0.0125)	(0.0146)
COFFEE	0.0176	0.0000	-0.0153	0.0046	-0.0229	0.0012	0.0069	-0.0031	0.0249	0.0080	-0.0111	-0.0021	-0.0021	-0.0034
	(0.0124)	(0.0055)	(0.0299)	(0.0175)	(0.0168)	(0.0083)	(0.0053)	(0.0079)	(0.0243)	(0.0141)	(0.0127)	(0.0016)	(0.0056)	(0.0061)
FRZN.D	0.0424	0.0156	-0.0183	0.0455	-0.0069	0.0727	-0.0243	0.0480	-0.0683	0.0510	0.0017	0.0026	0.0358	0.0266
	(0.0556)	(0.0395)	(0.0653)	(0.0379)	(0.0382)	(0.0437)	(0.0266)	(0.0242)	(0.1025)	(0.0231)	(0.0347)	(0.0128)	(0.0135)	(0.0268)
N.FOOD	-0.0016	-0.0021	-0.0089	-0.0023	-0.0006	-0.0004	0.0003	0.0001	-0.0031	-0.0034	-0.0016	-0.0003	-0.0008	-0.0009
	(0.0018)	(0.0013)	(0.0030)	(0.0017)	(0.0017)	(0.0013)	(0.0009)	(0.0009)	(0.0035)	(0.0014)	(0.0014)	(0.0004)	(0.0006)	(0.0009)
WEIGHT	0.0019	0.0014	0.0076	0.0016	0.0016	0.0012	0.0005	0.0006	0.0022	0.0020	0.0018	0.0005	0.0007	0.0005

Continued--

Appendix table--U.S. uncompensated food demand system--Continued (Matrix partition B13)

Food category	Price												EXPEND	CONST
	O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	NUTS	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD		
BEEF.V	-0.0117	-0.0088	-0.0026	-0.0066	0.0035	-0.0165	-0.0421	0.0456	-0.0076	0.0073	-0.0007	0.0310	0.3923	-0.0001
	(0.0048)	(0.0091)	(0.0014)	(0.0029)	(0.0034)	(0.0099)	(0.0197)	(0.0157)	(0.0180)	(0.0105)	(0.0093)	(0.1622)	(0.1240)	(0.0083)
PORK	0.0039	-0.0162	-0.0036	0.0004	0.0066	0.0176	-0.0268	-0.0157	0.0196	-0.0026	0.0202	-0.3084	0.6593	-0.0231
	(0.0052)	(0.0098)	(0.0016)	(0.0032)	(0.0038)	(0.0105)	(0.0213)	(0.0154)	(0.0192)	(0.0113)	(0.0099)	(0.1830)	(0.1461)	(0.0098)
O.MEAT	0.0489	0.0255	0.0507	0.0665	-0.0293	0.0266	0.2300	-0.0363	-0.1361	-0.0130	-0.2549	0.5954	-0.5737	0.0321
	(0.0596)	(0.0575)	(0.0190)	(0.0353)	(0.0438)	(0.0879)	(0.1506)	(0.0573)	(0.1364)	(0.0542)	(0.1211)	(1.0658)	(0.4802)	(0.0296)
CHICKN	-0.0283	0.0314	0.0130	0.0095	0.0043	0.0098	0.0666	-0.0114	-0.0413	0.0124	0.0704	-0.4768	0.0769	0.0286
	(0.0121)	(0.0191)	(0.0040)	(0.0077)	(0.0094)	(0.0237)	(0.0456)	(0.0191)	(0.0364)	(0.0178)	(0.0233)	(0.2905)	(0.1884)	(0.0123)
TURKEY	0.1453	-0.0016	-0.0176	-0.0560	-0.0093	0.0683	0.0459	-0.0826	0.0886	-0.0527	-0.0611	0.1292	-0.1267	0.0437
	(0.0389)	(0.0355)	(0.0131)	(0.0243)	(0.0300)	(0.0544)	(0.0943)	(0.0324)	(0.0685)	(0.0303)	(0.0748)	(0.6818)	(0.3449)	(0.0218)
FISH	-0.0430	0.1056	-0.0413	0.0030	0.0250	-0.1362	0.0277	0.0362	-0.0282	-0.0203	0.0042	1.0055	0.4290	-0.0187
	(0.0486)	(0.0444)	(0.0157)	(0.0295)	(0.0361)	(0.0690)	(0.1189)	(0.0376)	(0.0940)	(0.0360)	(0.0988)	(0.7372)	(0.3076)	(0.0188)
C.FISH	0.0166	0.0625	-0.0354	-0.0057	0.0241	-0.0098	0.0407	-0.0402	-0.0774	0.0457	-0.0979	-0.3428	0.3942	-0.0113
	(0.0489)	(0.0425)	(0.0179)	(0.0318)	(0.0393)	(0.0644)	(0.1154)	(0.0356)	(0.0840)	(0.0349)	(0.0979)	(0.7791)	(0.3621)	(0.0219)
EGGS	0.0064	-0.0328	-0.0012	-0.0041	0.0078	0.0043	0.0491	-0.0097	0.0492	0.0110	-0.0098	-0.2594	0.2865	-0.0223
	(0.0075)	(0.0091)	(0.0023)	(0.0044)	(0.0054)	(0.0121)	(0.0227)	(0.0097)	(0.0185)	(0.0084)	(0.0131)	(0.1387)	(0.0816)	(0.0053)
CHEESE	-0.0239	-0.0362	0.0069	0.0316	-0.0230	0.0161	0.0474	0.0523	-0.1834	0.0581	-0.0461	0.2038	0.4181	0.0119
	(0.0265)	(0.0267)	(0.0088)	(0.0165)	(0.0203)	(0.0396)	(0.0704)	(0.0241)	(0.0560)	(0.0226)	(0.0506)	(0.4176)	(0.1934)	(0.0118)
F.MILK	0.0027	0.0052	0.0049	0.0270	-0.0037	-0.0267	-0.0576	0.0069	-0.0268	0.0065	-0.0316	-0.0830	0.1193	-0.0150
	(0.0160)	(0.0078)	(0.0073)	(0.0102)	(0.0134)	(0.0122)	(0.0243)	(0.0069)	(0.0161)	(0.0064)	(0.0262)	(0.2318)	(0.0718)	(0.0044)
O.MILK	0.0268	0.0264	-0.0241	-0.1228	0.0193	0.0060	0.0709	-0.0120	-0.1027	0.0013	0.1498	-0.0315	0.5151	-0.0149
	(0.0739)	(0.0306)	(0.0340)	(0.0480)	(0.0625)	(0.0495)	(0.1008)	(0.0275)	(0.0653)	(0.0252)	(0.1206)	(0.9571)	(0.2584)	(0.0151)
FLOUR	-0.0102	0.0053	0.0074	0.0039	-0.0007	0.0115	0.0731	-0.0153	-0.0215	-0.0032	0.0556	-0.1767	0.1314	-0.0054
	(0.0130)	(0.0116)	(0.0046)	(0.0075)	(0.0088)	(0.0176)	(0.0289)	(0.0110)	(0.0244)	(0.0105)	(0.0256)	(0.2255)	(0.1172)	(0.0076)
RICE	0.0509	-0.0176	-0.0109	-0.0056	0.0145	-0.0303	-0.0709	-0.0265	0.1097	0.0270	-0.1212	-0.0733	0.1475	0.0144
	(0.0341)	(0.0459)	(0.0109)	(0.0182)	(0.0215)	(0.0612)	(0.1117)	(0.0450)	(0.0922)	(0.0434)	(0.0627)	(0.7031)	(0.4537)	(0.0295)
POTATO	-0.0072	-0.0480	0.0040	-0.0044	-0.0075	0.0113	0.1104	0.0415	0.0503	-0.0091	-0.0198	0.3714	0.1100	-0.0135
	(0.0209)	(0.0333)	(0.0057)	(0.0101)	(0.0116)	(0.0425)	(0.0772)	(0.0387)	(0.0705)	(0.0368)	(0.0326)	(0.4736)	(0.3235)	(0.0209)

