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U.S. Demand for Food: A Complete System of Price and Income Effects

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U.S. Demand for Food: A Complete System of Price and Income Effects.
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Abstract

This study develops statistical procedures using actual sample observations for estimating a large-scale demand system for foods. The result is a complete matrix of all direct, cross-price, and expenditure elasticities for 40 food items and 1 nonfood item. The demand system illustrates the interdependent nature of demand for foods at the disaggregated level and provides practical information for use in commodity forecasting and policy analysis.

Keywords: Disaggregated demand system, constrained maximum likelihood estimation, Engel aggregation, homogeneity, symmetry.

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Preface

U.S. food demand is a critical component in the economic analyses of various national food programs and agricultural policies. It is also an integral component in most commodity outlook and situation activities that forecast and project food prices, expenditures, and consumption. Demand information is also used in many other economic and marketing decisions.

This technical bulletin is one of three related publications representing research conducted during fiscal year 1985 in the Economic Research Service's continuing research program on U.S. food demand. *Food Spending in American Households, 1980-81* (SB-731) provides a tabular analysis of household food expenditures from the Continuing Consumer Expenditure Survey (CCES) of the Bureau of Labor Statistics for the years 1980-81. *U.S Demand for Food: Household Expenditures, Demographics, and Projections* (TB-1713) presents the results of a comprehensive econometric analysis of the CCES data and develops projections of food expenditures. *U.S. Demand for Food: A Complete System of Price and Income Effects* (TB-1714) uses ERS data on civilian disappearance for the years 1953-83 to estimate a complete system of price and expenditure elasticities for 40 food commodity categories and 1 nonfood category.

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Summary

The author developed statistical procedures for estimating a large-scale demand system. He used a constrained maximum likelihood method incorporating into estimation the parametric restrictions derived from classical demand theory. Using constrained estimation ensures consistency within the framework of classical demand theory and greater statistical efficiency for the estimated demand parameters. The procedures provide a methodology for directly estimating a complete demand system from time-series data.

The author then applied the procedures to an estimation of a U.S. food demand system including 40 food items and 1 nonfood item. Data are annual observations for 1953-83. The estimated demand system gives information about the interdependent nature of demand for foods in terms of price and income effects. Based on simulation results over the sample period, the demand system can be an effective instrument for assessing the effects of changes in food prices and income on commodity forecasts and policy analyses. The errors of forecasts are within 8 percent of sample means for all items, and less than 3 percent for major items such as beef and veal, pork, chicken, eggs, fluid milk, wheat flour, and sugar.

Using this system, the author found that of some 40 food items studied, consumption of only 12 items will increase significantly if their prices drop. These items are beef and veal, pork, other meats, chicken, turkey, evaporated and dry milk, oranges, grapes, tomatoes, fruit juice, canned peas, and fruit cocktail. If consumer spending increases, the consumption of certain processed foods will increase significantly. These items are fruit juice, canned tomatoes, fruit cocktail, dried beans and peas, other processed fruits and vegetables, and cheese.

A complete set of direct-price and expenditure elasticities are presented in the following table:

Estimated direct-price and expenditure elasticities

Commodity	Direct-price elasticity	Expenditure elasticity
(1) Beef and veal	-0.6166(0.0483)	0.4549(0.0585)
(2) Pork	-.7297 (.0327)	.4427 (.0624)
(3) Other meats	-1.3712 (.2045)	.0607 (.1123)
(4) Chicken	-.5308 (.0608)	.3645 (.0863)
(5) Turkey	-.6797 (.1332)	.3196 (.1691)
(6) Fresh and frozen fish	.0142 (.1615)	.1155 (.1783)
(7) Canned and cured fish	.0350 (.1706)	.0005 (.2049)
(8) Eggs	-.1452 (.0225)	-.0283 (.0445)
(9) Cheese	-.3319 (.1174)	.5927 (.1197)
(10) Fluid milk	-.2588 (.1205)	-.2209 (.0686)
(11) Evaporated and dry milk	-.8255 (.2642)	-.2664 (.2230)
(12) Wheat flour	-.1092 (.1026)	-.1333 (.0701)
(13) Rice	-.1467 (.1438)	-.3664 (.2301)
(14) Potatoes	-.3688 (.0689)	.1586 (.2225)
(15) Butter	-.1670 (.1748)	.0227 (.1915)
(16) Margarine	-.2674 (.1379)	.1112 (.1073)
(17) Other fats and oils	-.2191 (.0496)	.3691 (.0531)
(18) Apples	-.2015 (.1469)	-.3514 (.2126)
(19) Oranges	-.9996 (.1465)	.4866 (.2587)
(20) Bananas	-.4002 (.1334)	-.0429 (.1899)
(21) Grapes	-1.3780 (.1829)	.4407 (.3263)
(22) Grapefruits	-.2191 (.1067)	.4588 (.2636)
(23) Other fresh fruits	-.2357 (.5471)	-.3401 (.2360)
(24) Lettuce	-.1371 (.0656)	.2344 (.1154)
(25) Tomatoes	-.5584 (.0624)	.4619 (.0904)
(26) Celery	-.2516 (.0636)	.1632 (.1501)
(27) Onions	-.1964 (.0693)	.1603 (.2045)
(28) Carrots	-.0388 (.1816)	-.1529 (.3365)
(29) Cabbage	-.0385 (.0405)	-.3767 (.1577)
(30) Other fresh vegetables	-.2102 (.1436)	.2837 (.1526)
(31) Fruit juice	-.5612 (.1006)	1.1254 (.2505)
(32) Canned tomatoes	-.3811 (.1072)	.7878 (.1454)
(33) Canned peas	-.6926 (.1746)	.3295 (.1616)
(34) Canned fruit cocktail	-.7323 (.3677)	.7354 (.2788)
(35) Dried beans, peas, and nuts	-.1248 (.0313)	.5852 (.1167)
(36) Other processed fruits and vegetables	-.2089 (.0921)	.6311 (.0675)
(37) Sugar	-.0521 (.0172)	-.1789 (.0627)
(38) Sweeteners	-.0045 (.0895)	-.0928 (.1241)
(39) Coffee and tea	-.1868 (.0294)	.0937 (.1027)
(40) Ice cream and other frozen dairy products	-.1212 (.0848)	.0111 (.0580)
(41) Nonfood	-.9875 (.0125)	1.1873 (.0043)

Note: The figures in parentheses are the standard errors of estimated elasticities.

U.S. Demand for Food

A Complete System of Price and Income Effects

Kuo S. Huang*

Introduction

Consumer demand for food is an important component, along with the supply of food, in the formation of agricultural policy and related decisions. Empirical estimates of the demand structure are also essential for providing commodity forecasts and analyzing the effects of changes in commodity prices and income.

Numerous quantitative studies on the application of demand theory to U.S. food commodities have been conducted. Since the landmark 1938 work of Schultz (*13*)[1] who estimated the demand relationships for a variety of agricultural commodities, most of these studies were partial demand analyses, in which direct price and per capita income were considered as major determinant variables in the analysis, without considering the complete interdependent nature of demand. However, in the consumer's budgeting process, changes in other commodity prices may be important factors in determining demand. At least to avoid specification errors, one must estimate a complete demand system, explicitly recognizing the interdependent relationships among all commodities.

The application of demand systems to modeling the disaggregated demand for food commodities in the United States was first undertaken by Brandow (*1*), who used a synthetic approach to generate a demand elasticity matrix for 24 food commodities and 1 nonfood commodity. George and King (*9*) later used a similar approach to obtain a demand matrix for 49 food commodities and 1 nonfood commodity. Both studies made a significant contribution in bridging the gap between theory and empirical application of demand. They demonstrated the feasibility and the potential practical use of a demand system approach in applied economic analysis. The major drawback in their studies was the use of the synthetic approach in generating a demand matrix. Under this approach, many entries of the demand matrix are not estimated directly from sample observations. Thus, the variance of estimated demand parameters could not be derived for verifying the statistical reliability of the estimates. Moreover, the generated demand parameters are affected by the sequential ordering of the commodities. Consequently, such demand systems may not provide an accurate representation of the economic structure or a reliable model for food consumption forecasts. To circumvent these problems, this study develops statistical procedures for direct estimation of a disaggregated demand system based on time-series data. Appendix A briefly reviews the approaches used by Brandow and by George and King to help clarify the differences between their synthetic approaches and the direct estimation approach I have developed.