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Appendix table--U.S. uncompensated food demand system--Continued   (Matrix partition B23)

Food category	O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	NUTS	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD	EXPEND	CONST
BUTTER	0.0556	0.0242	0.0201	0.0340	0.0559	-0.0423	-0.0160	0.0404	-0.0996	0.0478	0.0815	-0.1938	0.5386	-0.0342
	(0.0510)	(0.0331)	(0.0153)	(0.0268)	(0.0305)	(0.0549)	(0.1025)	(0.0344)	(0.0885)	(0.0327)	(0.1083)	(0.7132)	(0.3659)	(0.0207)
MARGAR	-0.0597	-0.0509	-0.0694	0.0091	0.0980	0.0968	-0.0305	-0.0092	0.0377	0.0059	0.0435	0.0288	-0.3355	0.0349
	(0.0604)	(0.0232)	(0.0246)	(0.0384)	(0.0495)	(0.0377)	(0.0733)	(0.0209)	(0.0511)	(0.0196)	(0.1043)	(0.7166)	(0.2494)	(0.0148)
O.FATS	0.0036	0.0259	0.0197	0.0022	-0.0183	0.0240	0.1226	0.0007	-0.0584	-0.0085	-0.0098	-0.4041	0.4938	-0.0051
	(0.0181)	(0.0199)	(0.0063)	(0.0103)	(0.0131)	(0.0243)	(0.0603)	(0.0204)	(0.0394)	(0.0197)	(0.0318)	(0.2941)	(0.1713)	(0.0110)
APPLES	0.0398	-0.0629	0.0010	0.0201	0.0454	-0.0637	-0.0395	-0.0392	0.2201	0.0202	0.1075	0.0534	-0.3617	-0.0111
	(0.0381)	(0.0526)	(0.0113)	(0.0223)	(0.0265)	(0.0677)	(0.1364)	(0.0569)	(0.1131)	(0.0548)	(0.0877)	(0.7811)	(0.4206)	(0.0284)
ORANGE	0.0964	-0.1619	-0.0129	-0.0115	0.0386	0.1579	-0.0159	-0.0754	0.1443	-0.0667	-0.0143	0.7614	-0.1646	0.0137
	(0.0397)	(0.0493)	(0.0113)	(0.0229)	(0.0277)	(0.0604)	(0.1236)	(0.0549)	(0.0905)	(0.0525)	(0.0884)	(0.7988)	(0.4765)	(0.0326)
BANANA	-0.1126	0.0415	-0.0509	0.0531	0.0690	0.0646	-0.0179	-0.0848	-0.0203	0.0085	0.2248	0.5804	0.0940	-0.0119
	(0.0584)	(0.0403)	(0.0179)	(0.0367)	(0.0438)	(0.0638)	(0.1128)	(0.0363)	(0.0914)	(0.0345)	(0.1348)	(0.8508)	(0.3658)	(0.0230)
GRAPES	-0.0755	0.0524	-0.0568	-0.1184	-0.1027	0.1171	0.4315	0.0536	-0.3147	0.0701	-0.1812	0.9628	0.5613	-0.0198
	(0.0821)	(0.0720)	(0.0271)	(0.0517)	(0.0616)	(0.1116)	(0.1944)	(0.0553)	(0.1394)	(0.0530)	(0.1970)	(1.3482)	(0.5710)	(0.0358)
GRAFRU	0.0528	-0.0543	0.0006	0.0344	0.0617	0.0419	-0.0848	-0.1264	0.2036	-0.0190	0.2989	1.5285	-0.4896	0.0486
	(0.0616)	(0.0752)	(0.0201)	(0.0379)	(0.0438)	(0.1162)	(0.2037)	(0.0676)	(0.1563)	(0.0657)	(0.1492)	(1.1850)	(0.5712)	(0.0375)
O.FRUT	-0.1399	0.1048	0.0164	-0.0038	-0.0754	-0.1300	-0.1304	0.0000	-0.1034	0.0600	-0.1144	-0.3104	0.1234	-0.0350
	(0.0726)	(0.0648)	(0.0221)	(0.0432)	(0.0525)	(0.0964)	(0.1729)	(0.0587)	(0.1269)	(0.0553)	(0.1724)	(1.2284)	(0.5278)	(0.0328)
LETTUC	-0.0415	-0.0119	-0.0042	0.0056	-0.0112	-0.0469	-0.0351	-0.0313	-0.0080	0.0221	0.0940	-0.7499	0.3720	0.0051
	(0.0431)	(0.0339)	(0.0063)	(0.0127)	(0.0115)	(0.0491)	(0.0900)	(0.0354)	(0.0829)	(0.0352)	(0.0428)	(0.5242)	(0.2803)	(0.0184)
TOMATO	0.0092	-0.0025	-0.0333	-0.0466	-0.0185	0.0741	0.0101	-0.0598	0.0634	-0.0314	0.0011	-0.5139	0.9184	-0.0131
	(0.0651)	(0.0393)	(0.0110)	(0.0215)	(0.0197)	(0.0608)	(0.1107)	(0.0362)	(0.0886)	(0.0353)	(0.0713)	(0.5966)	(0.1906)	(0.0116)
CELERY	0.0917	-0.0392	-0.0503	-0.0666	-0.0491	0.0441	0.2012	-0.0297	0.0120	-0.0209	0.0177	-0.1471	0.7250	-0.0389
	(0.1067)	(0.0181)	(0.0196)	(0.0345)	(0.0343)	(0.0308)	(0.0601)	(0.0174)	(0.0432)	(0.0162)	(0.0951)	(0.6530)	(0.2283)	(0.0135)
ONIONS	0.1440	-0.0134	-0.0077	0.0092	0.0209	-0.0535	-0.0907	0.0311	-0.0873	-0.0116	0.1896	-0.0868	0.0783	0.0030
	(0.0702)	(0.0463)	(0.0109)	(0.0216)	(0.0197)	(0.0676)	(0.1243)	(0.0413)	(0.1003)	(0.0399)	(0.0715)	(0.6492)	(0.3184)	(0.0209)
CARROT	-0.3914	-0.1736	0.0614	0.0778	-0.0508	0.1318	0.3033	-0.0044	-0.1470	-0.0335	0.1949	-1.0495	0.6750	-0.0220
	(0.1794)	(0.0686)	(0.0296)	(0.0575)	(0.0490)	(0.1119)	(0.1915)	(0.0642)	(0.1633)	(0.0614)	(0.1981)	(1.4410)	(0.5309)	(0.0322)

Continued--

Appendix table--U.S. uncompensated food demand system--Continued (Matrix partition B33)

Food category	O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	NUTS	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD	EXPEND	CONST
O.VEGE	-0.2152	-0.0339	0.0479	0.0772	-0.0199	0.0045	-0.0159	-0.0379	0.1092	-0.0426	-0.1604	-0.4427	1.2917	-0.0656
	(0.2407)	(0.0560)	(0.0336)	(0.0626)	(0.0599)	(0.0900)	(0.1594)	(0.0437)	(0.1084)	(0.0414)	(0.1813)	(1.1307)	(0.4331)	(0.0262)
JUICE	-0.0176	-0.5575	0.0276	0.0268	0.0138	0.0486	-0.1713	-0.0323	0.0972	-0.0122	0.0487	0.3878	0.3664	0.0373
	(0.0302)	(0.1081)	(0.0106)	(0.0192)	(0.0226)	(0.0786)	(0.1662)	(0.0638)	(0.1164)	(0.0623)	(0.0362)	(0.7778)	(0.5539)	(0.0377)
C.TOMA	0.1121	0.1188	-0.1688	0.0400	-0.0436	0.0830	-0.4071	0.0088	-0.1252	0.0191	0.1056	-0.6535	0.8684	-0.0205
	(0.0785)	(0.0459)	(0.0885)	(0.0995)	(0.1258)	(0.0762)	(0.1610)	(0.0286)	(0.0616)	(0.0268)	(0.1223)	(0.9275)	(0.2654)	(0.0161)
C.PEAS	0.1355	0.0869	0.0301	-0.5335	-0.0638	0.2569	-0.3404	-0.0320	0.0201	0.0241	0.0791	-0.6915	0.6282	-0.0305
	(0.1096)	(0.0622)	(0.0746)	(0.1580)	(0.1522)	(0.0992)	(0.2179)	(0.0391)	(0.0884)	(0.0358)	(0.1767)	(1.1467)	(0.3599)	(0.0217)
COCKTL	-0.0461	0.0591	-0.0436	-0.0850	-0.7400	-0.0081	-0.0422	-0.0249	-0.0773	0.0185	0.2310	-0.7570	0.7172	-0.0025
	(0.1398)	(0.0977)	(0.1258)	(0.2029)	(0.3536)	(0.1524)	(0.3582)	(0.0629)	(0.1386)	(0.0560)	(0.2573)	(1.9001)	(0.5848)	(0.0350)
NUTS	0.0021	0.0267	0.0106	0.0430	-0.0008	-0.1685	-0.1194	-0.0445	0.0670	-0.0446	-0.1107	0.2117	0.0992	0.0213
	(0.0262)	(0.0425)	(0.0095)	(0.0165)	(0.0191)	(0.0778)	(0.1020)	(0.0290)	(0.0681)	(0.0288)	(0.0325)	(0.4656)	(0.2551)	(0.0165)
O.PRFV	-0.0004	-0.0258	-0.0141	-0.0158	-0.0013	-0.0335	-0.1509	-0.0018	-0.0132	-0.0128	0.0062	-0.0012	0.0216	0.0398
	(0.0131)	(0.0251)	(0.0057)	(0.0102)	(0.0126)	(0.0285)	(0.0752)	(0.0195)	(0.0399)	(0.0177)	(0.0177)	(0.2624)	(0.1541)	(0.0096)
SUGAR	-0.0009	-0.0023	0.0004	-0.0006	-0.0003	-0.0069	-0.0009	-0.0368	0.0013	0.0067	0.0030	-0.0277	0.0059	0.0023
	(0.0020)	(0.0055)	(0.0006)	(0.0010)	(0.0013)	(0.0046)	(0.0110)	(0.0220)	(0.0137)	(0.0084)	(0.0045)	(0.1858)	(0.1761)	(0.0120)
SWEET	0.0143	0.0225	-0.0066	0.0015	-0.0040	0.0279	-0.0234	-0.0028	-0.0522	-0.0867	0.0512	0.0472	0.4190	-0.0170
	(0.0136)	(0.0270)	(0.0033)	(0.0063)	(0.0074)	(0.0292)	(0.0606)	(0.0362)	(0.0938)	(0.0317)	(0.0273)	(0.3767)	(0.2659)	(0.0168)
COFFEE	-0.0056	-0.0038	0.0012	0.0019	0.0011	-0.0232	-0.0284	0.0079	-0.0994	-0.1761	-0.0334	-0.5113	0.8176	-0.0349
	(0.0058)	(0.0162)	(0.0016)	(0.0029)	(0.0034)	(0.0138)	(0.0301)	(0.0253)	(0.0356)	(0.0289)	(0.0109)	(0.2567)	(0.2153)	(0.0142)
FRZN.D	-0.0296	0.0173	0.0087	0.0087	0.0189	-0.0722	0.0123	0.0085	0.0784	-0.0423	-0.0784	-0.3677	0.2534	0.0000
	(0.0343)	(0.0127)	(0.0099)	(0.0191)	(0.0209)	(0.0211)	(0.0407)	(0.0175)	(0.0414)	(0.0147)	(0.0955)	(0.3847)	(0.1366)	(0.0077)
N.FOOD	-0.0003	-0.0004	-0.0003	-0.0006	-0.0004	-0.0019	-0.0097	-0.0179	-0.0039	-0.0049	-0.0050	-0.9795	1.1661	-0.0015
	(0.0010)	(0.0014)	(0.0004)	(0.0006)	(0.0007)	(0.0015)	(0.0030)	(0.0043)	(0.0030)	(0.0019)	(0.0018)	(0.0198)	(0.0093)	(0.0005)
WEIGHT	0.0007	0.0013	0.0003	0.0004	0.0003	0.0024	0.0085	0.0150	0.0056	0.0050	0.0037	0.8137	NA	NA

Appendix C:

Compensated Food Demand System

The computed compensated demand system is represented as

$$q_i' = \sum_{j=1}^{n} e_{ij}^* \, p_j' + \alpha_i \qquad i=1,2,..,n$$

where variables q_i' and p_i' are the relative changes in per capita quantity and price. The parameters e_{ij}^* and α_i are compensated price elasticity and constant. These parameters of the demand system may be presented in a matrix form of order $n \times (n+1)$ for n commodity case as follows:

Food category	Price						
	p_1'	p_2'	.	.	.	p_n'	1
q_1'	e_{11}^*	e_{12}^*	.	.	.	e_{1n}^*	α_1
q_2'	e_{21}^*	e_{22}^*	.	.	.	e_{2n}^*	α_2
.							
.							
q_n'	e_{n1}^*	e_{n2}^*	.	.	.	e_{nn}^*	α_n

To illustrate empirical estimation results, the matrix of parameter estimates is then partitioned into six blocks and presented in a sequential table ordering as C11, C21, C12, C22, C13, and C23.