The direct estimation of a complete disaggregated demand system is quite difficult because of the problems of insufficient degrees of freedom and multicollinearity. The number of demand parameters to be estimated may be large in relation to the number of available sample observations. Also, some price and expenditure variables in a demand system may be highly correlated. The degrees of freedom may not be a technical problem when sufficient data observations are available, but the use of sufficiently long historical data series may introduce additional problems because of structural changes in consumer demand.

The S-branch system of Brown and Heien (*2*) and the hierarchic linear expenditure system of Deaton (*6*) were designed for disaggregate application. To accomplish this, those researchers reduced the dimension of the demand parameter space by imposing the assumption of direct additivity on the consumer's preference relation. As a consequence, the models preclude the occurrence of inferior goods and permit goods within a group to be substitutes only. While these approaches are consistent with the theory of choice, applying such separability assumptions arbitrarily rules out possible specific substitution effects in the Slutsky term and thus imposes a very restrictive pattern on the cross-price elasticities across different commodity groups (*7*). Without a substantive theoretical or empirical justification, the usefulness of such restrictive separability assumptions is questionable, especially for the study of demand relationships among food commodities. For this reason, this study avoids the use of separability assumptions in estimating the demand elasticities.

In this study, I formulated statistical procedures for solving or alleviating the problems of estimating a disaggregated demand system, and then used these procedures to estimate

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

a U.S. food demand system designed for practical use in commodity forecasting and analysis of policy and programs. I used a constrained maximum likelihood method incorporating into estimation the parametric constraints derived from classical demand theory. Using constrained estimation ensures consistency within the framework of classical demand theory and greater statistical efficiency for the estimated demand parameters.

Other studies have tested the validity of applying theoretical demand constraints in empirical work. However, the test results can hardly distinguish whether the hypotheses are false, whether the approximation of the demand system is inaccurate, or whether the aggregated data used in most empirical studies do not adequately correspond to the individual consumer behavior specified by the theory (*7*). Thus, I did not test such underlying theoretical propositions in this study because the main purpose of introducing the prior demand constraints is to improve the efficiency of the estimates.

The Economic Model and Estimation Procedures

This section provides a detailed presentation of the model and procedures I used to obtain the empirical estimates of 1,722 price and expenditure elasticities which make up a complete disaggregated demand system of 40 food commodities and a nonfood component. The developed procedures are not specific to the set of 41 commodities defined herein but have more general applicability to the estimation of demand systems from time-series data where a high level of commodity disaggregation is required for practical use.

The economic model is firmly based on the concept of Marshallian demand, derived from the classical theory of individual consumer demand behavior. However, while substantial progress has been made in bridging the gap between theory and application in the last two decades, the crossing is neither straightforward nor free of pitfalls. The approach adopted in this study involves a combination of contemporary knowledge of demand, acute recognition of end-use objectives, and judgment in assessing the trade-off between a number of more or less plausible assumptions. For example, issues such as the appropriate transition from the theory of individual consumer demand to the aggregate or market demand have not been fully resolved. The concept and underlying rationale of the "representative consumer" is assumed to be valid. Deeper issues such as the implications of the assumption of constant elasticities (which is maintained throughout this report) or questions regarding the structure of the stochastic disturbances of the system are not pursued.

Because the methods and procedures used in this study are significantly different from other studies, the demand elasticities thus obtained have certain properties and characteristics that distinguish them from other demand elasticity estimates. These unique properties have important implications for the interpretation and practical application of the empirical estimates.

Here are some of the important features of the demand elasticities obtained in this study:

- The estimates are computed directly from time-series data, which, among other things, permit the computation and presentation of the associated standard errors.
- The estimates satisfy the theoretical demand properties of symmetry, homogeneity, and Engel aggregation.
- The estimates are not constrained by any particular parameters derived from specific prior assumptions about separability of the consumer preference relation.
- Finally, the estimates are not affected by the initial ordering of the commodities and by any sequential aspects of the estimation procedures.