Partition of compensated elasticity matrix

C11	C12	C13
C21	C22	C23

The notations in the tables are BEEF.V (beef and veal), PORK (pork), O.MEAT (other meats), CHICKN (chicken), TURKEY (turkey), FISH (fresh and frozen fish), C.FISH (canned and cured fish), EGGS (eggs), CHEESE (cheese), F.MILK (fluid milk), O.MILK (evaporated and dry milk), FLOUR (wheat flour), RICE (rice), POTATO (potatoes), BUTTER (butter), MARGAR (margarine), O.FATS (other fats and oils), APPLES (apples), ORANGE (oranges), BANANA (bananas), GRAPES (grapes), GRAFRU (grapefruits), O.FRUT (other fresh fruits), LETTUC (lettuce), TOMATO (tomatoes), CELERY (celery), ONIONS (onions), CARROT (carrots), O.VEGE (other fresh vegetables), JUICE (fruit juice), C.TOMA (canned tomatoes), C.PEAS (canned peas), COCKTL (canned fruit cocktail), NUTS (peanuts and tree nuts), O.PRFV (other processed fruits and vegetables), SUGAR (sugar), SWEET (sweeteners), COFFEE (coffee and tea), FRZN.D (ice cream and other frozen dairy products), N.FOOD (nonfood), CONST (constant term), WEIGHT (expenditure weight), and NA (not applicable).

Appendix table--U.S. compensated food demand system   (Matrix partition C11)

Food category							Price							
	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
BEEF.V	-0.6088	0.1214	0.1089	0.0207	0.0048	-0.0057	0.0012	0.0262	-0.0243	-0.0048	-0.0072	-0.0678	0.0515	0.0048
PORK	0.2130	-0.7162	0.0823	0.0167	0.0139	0.0264	0.0111	0.0078	-0.0037	0.0127	-0.0139	0.0080	0.0249	-0.0073
O.MEAT	0.7999	0.3447	-1.8764	0.2764	-0.0570	-0.0251	0.0222	-0.1741	0.3555	-0.0808	0.2445	1.0138	-0.3923	-0.1339
CHICKN	0.1054	0.0484	0.1917	-0.3718	-0.0225	-0.0134	0.0179	0.0797	-0.0386	-0.0571	0.1167	0.0395	-0.0643	0.0174
TURKEY	0.0847	0.1387	-0.1363	-0.0775	-0.5347	0.0378	0.1352	-0.0738	0.2213	0.4294	-0.2257	0.1787	-0.0695	0.0081
FISH	-0.0996	0.2636	-0.0601	-0.0458	0.0378	0.1220	0.0152	0.0040	0.0128	-0.4237	-0.1652	-0.2936	0.0266	0.0287
C.FISH	0.0218	0.1108	0.0529	0.0617	0.1352	0.0152	-0.3708	-0.2352	0.1305	0.2046	-0.2286	-0.0569	0.0474	-0.0158
EGGS	0.1009	0.0172	-0.0913	0.0603	-0.0162	0.0009	-0.0516	-0.1080	0.0098	0.0471	0.0403	-0.0859	0.0106	0.0062
CHEESE	-0.2136	-0.0184	0.4246	-0.0664	0.1107	0.0065	0.0653	0.0223	-0.2457	0.0389	-0.1786	-0.2317	0.1251	-0.0028
F.MILK	-0.0092	0.0138	-0.0211	-0.0215	0.0468	-0.0462	0.0223	0.0234	0.0085	-0.0411	-0.0598	0.0258	-0.0277	0.0023
O.MILK	-0.0574	-0.0625	0.2628	0.1809	-0.1016	-0.0744	-0.1029	0.0827	-0.1607	-0.2466	-0.2743	0.0391	-0.0077	-0.0165
FLOUR	-0.1274	0.0086	0.2595	0.0145	0.0191	-0.0315	-0.0061	-0.0419	-0.0496	0.0254	0.0093	-0.0755	0.0194	-0.0091
RICE	0.6786	0.1864	-0.7029	-0.1661	-0.0521	0.0200	0.0356	0.0361	0.1876	-0.1907	-0.0127	0.1357	0.0665	-0.0256
POTATO	0.0755	-0.0651	-0.2880	0.0538	0.0073	0.0258	-0.0142	0.0252	-0.0050	0.0193	-0.0329	-0.0767	-0.0307	-0.0981
BUTTER	0.1167	0.0381	-0.0920	0.2574	0.0464	-0.2671	-0.1368	-0.0666	-0.3859	0.1850	0.2025	-0.0431	-0.1214	-0.0243
MARGAR	-0.2128	-0.0270	0.4148	-0.0069	-0.1218	0.0386	-0.0400	0.0291	0.0713	0.4278	-0.3809	-0.0894	0.0237	-0.0505
O.FATS	0.1089	0.1294	-0.1355	0.0138	0.0383	-0.0186	0.0363	-0.0161	-0.0585	0.0251	0.1141	0.0104	-0.0218	-0.0220
APPLES	0.0024	-0.0270	0.3258	-0.0388	0.0956	0.0853	-0.0111	-0.1006	-0.0171	-0.1350	0.1179	-0.1334	0.0352	-0.0535
ORANGE	0.0198	-0.2281	0.5345	0.0025	-0.0630	-0.0141	-0.1235	0.0242	-0.1247	-0.1847	-0.1362	0.1867	-0.0231	-0.0974
BANANA	-0.0665	0.0082	0.1710	-0.1210	0.0713	-0.1088	-0.0462	-0.0192	0.0499	-0.3226	-0.1544	0.1326	-0.1059	0.0675

Continued--

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Appendix table--U.S. compensated food demand system--Continued (Matrix partition C21)

Food category	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
							Price							
GRAPES	0.0774	0.4590	-0.5130	-0.1057	-0.0098	-0.2636	0.5587	0.3419	-0.4733	-0.0497	-0.1468	-0.8295	0.1237	-0.0563
GRAFRU	-0.5997	-0.4034	1.1633	0.1288	0.0238	-0.2719	0.1981	-0.0855	-0.0139	0.5444	-0.4766	-0.0681	-0.1212	-0.0326
O.FRUT	0.5662	0.3481	-1.3266	0.0210	-0.1460	0.0483	0.0720	0.0313	0.3376	0.3619	-0.0592	-0.1926	-0.0646	0.0854
LETTUC	0.0498	-0.0846	-0.1176	0.1158	-0.0055	-0.0031	-0.0231	0.0021	0.0138	0.1590	0.0836	-0.0833	0.0584	0.0048
TOMATO	-0.2041	-0.0346	0.1606	0.3356	-0.0990	-0.1405	0.0606	0.0194	-0.1382	0.2928	0.1511	0.1195	-0.0259	-0.0577
CELERY	-0.1874	-0.2400	0.5508	0.0954	-0.1858	-0.3388	0.2390	0.1739	-0.0171	0.6966	-0.7479	0.0661	-0.0378	0.0199
ONIONS	0.1841	0.1582	-0.4310	-0.0954	-0.0799	0.1345	-0.1031	0.0959	-0.0105	-0.0723	-0.0974	0.0054	0.1100	-0.0352
CARROT	0.5057	0.0546	-0.4550	0.2626	-0.1280	-0.3532	0.0405	-0.0024	-0.1756	0.2358	0.7008	-0.5427	0.1828	0.0928
O.VEGE	-0.5159	0.1131	0.2978	-0.2502	0.3734	-0.1098	0.0434	0.0775	-0.1215	0.0663	0.1553	-0.2433	0.1748	-0.0204
JUICE	-0.2004	-0.2119	0.0821	0.1501	-0.0024	0.1470	0.0873	-0.2042	-0.0989	0.0680	0.0834	0.0704	-0.0322	-0.0736
C.TOMA	-0.2646	-0.2029	0.7247	0.2682	-0.1061	-0.2467	-0.2116	-0.0308	0.0846	0.2710	-0.3193	0.4184	-0.0868	0.0268
C.PEAS	-0.5090	0.0302	0.7126	0.1475	-0.2523	0.0141	-0.0249	-0.0809	0.2857	1.1140	-1.2257	0.1681	-0.0334	-0.0219
COCKTL	0.3840	0.4103	-0.4221	0.0883	-0.0562	0.1511	0.1453	0.2149	-0.2749	-0.2005	0.2589	-0.0386	0.1163	-0.0499
NUTS	-0.2055	0.1437	0.0451	0.0257	0.0510	-0.1014	-0.0066	0.0171	0.0256	-0.1817	0.0121	0.0831	-0.0300	0.0097
O.PRFV	-0.1443	-0.0450	0.1139	0.0490	0.0095	0.0066	0.0093	0.0498	0.0216	-0.1098	0.0354	0.1467	-0.0196	0.0262
SUGAR	0.1084	-0.0070	-0.0129	-0.0043	-0.0101	0.0051	-0.0041	-0.0030	0.0140	0.0096	-0.0012	-0.0149	-0.0039	0.0057
SWEET	-0.0303	0.0748	-0.1070	-0.0452	0.0283	-0.0082	-0.0241	0.0743	-0.1164	-0.0771	-0.0713	-0.0622	0.0473	0.0182
COFFEE	0.0583	0.0023	-0.0136	0.0159	-0.0192	-0.0065	0.0172	0.0204	0.0433	0.0234	0.0031	-0.0085	0.0133	-0.0035
FRZN.D	0.0062	0.1102	-0.2987	0.1185	-0.0299	0.0029	-0.0469	-0.0194	-0.0433	-0.1392	0.1640	0.2548	-0.0783	-0.0105
N.FOOD	0.0136	0.0051	0.0007	-0.0032	0.0001	0.0030	0.0000	-0.0002	0.0024	0.0002	0.0019	-0.0014	0.0001	0.0011
WEIGHT	0.0316	0.0180	0.0043	0.0062	0.0018	0.0018	0.0018	0.0082	0.0036	0.0165	0.0040	0.0168	0.0024	0.0020

Continued--

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Appendix table--U.S. compensated food demand system--Continued   (Matrix partition C12)

Food category	BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
							Price							
BEEF.V	0.0070	-0.0095	0.0262	0.0001	0.0010	-0.0025	0.0012	-0.0114	0.0395	0.0032	-0.0116	-0.0030	0.0041	0.0080
PORK	0.0041	-0.0021	0.0546	-0.0024	-0.0202	0.0006	0.0127	-0.0134	0.0426	-0.0094	-0.0034	-0.0067	0.0062	0.0015
O.MEAT	-0.0407	0.1350	-0.2394	0.1213	0.1989	0.0477	-0.0597	0.1624	-0.6788	-0.0546	0.0673	0.0640	-0.0702	-0.0529
CHICKN	0.0789	-0.0016	0.0169	-0.0101	0.0006	-0.0234	-0.0086	0.0124	0.0075	0.0374	0.0974	0.0077	-0.0107	0.0211
TURKEY	0.0489	-0.0947	0.1616	0.0850	-0.0560	0.0475	-0.0028	0.0079	-0.1784	-0.0062	-0.0990	-0.0516	-0.0311	-0.0356
FISH	-0.2820	0.0300	-0.0785	0.0759	-0.0125	-0.0726	-0.0732	-0.0906	0.0590	-0.0034	-0.1406	-0.0941	0.0523	-0.0981
C.FISH	-0.1445	-0.0311	0.1533	-0.0099	-0.1098	-0.0308	0.1552	0.0660	0.0881	-0.0257	0.0605	0.0664	-0.0400	0.0112
EGGS	-0.0155	0.0050	-0.0149	-0.0196	0.0047	-0.0029	0.0208	-0.0062	0.0084	0.0005	0.0043	0.0106	0.0082	-0.0002
CHEESE	-0.2036	0.0277	-0.1236	-0.0076	-0.0554	0.0166	-0.0657	-0.0023	0.2063	0.0077	-0.0690	-0.0024	-0.0020	-0.0244
F.MILK	0.0213	0.0363	0.0116	-0.0131	-0.0179	-0.0235	-0.0015	0.0198	0.0483	0.0192	0.0319	0.0211	-0.0031	0.0072
O.MILK	0.0962	-0.1333	0.2167	0.0471	-0.0545	-0.0463	-0.0183	-0.0715	-0.0326	0.0417	0.0679	-0.0934	-0.0170	0.0876
FLOUR	-0.0049	-0.0074	0.0047	-0.0127	0.0178	0.0095	-0.0247	-0.0024	-0.0252	-0.0099	0.0128	0.0020	0.0002	-0.0161
RICE	-0.0961	0.0138	-0.0691	0.0235	-0.0155	-0.0529	0.0258	-0.0303	-0.0593	0.0486	-0.0194	-0.0078	0.0321	0.0381
POTATO	-0.0231	-0.0353	-0.0837	-0.0428	-0.0779	0.0405	-0.0140	-0.0097	0.0940	0.0048	-0.0519	0.0050	-0.0123	0.0233
BUTTER	-0.2418	0.1100	-0.1571	-0.0948	-0.0270	0.1423	0.0420	-0.0416	0.2275	-0.0159	-0.1203	-0.0099	-0.0118	0.0202
MARGAR	0.1493	-0.0092	0.0043	0.1289	0.1180	0.0191	-0.0190	0.1065	-0.4886	-0.0144	0.1367	0.0282	-0.0163	-0.0319
O.FATS	-0.0393	0.0008	-0.1355	-0.0532	-0.0476	-0.0150	-0.0128	-0.0436	0.1008	0.0238	-0.0773	-0.0193	-0.0018	-0.0066
APPLES	-0.1126	0.1128	-0.2526	-0.1908	0.1227	0.1017	0.0552	0.0685	-0.0437	0.0468	-0.1080	0.0308	0.0062	0.0247
ORANGE	-0.0322	0.1032	-0.2264	0.1226	-0.8489	-0.0637	-0.0022	-0.1036	0.4062	0.1669	-0.0379	0.0229	-0.0092	0.0306
BANANA	0.2254	0.0222	-0.0948	0.1356	-0.0849	-0.4984	-0.0178	-0.0545	0.1614	-0.0340	0.1108	-0.0717	-0.0684	-0.1229

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Appendix table--U.S. compensated food demand system--Continued (Matrix partition C22)