Marshallian Demand Systems and Parametric Constraints

The classical theory of consumer demand is based on the allocation of a consumer's budget to each commodity such that the maximum level of utility is attained. Let q denote an n-coordinate column vector of quantities demanded; p is an n-coordinate column vector of their prices; $m = p'q$, the consumer's expenditure constraint; and U(q), the utility function, is assumed only to be nondecreasing and quasi-concave in q. By maximizing U(q) subject to the expenditure constraint, we can derive a set of demand relationships in which the quantity demanded of each commodity is expressed as a function of all commodity prices and expenditures:

$$q_i = f_i(p, m) \quad i = 1,2,\ldots,n. \qquad (1)$$

This equation is the set of Marshallian demand functions; it is distinguished from the Hicksian or compensated demand functions which are obtained by fixing a given utility level.

The Marshallian demand functions are useful to applied economists for the study of consumers' behavior. The difficulty is in transforming the conceptual demand relationships into a workable functional form for direct estimation of a complete demand system. Three approaches are commonly used to derive the explicit form of the Marshallian demand functions. The first approach initially assumes a specific functional form for the utility function U(q), and then derives a set of the Marshallian demand equations through the maximization of the utility function. Typical examples are the linear expenditure system (*14*) and the direct translog model (*5*). In a similar manner, the second approach is based on an assumed functional form for the indirect utility function, say V(p, m). The indirect utility function, showing the maximum attainable utility for given prices p and expenditure m, is conceptually obtainable by substituting the optimal quantities demanded into the original utility function. By applying the so-called "Roy's identity" to the assumed indirect utility function, one can then derive the Marshallian demands (*7*). Examples of this approach are the indirect addilog model (*11*), and the indirect translog model (*5*). Finally, the third approach is based on a direct approximation of the Marshallian demand functions. Examples are the Rotterdam model (*15*) and the composite food demand model (*12*). The three approaches are conceptually interrelated within the framework of demand system research. Figure 1 depicts their relationships with arrows showing the direction of transformation.

The first two approaches rely heavily on the assumption of a specific functional form for the direct or indirect utility function. Although an infinite variety of possible functional forms theoretically exists, only a few models such as those mentioned above are considered realistic and manageable in applied demand analysis. Consequently, the choice of a particular functional form for the utility function is quite arbitrary and may introduce assumptions about the utility structure that are too rigid. Although some functional forms such as in the translog model are more flexible, the derived demand systems are complicated and nonlinear in parameters; their estimation can be time-consuming and expensive. Because of the difficulty in defining a proper utility function, the third approach, which directly approximates the Marshallian demand functions, has considerable appeal for empirical applications. Although obtaining a satisfactory approximation of the Marshallian demand system may still pose difficulties, the generated functional forms in the third approach are explicit and easily implemented, especially when the number of commodities included in a demand system is quite large. I adopted this approach for this study.

The Marshallian demand functions in (1) can be stated in differential form as

$$dq = Q_p\, dp + q_m\, dm \qquad (2)$$

in which Q_p is the n x n matrix of price slopes, the ith row of which consists of elements $\partial q_i/\partial p_j$ (j=1,2,..,n), q_m is the n x 1 vector of expenditure slopes $\partial q_i/\partial m$, and dp and dq are n x 1 vectors of price and quantity differentials. When we replace derivatives with elasticities, equation (2) becomes:

$$\dot{q} = E_p\, \dot{p} + \delta\, \dot{m} \qquad (3)$$

with $E_p = D_q^{-1} Q_p D_p$, $\delta = m\, D_q^{-1} q_m$, $\dot{p} = D_p^{-1} dp$, $\dot{q} = D_q^{-1} dq$, $\dot{m} = dm/m$, and D_p and D_q are diagonal matrices with the elements of the vectors p and q in the diagonal. Thus, E_p is an n x n matrix of all direct and cross-price elasticities, and δ is a vector of n expenditure elasticities.

Classical demand theory provides n(n+1)/2 + 1 independent linear equality constraints on the elasticities of equation (3); these constraints are as follows:

Engel aggregation: $w'\delta = 1$

Homogeneity: $E_p\, \ell = -\delta$

Symmetry: $[D_w (E_p + \delta w')]' = D_w (E_p + \delta w')$ (4)

in which expenditure weights $w = m^{-1} D_p q$, $\ell = (1,1,\ldots,1)'$ and D_w is a diagonal matrix with the elements of the vector w in the diagonal; and other variables are previously defined. I did not consider the negativity condition, in which $e_{ii} + \delta_i w_i < 0$ (i=1,2,..,n). In addition to complicating the estimation procedure by introducing inequality constraints, there is no reduction in the number of parameters to be estimated and, thus, no gain in asymptotic efficiency of the estimators.