Food category	BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
GRAPES	0.1595	-0.0530	-0.1940	0.1768	-0.0069	-0.0426	-1.1792	-0.1461	0.5896	0.1565	0.2566	-0.0665	-0.0182	-0.0649
GRAFRU	-0.1315	0.2486	-0.5529	0.1827	-0.2762	-0.1091	-0.1217	-0.4549	-0.1651	0.1003	-0.2626	-0.0145	-0.0634	0.1164
O.FRUT	0.1964	-0.3109	0.3480	-0.0318	0.2955	0.0880	0.1340	-0.0450	-0.4156	0.0809	0.2600	-0.0473	0.0527	0.0329
LETTUC	-0.0152	-0.0101	0.0905	0.0374	0.1335	-0.0204	0.0391	0.0301	0.0890	-0.0897	-0.0570	0.0129	0.0735	0.0161
TOMATO	-0.1270	0.1063	-0.3264	-0.0959	-0.0337	0.0738	0.0713	-0.0875	0.3178	-0.0634	-0.6203	-0.0401	0.0550	0.0918
CELERY	-0.0376	0.0792	-0.2925	0.0986	0.0733	-0.1718	-0.0664	-0.0175	-0.2081	0.0517	-0.1445	-0.0771	-0.0330	0.0740
ONIONS	-0.0321	-0.0327	-0.0192	0.0143	-0.0211	-0.1173	-0.0131	-0.0544	0.1657	0.2099	0.1414	-0.0236	-0.2065	0.1141
CARROT	0.0766	-0.0893	-0.1000	0.0792	0.0978	-0.2948	-0.0649	0.1396	0.1444	0.0644	0.3303	0.0739	0.1598	-0.5336
O.VEGE	0.1520	-0.1199	0.0430	0.0904	0.2200	-0.1928	-0.0537	0.0450	-0.4394	-0.1178	0.0253	0.0658	0.1440	-0.2793
JUICE	0.0364	-0.0553	0.1551	-0.0780	-0.1995	0.0384	0.0205	-0.0254	0.1776	-0.0175	-0.0018	-0.0147	-0.0071	-0.0664
C.TOMA	0.1283	-0.3245	0.5027	0.0050	-0.0690	-0.2037	-0.0945	0.0010	0.1208	-0.0274	-0.1982	-0.0836	-0.0178	0.1027
C.PEAS	0.1626	0.0313	0.0451	0.0799	-0.0464	0.1595	-0.1478	0.0513	-0.0204	0.0287	-0.2082	-0.0829	0.0160	0.0975
COCKTL	0.3551	0.4569	-0.4608	0.2418	0.2056	0.2762	-0.1708	0.1231	-0.5524	-0.0742	-0.1093	-0.0815	0.0488	-0.0842
NUTS	-0.0324	0.0560	0.0799	-0.0430	0.1050	0.0324	0.0246	0.0102	-0.1189	-0.0384	0.0573	0.0095	-0.0155	0.0277
O.PRFV	-0.0026	-0.0055	0.1134	-0.0080	-0.0033	-0.0024	0.0256	-0.0063	-0.0335	-0.0076	0.0037	0.0122	-0.0074	0.0182
SUGAR	0.0061	-0.0013	0.0041	-0.0048	-0.0083	-0.0067	0.0021	-0.0054	0.0003	-0.0034	-0.0055	-0.0006	0.0015	0.0002
SWEET	-0.0328	0.0090	-0.0755	0.0623	0.0410	-0.0042	-0.0278	0.0216	-0.0404	-0.0022	0.0221	0.0014	-0.0109	-0.0128
COFFEE	0.0192	0.0011	-0.0091	0.0059	-0.0216	0.0022	0.0073	-0.0026	0.0267	0.0096	-0.0096	-0.0017	-0.0015	-0.0030
FRZN.D	0.0429	0.0160	-0.0164	0.0459	-0.0065	0.0730	-0.0242	0.0482	-0.0677	0.0515	0.0022	0.0027	0.0360	0.0267
N.FOOD	0.0006	-0.0005	0.0000	-0.0004	0.0013	0.0010	0.0009	0.0008	-0.0005	-0.0011	0.0005	0.0003	0.0000	-0.0003
WEIGHT	0.0019	0.0014	0.0076	0.0016	0.0016	0.0012	0.0005	0.0006	0.0022	0.0020	0.0018	0.0005	0.0007	0.0005

Continued--

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Appendix table--U.S. compensated food demand system--Continued   (Matrix partition C13)

Food category	| Price O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	NUTS	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD	CONST
BEEF.V	-0.0114	-0.0083	-0.0025	-0.0064	0.0036	-0.0156	-0.0388	0.0515	-0.0054	0.0093	0.0008	0.3502	-0.0001
PORK	0.0044	-0.0153	-0.0034	0.0007	0.0068	0.0192	-0.0212	-0.0058	0.0233	0.0007	0.0226	0.2281	-0.0231
O.MEAT	0.0485	0.0248	0.0505	0.0663	-0.0295	0.0252	0.2251	-0.0449	-0.1393	-0.0159	-0.2570	0.1286	0.0321
CHICKN	-0.0282	0.0315	0.0130	0.0095	0.0043	0.0100	0.0673	-0.0102	-0.0409	0.0128	0.0707	-0.4142	0.0286
TURKEY	0.1452	-0.0018	-0.0176	-0.0561	-0.0093	0.0680	0.0448	-0.0845	0.0879	-0.0533	-0.0616	0.0261	0.0437
FISH	-0.0427	0.1062	-0.0412	0.0032	0.0251	-0.1352	0.0313	0.0426	-0.0258	-0.0182	0.0058	1.3546	-0.0187
C.FISH	0.0169	0.0630	-0.0353	-0.0055	0.0242	-0.0089	0.0441	-0.0343	-0.0752	0.0477	-0.0964	-0.0220	-0.0113
EGGS	0.0066	-0.0324	-0.0011	-0.0040	0.0079	0.0050	0.0515	-0.0054	0.0508	0.0124	-0.0087	-0.0263	-0.0223
CHEESE	-0.0236	-0.0357	0.0070	0.0318	-0.0229	0.0171	0.0510	0.0586	-0.1811	0.0602	-0.0446	0.5440	0.0119
F.MILK	0.0028	0.0054	0.0049	0.0270	-0.0037	-0.0264	-0.0566	0.0087	-0.0261	0.0071	-0.0312	0.0141	-0.0150
O.MILK	0.0272	0.0271	-0.0239	-0.1226	0.0195	0.0072	0.0753	-0.0043	-0.0998	0.0039	0.1517	0.3876	-0.0149
FLOUR	-0.0101	0.0055	0.0074	0.0040	-0.0007	0.0118	0.0742	-0.0133	-0.0208	-0.0025	0.0561	-0.0698	-0.0054
RICE	0.0510	-0.0174	-0.0109	-0.0055	0.0145	-0.0299	-0.0696	-0.0243	0.1105	0.0277	-0.1207	0.0467	0.0144
POTATO	-0.0071	-0.0479	0.0040	-0.0044	-0.0075	0.0116	0.1113	0.0431	0.0509	-0.0085	-0.0194	0.4609	-0.0135
BUTTER	0.0560	0.0249	0.0203	0.0342	0.0561	-0.0410	-0.0114	0.0485	-0.0966	0.0505	0.0835	0.2445	-0.0342
MARGAR	-0.0599	-0.0513	-0.0695	0.0090	0.0979	0.0960	-0.0334	-0.0142	0.0358	0.0042	0.0423	-0.2442	0.0349
O.FATS	0.0039	0.0265	0.0198	0.0024	-0.0182	0.0252	0.1268	0.0081	-0.0556	-0.0060	-0.0080	-0.0023	-0.0051
APPLES	0.0395	-0.0634	0.0009	0.0200	0.0453	-0.0646	-0.0426	-0.0446	0.2181	0.0184	0.1062	-0.2409	-0.0111
ORANGE	0.0963	-0.1621	-0.0129	-0.0116	0.0386	0.1575	-0.0173	-0.0779	0.1434	-0.0675	-0.0149	0.6275	0.0137
BANANA	-0.1125	0.0416	-0.0509	0.0531	0.0690	0.0648	-0.0171	-0.0834	-0.0198	0.0090	0.2251	0.6569	-0.0119