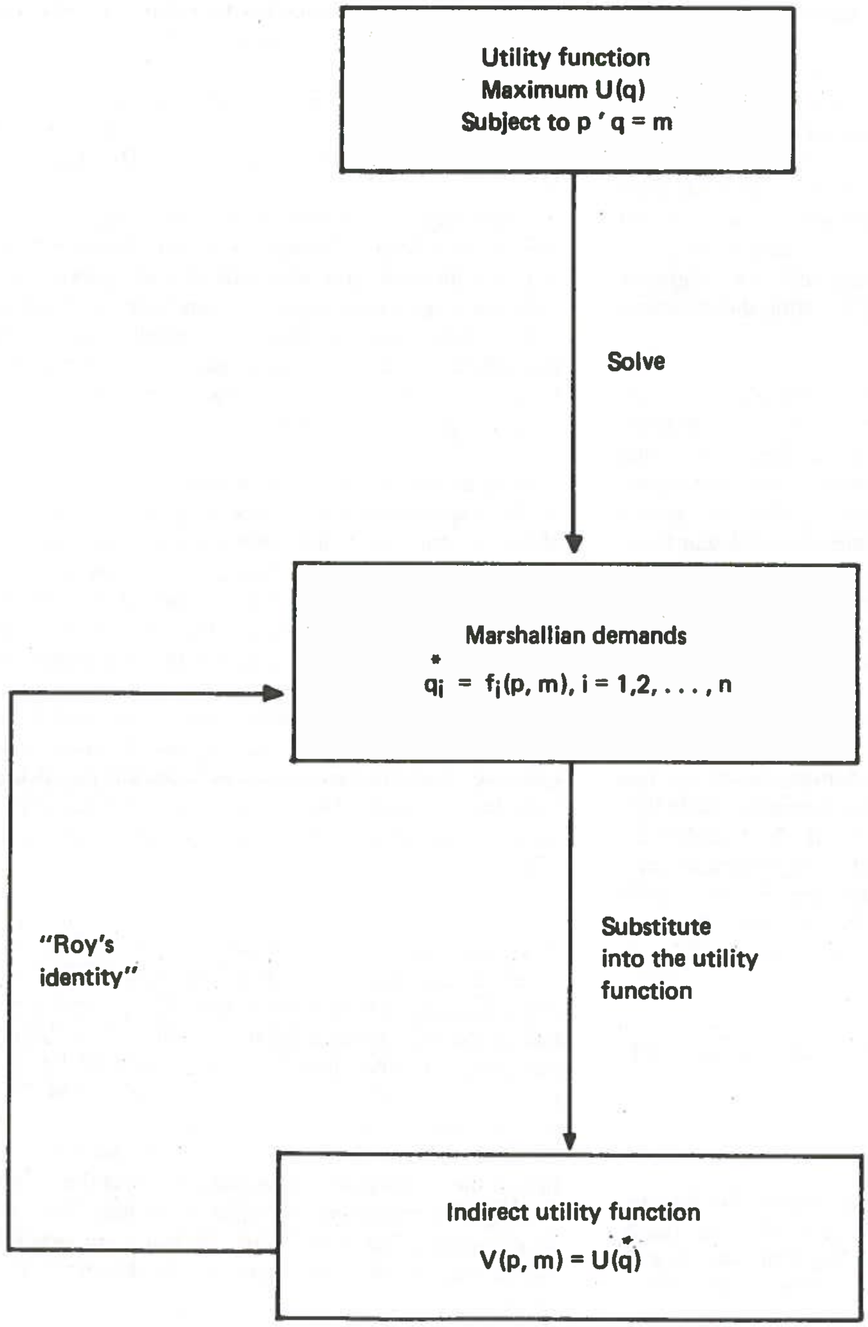
Among these constraints, Engel aggregation states that the sum of the expenditure elasticities weighted by the expenditure shares of corresponding commodities equals one. The relation is derivable from the budget constraint ($p'q = m$). The homogeneity condition states the sum of price elasticities in each demand equation equals the negative of expenditure elasticity for that equation. This relationship implies that a consumer has no money illusion, and thus a proportional change in both price and income leaves quantity demanded unchanged. Finally, the symmetry conditions state the relationship of the pairwise cross-price elasticities between any two demand equations in the system. The relationship is derived from the symmetry of the Slutsky income compensated substitution terms (*7*).

These parametric constraints provide useful prior information for empirical estimation of a demand system. The constrained demand relationships make it possible to express more than half of the total demand parameters in terms of other demand parameters. By incorporating these constraints into the estimation, we can obtain an empirical demand system which is internally consistent with the demand structure provided by classical demand theory. Moreover, because the incorporation of the constraints substantially reduces the number of demand parameters to be estimated, it not only saves much time in computing but also helps alleviate the possible multicollinearity problem and improves the statistical efficiency of estimates.

Modeling a Disaggregated Food Demand System

Adapting the elasticity form of demand system (3) to a disaggregated demand system with N food commodities (their prices and quantities being p_i and q_i, i=1,2,..,N) and a composite

Figure 1
Derivation of Marshallian Demands



nonfood (its price and quantity being P_o and Q_o), we find that the demand system gives the following N+1 relations:

$$\dot{q}_i = \sum_{j=1}^{N} e_{ij} \dot{p}_j + e_{io} \dot{P}_o + \delta_i \dot{m} \qquad i = 1,2,\ldots,N$$

$$\dot{Q}_o = \sum_{j=1}^{N} e_{oj} \dot{p}_j + e_{oo} \dot{P}_o + \delta_o \dot{m} \qquad (5)$$

where all (N+1)(N+2) parameters satisfy Engel aggregation, homogeneity, and symmetry.

In principle, by incorporating the theoretical constraints, we can directly estimate the disaggregated demand system (5). In fact the procedure was developed for and employed in the estimation of a composite food demand system (*12*) using the following logic. Suppose that the N food items are partitioned into G groups (their aggregate prices and quantities being P_I and Q_I, I=1,2,...,G) and a nonfood composite (its price and quantity being P_o and Q_o, respectively), then the demand system can be expressed in G + 1 equations:

$$\dot{Q}_I = \sum_{J=1}^{G} E_{IJ} \dot{P}_J + E_{Io} \dot{P}_o + E_{Im} \dot{m} \quad I = 1,2,\ldots,G$$

$$\dot{Q}_o = \sum_{J=1}^{G} E_{oJ} \dot{P}_J + E_{oo} \dot{P}_o + E_{om} \dot{m} \qquad (6)$$

with the parameters satisfying Engel aggregation, homogeneity, and symmetry. Where the number of groups is sufficiently small, one can obtain consistent estimates of the variances and covariances of disturbances and thus compute efficient constrained estimates of parameters (*12*).

However, when the number of commodities considered is large, such as in a disaggregated demand system of (5), the problem of insufficient degrees of freedom may occur when the number of demand parameters in each equation is larger than the number of available sample observations. For example, the problem confronted in this study is to exhaustively use the available data sources for consistent annual data in order to estimate a food demand system consisting of 41 commodity prices and one income variable in each demand equation using 31 sample observations. To make the estimation of a large-scale demand system feasible using limited sample observations, this study uses certain prior information from (6) to facilitate the estimation of demand parameters in the disaggregated demand system.

I generally estimated the disaggregated demand system by grouping the commodities into G groups and dividing the demand elasticity matrix into blocks. I then carried out the estimation block by block. I obtained the estimates of the parameters within each food commodity group (including expenditure elasticities), subject to the symmetry constraint, first. I then obtained cross-group demand elasticities, subject to symmetry and homogeneity constraints, for two groups at a time; this procedure required G(G−1)/2 sets of computations. Finally, to complete the entire demand system, I derived the microparameters for the nonfood sector by applying the conditions of Engel aggregation, homogeneity, and symmetry.