Continued--

Appendix table--U.S. compensated food demand system--Continued   (Matrix partition C23)

Food category	O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	NUTS	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD	CONST
							Price						
GRAPES	-0.0751	0.0531	-0.0566	-0.1182	-0.1025	0.1184	0.4363	0.0620	-0.3116	0.0729	-0.1791	1.4195	-0.0198
GRAFRU	0.0525	-0.0549	0.0005	0.0342	0.0616	0.0407	-0.0890	-0.1337	0.2009	-0.0214	0.2971	1.1301	0.0486
O.FRUT	-0.1398	0.1050	0.0164	-0.0038	-0.0754	-0.1297	-0.1294	0.0019	-0.1027	0.0606	-0.1139	-0.2100	-0.0350
LETTUC	-0.0412	-0.0114	-0.0041	0.0057	-0.0111	-0.0460	-0.0319	-0.0257	-0.0059	0.0240	0.0954	-0.4472	0.0051
TOMATO	0.0098	-0.0013	-0.0330	-0.0462	-0.0182	0.0763	0.0179	-0.0460	0.0685	-0.0268	0.0045	0.2334	-0.0131
CELERY	0.0922	-0.0383	-0.0501	-0.0663	-0.0489	0.0458	0.2074	-0.0188	0.0161	-0.0173	0.0204	0.4428	-0.0389
ONIONS	0.1441	-0.0133	-0.0077	0.0092	0.0209	-0.0533	-0.0900	0.0323	-0.0869	-0.0112	0.1899	-0.0231	0.0030
CARROT	-0.3909	-0.1727	0.0616	0.0781	-0.0506	0.1334	0.3090	0.0057	-0.1432	-0.0301	0.1974	-0.5003	-0.0220
O.VEGE	-0.2143	-0.0322	0.0483	0.0777	-0.0195	0.0076	-0.0049	-0.0185	0.1164	-0.0361	-0.1556	0.6084	-0.0656
JUICE	-0.0173	-0.5570	0.0277	0.0269	0.0139	0.0495	-0.1682	-0.0268	0.0993	-0.0104	0.0501	0.6859	0.0373
C.TOMA	0.1127	0.1199	-0.1685	0.0403	-0.0433	0.0851	-0.3997	0.0218	-0.1203	0.0234	0.1088	0.0531	-0.0205
C.PEAS	0.1359	0.0877	0.0303	-0.5332	-0.0636	0.2584	-0.3351	-0.0226	0.0236	0.0272	0.0814	-0.1803	-0.0305
COCKTL	-0.0456	0.0600	-0.0434	-0.0847	-0.7398	-0.0064	-0.0361	-0.0141	-0.0733	0.0221	0.2337	-0.1734	-0.0025
NUTS	0.0022	0.0268	0.0106	0.0430	-0.0008	-0.1683	-0.1186	-0.0430	0.0676	-0.0441	-0.1103	0.2924	0.0213
O.PRFV	-0.0004	-0.0258	-0.0141	-0.0158	-0.0013	-0.0334	-0.1507	-0.0015	-0.0131	-0.0127	0.0063	0.0164	0.0398
SUGAR	-0.0009	-0.0023	0.0004	-0.0006	-0.0003	-0.0069	-0.0008	-0.0367	0.0013	0.0067	0.0030	-0.0229	0.0023
SWEET	0.0146	0.0230	-0.0065	0.0017	-0.0039	0.0289	-0.0198	0.0035	-0.0499	-0.0846	0.0528	0.3881	-0.0170
COFFEE	-0.0050	-0.0027	0.0014	0.0022	0.0013	-0.0212	-0.0215	0.0202	-0.0948	-0.1720	-0.0304	0.1540	-0.0349
FRZN.D	-0.0294	0.0176	0.0088	0.0088	0.0190	-0.0716	0.0145	0.0123	0.0798	-0.0410	-0.0775	-0.1615	0.0000
N.FOOD	0.0005	0.0011	0.0000	-0.0001	-0.0001	0.0009	0.0002	-0.0004	0.0026	0.0009	-0.0007	-0.0306	0.0015
WEIGHT	0.0007	0.0013	0.0003	0.0004	0.0003	0.0024	0.0085	0.0150	0.0056	0.0050	0.0037	0.8137	NA

Appendix D:

The Brandow and the George and King Procedures

The purpose of this review is to provide a better understanding about the evolution of methodological issues regarding the estimation of a complete disaggregate food demand system in the United States. In fact, the noteworthy work of Brandow (2) and of George and King (11) provided the motivation for this report to develop an alternative approach to improve their procedures. For an easy illustration of their procedures, a demand elasticity matrix for the case of (n-1) food categories and one nonfood sector is represented as follows:

Food category	Price						
	p_1'	p_2'	.	.	.	p_n'	m'
q_1'	e_{11}	e_{12}	.	.	.	e_{1n}	δ_1
q_2'	e_{21}	e_{22}	.	.	.	e_{2n}	δ_2
.							
.							
q_n'	e_{n1}	e_{n2}	.	.	.	e_{nn}	δ_n

where variables are relative changes of per capita quantities (q_i's), prices (p_i's) and per capita expenditure (m'). Parameters are e_{ij}'s (the price elasticity of the ith food category with respect to the price change of the jth food category), and δ_i's (income elasticity of the ith food category).

The Brandow Procedures

Brandow (2) constructed a demand system for 24 food categories and 1 nonfood sector. The basic data used are some prior estimates of direct-price elasticities (e_{ii}'s), income elasticities (δ_i's), and expenditure shares (w_i) for (n-1) food categories. The sequential calculation procedures are as follows:

(1) Income elasticity for nonfood (δ_n) was derived by using the Engel aggregation:

$$\delta_n = (1 - \sum_{i=1}^{n-1} w_i \delta_i)/w_n$$

(2) Cross-price elasticities for individual foods with respect to nonfood price were calculated using the additive utility assumption (the marginal utility of a good is independent of any other good), in which each of the cross-price elasticities is proportional to its income elasticity with a proportional factor k assumed to be 0.33; that is

$$e_{in}/\delta_i = 0.33 \qquad i=1,2,..,(n-1)$$

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On the other hand, according to an equation by Frisch (10) based on the additive utility assumption, the cross-price elasticity can be linked with expenditure share of nonfood (w_n), income elasticities (δ_i's), and a money flexibility measure θ as follows:

$$e_{in} = - \delta_i \, w_n \, (1 + \delta_n/\theta) \qquad i=1,2,..,(n-1)$$

The equality of above two cross-price elasticities gives the proportional factor $k = - w_n \, (1 + \delta_n/\theta)$. Thus, for the given values of w_n, δ_n, and k, Brandow (2) obtained the implied money flexibility estimate $\theta = -0.86$.

(3) Cross-price elasticities for nonfood with respect to food category prices were obtained by using the symmetry relationship:

$$e_{nj} = (w_j/w_n) \, e_{jn} + (\delta_j - \delta_i) \, w_j \qquad j=1,2,..,(n-1)$$

(4) Cross-price elasticities for food categories within the food group were calculated by means of the following routines:

(a) The sum of cross-price elasticities for the foods in each row designated as R_i was calculated by applying the homogeneity condition:

$$R_i = - (e_{ii} + e_{in} + \delta_i) \qquad i=1,2,..,(n-1)$$

(b) Brandow calculated the column vector of cross-price elasticities by means of Cournot aggregation and by assuming that the individual cross-price elasticities were proportional to R_i. For example, the individual cross-price elasticities in the first column were obtained by

$$e_{i1} = \ell \, R_i \qquad i=2,3,..,(n-1).$$

The proportional factor ℓ was derived by substituting the above cross-price elasticities e_{i1}'s in the following Cournot aggregation:

$$\sum_{i=1}^{n} w_i \, e_{i1} = - w_1$$

$$\ell = (- w_1 - w_1 \, e_{11} - w_n \, e_{n1})/(\sum_{i=2}^{n-1} w_i \, R_i)$$

(c) Given a column vector of cross-price elasticities, the corresponding row vector was calculated by the symmetry relation:

$$e_{1j} = (w_j/w_1) \, e_{j1} + (\delta_j - \delta_1) \, w_j \qquad i=2,3,..,(n-1)$$

(d) The weighted sum of the missing cross-price elasticities in the second column was then determined. As before, the individual cross-price elasticities in the column were chosen to be

proportional to the R_i and to add to the required weighted total. Then row two was computed by symmetry. Brandow then completed the price elasticity matrix by repeating the column-row steps.

Remarks on the Brandow Procedures

Since most price elasticities are not estimated directly from sample observations, the price elasticity matrix generated by the synthetic approach may not closely reflect actual data situation. Thus, the demand system may not be a reliable model for structural interpretation and forecasting food consumption. Also, no statistical inference can be derived to verify the accuracy of the generated price elasticities.

The prior information on direct-price elasticities and income elasticities for food categories is obtained from a variety of sources. These elasticity estimates may not be consistent, in the sense that different studies may apply different estimation procedures, and the data used may belong to different time periods and different data sources.

The cross-price elasticities for food categories in relation to the nonfood sector are derived under an arbitrary assumption of additive utility between each food category and nonfood, and a fixed proportion (33 percent) of the corresponding income elasticity.

To obtain the column vector of cross-price elasticities, Brandow assumed each elasticity to be proportional to the sum of the missing food cross-price elasticities in each row. The allocation procedure is difficult to justify on theoretical grounds. Also, the generated cross-price elasticities are affected by the ordering of the commodities in the demand matrix.

The George and King Procedures

George and King (11) constructed a demand matrix for 49 food categories and 1 nonfood sector. All foods were grouped into 16 major groups. The income elasticities for foods were obtained from cross-section household survey data. Some of the direct- and cross-price elasticities within each food group were estimated from single-equation regression based on time-series data.

The remaining unknown cross-price elasticities in each group were generated by applying the symmetry condition. To generate the demand elasticities in association with nonfood, they followed the first three steps of the Brandow procedure and used the money flexibility estimate of -0.86. George and King, however, deviated from the Brandow (2) procedures for obtaining the cross-price elasticities of food categories in a food group with respect to food category prices outside the group. For a grouping of G food groups, George and King proposed to obtain the price elasticities inside a food group, say I, as follows:

(1) The sum of the remaining unknown cross-price elasticities in each row, say Ri for the ith row, was calculated by applying the homogeneity

condition:

$$R_i = - (e_{in} + \delta_i + \sum_{J=1}^{I} \sum_{j\epsilon J} e_{ij}) \qquad i\epsilon I$$

(2) The R_i was then distributed over the unknown entries of the cross-price elasticities in that row with weights derived from the Frisch (*11*) equation and assuming $\theta = -0.86$ as follows:

$$k_{ij} = - \delta_i\ w_j\ (1 + \delta_j/\theta) \qquad j\epsilon J,\ J\epsilon(I+1,\ G)$$

Then the cross-price elasticities were obtained as:

$$e_{ij} = R_i\ [k_{ij}/(\sum_{J=I+1}^{G} \sum_{j\epsilon J} k_{ij})] \qquad j\epsilon J,\ J\epsilon(I+1,\ G)$$

(3) Given a column block of cross-price elasticities, they calculated the corresponding row block by the symmetry relation. By repeating the column block-row block steps, George and King completed the price elasticity matrix.

Remarks on the George and King Procedures

The George and King (*11*) procedures are quite parallel to those used by Brandow (*2*). Thus, the general drawbacks of the synthetic approach also apply to the George and King report.

Some of the demand elasticities in each food category are estimated and others are generated by satisfying the symmetry condition. This introduces a subjective choice for determining the cross-price elasticities instead of estimation within a consistent framework. Moreover, the estimated standard errors are not reported for verifying the directly estimated elasticities.

The cross-price elasticities of food categories with respect to the price change of nonfood are derived from the Frisch equation by using a money flexibility estimate of -0.86 obtained from Brandow. In addition to using the rigid assumption on additive utility structure, the money flexibility implied from Brandow's rough estimate could be too arbitrary. This is because the money flexibility is derived by simply assuming that the cross-price elasticity of each food category, with respect to the price of nonfood, is 33 percent of the corresponding income elasticity of that food category.

The procedures to generate the cross-price elasticities outside a food group are quite subjective. The weights are derived from the Frisch equation, in which the implicit assumption of additive utility among food categories could be too strong. Even if the assumption is applicable, the use of weights for allocating the cross-price elasticities in each row is difficult to justify. Taking the meat group for example, the sum of the unknown cross-price elasticities Ri are all positive, while the weights $kij's$ are uniformly negative. That is, the values of R_i as being 0.020032 (beef), 0.110177

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(veal), 0.038269 (pork), 0.05967 (lamb), 0.034025 (chicken), 0.032676 (turkey), and 0.164376 (fish). The values of k_{ij}'s are negative in all cases, because the income elasticity for every meat category is positive, and the income elasticities for food categories outside the meat group are less than the money flexibility (-0.86) in absolute value. Accordingly, to compute an unknown cross-price elasticity with higher negative weights, this procedure may allocate more of the positive amount of total missing cross-price elasticities. Besides, the generated cross-price elasticities are affected by the ordering of the food categories in the demand matrix.