The following section delineates the procedures for obtaining the demand elasticities of within-group and cross-group demand subsystems. Specifically, taking group I as an example, the within-group estimation of the demand subsystem is

$$\overset{*}{q}_i = \sum_{j\varepsilon I} e_{ij} \dot{p}_j + \delta_i \dot{m} \qquad i \,\varepsilon\, I \qquad (7)$$

$$\text{with } \overset{*}{q}_i = \dot{q}_i - \sum_{\substack{K=1 \\ (K\neq I)}}^{G} \tilde{E}_{IK} \dot{P}_K - \tilde{E}_{Io} \dot{P}_o$$

The adjustment of the quantity in $\dot{q}_i$ is intended to exclude the impacts of those commodity prices outside the group. Because the estimated microparameters in any cross-group are not available at this stage, the estimates $\tilde{E}_{IK}$ of the composite demand system (6) are used. The use of the composite cross-price elasticity is a crude approximation to the impacts of other prices outside the commodity group under estimation, but it is the only way that we can evaluate the price and expenditure responses solely for the within-group commodities. For the purpose here, the main function of the composite food demand system is to provide a mechanism for estimating the microparameters in the disaggregated demand system. Equation (7) is a demand subsystem in which the only relevant restriction imposed on the parameters is that of symmetry. Because the process of quantity adjustment makes use of the same aggregate estimates as prior information, the adjusted quantities are not affected by any ordering of commodity groups, and thus the estimates of the demand parameters within each group are also invariant.

I then estimated the 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, for the price change of nonfood) in a given demand equation 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 food commodity prices and expenditure by subtracting the relative change of nonfood price from them and deleting the cross-price elasticities of nonfood from the estimation. This adjustment process is equivalent to deflating all prices and expenditure of a demand equation by the nonfood price, leaving no change in the quantity demanded. We can then estimate simultaneously the cross-price elasticities in each pair of cross-groups by applying the symmetry restriction. As such, we can estimate the cross-price elasticities for groups I and J by means of the structure:

$$[\overset{*}{q}_I\, ,\ \overset{*}{q}_J] = [\overset{*}{p}_I{}',\ \overset{*}{p}_J{}'] \begin{bmatrix} 0 & Z_{JI} \\ Z_{IJ} & 0 \end{bmatrix} \qquad (8)$$

where Z_{IJ}, Z_{JI} = matrices of cross-price elasticities for the pair of cross groups with element e_{ij} in Z_{IJ} and e_{ji} in Z_{JI}; $i \,\varepsilon\, I$, $j \,\varepsilon\, J$

$\overset{*}{p}_I$, $\overset{*}{p}_J$ = adjusted price vectors with components defined by $\overset{*}{p}_i = \dot{p}_i - \dot{P}_o$, $i \,\varepsilon\, I$; $\overset{*}{p}_j = \dot{p}_j - \dot{P}_o$, $j \,\varepsilon\, J$

$\overset{*}{q}_I$, $\overset{*}{q}_J$ = adjusted quantity vectors with components defined as below:

$$\overset{*}{q}_i = \dot{q}_i - \sum_{k \varepsilon I} \tilde{e}_{ik}(\dot{p}_k - \dot{P}_o) - \tilde{\delta}_i(\dot{m} - \dot{P}_o) - \sum_{\substack{K=1 \\ (K \neq I)}}^{G} \tilde{E}_{IK} (\dot{P}_K - \dot{P}_o), \text{ for } i \varepsilon I,$$

and

$$\overset{*}{q}_j = \dot{q}_j - \sum_{k \varepsilon J} \tilde{e}_{jk}(\dot{p}_k - \dot{P}_o) - \tilde{\delta}_j(\dot{m} - \dot{P}_o) - \sum_{\substack{K=1 \\ (K \neq J)}}^{G} \tilde{E}_{JK} (\dot{P}_K - \dot{P}_o), \text{ for } j \varepsilon J.$$

Again, the adjustment of quantities in $\dot{q}_i$ and $\dot{q}_j$ is intended to exclude the impact of those commodity prices outside the corresponding cross group. Because the estimated microparameters for the within-group demand system of (7) are available at this stage, these estimates ($\tilde{e}_{ij}$'s) are used for the quantity adjustment. Besides, the aggregate estimates $\tilde{E}_{IK}$ and $\tilde{E}_{JK}$ of (6) have been used to represent the unknown price response for commodities in various cross-groups outside the group under estimation. We note that, in estimating the demand parameters of any cross-group in the same row, the quantity adjustment process makes use of the same set of prior information for the within-group microparameters and the aggregate estimates for other cross groups in that row. Consequently, the estimation of microparameters for each pair of cross-groups is not affected by the ordering of commodity groups, because there is no difference in the adjusted quantity regardless of the ordering of commodity groups. For convenience, we may start with the first cross-group in the first row and its symmetric pair in the first column, and complete the cross-price elasticities of food commodities in the group in that row and column. Then, we can complete the remaining unknown demand elasticities in the groups in the second row and their symmetric counterparts. Thus, continuing such a row-column group operation, we can sequentially obtain all the cross-price elasticities of food commodities, group by group.

For estimation purpose, it is useful to make the demand structure in (8) more explicit. Given the Ith group with m commodities, ordered 1,2,. . ,m and the Jth group with n commodities ordered m+1, m+2,. . , m+n, the demand subsystem can be expressed as follows:

$$\begin{aligned}
\overset{*}{q}_1 &= e_{1,m+1}\, \overset{*}{p}_{m+1} + e_{1,m+2}\, \overset{*}{p}_{m+2} + \cdots + e_{1,m+n}\, \overset{*}{p}_{m+n} \\
&\ \ \vdots \\
\overset{*}{q}_m &= e_{m,m+1}\, \overset{*}{p}_{m+1} + e_{m,m+2}\, \overset{*}{p}_{m+2} + \cdots + e_{m,m+n}\, \overset{*}{p}_{m+n} \\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (9) \\
\overset{*}{q}_{m+1} &= e_{m+1,1}\, \overset{*}{p}_1 + e_{m+1,2}\, \overset{*}{p}_2 + \cdots + e_{m+1,m}\, \overset{*}{p}_m \\
&\ \ \vdots \\
\overset{*}{q}_{m+n} &= e_{m+n,1}\, \overset{*}{p}_1 + e_{m+n,2}\, \overset{*}{p}_2 + \cdots + e_{m+n,m}\, \overset{*}{p}_m
\end{aligned}$$

We may estimate the pair of cross-group demand elasticities for commodities in Ith and Jth groups by incorporating the symmetry constraint which provides m x n independent linear restrictions on the parameters of the system:

$$e_{m+j,i} = (e_{i,m+j}/w_{m+j} + \tilde{\delta}_i - \tilde{\delta}_{m+j})\, w_i \quad i=1,2,\ldots,m \quad (10)$$
$$j=1,2,\ldots,n$$

in which the expenditure elasticities $\tilde{\delta}_i$'s are obtained from (7), and w_i is an expenditure weight.

Substituting the symmetry conditions (10) into (9) transforms the demand subsystem for the Jth group commodities as follows:

$$\begin{aligned}
\bar{q}_{m+1} &= e_{1,m+1}\, \bar{p}_1^{(m+1)} + e_{2,m+1}\, \bar{p}_2^{(m+1)} + \cdots + e_{m,m+1}\, \bar{p}_n^{(m+1)} \\
&\ \ \vdots \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (11) \\
\bar{q}_{m+n} &= e_{1,m+n}\, \bar{p}_1^{(m+n)} + e_{2,m+n}\, \bar{p}_2^{(m+n)} + \cdots + e_{m,m+n}\, \bar{p}_n^{(m+n)}
\end{aligned}$$

in which the variables are defined as:

$$\bar{q}_{m+j} = \overset{*}{q}_{m+j} - \sum_{k=1}^{m} (\tilde{\delta}_k - \tilde{\delta}_{m+j})\, w_j\, \overset{*}{p}_j \qquad j=1, 2,\ldots,n$$

$$\bar{p}_i^{(m+j)} = (w_i/w_{m+j})\, \overset{*}{p}_i. \qquad i=1,2,\ldots,m \quad j=1,2,\ldots,n$$

This demand subsystem for Jth group commodities, along with the demand subsystem specified for Ith group in (9), completes the economic model for estimating the set of cross-group demand elasticities.

Thus far, the focus of the modeling effort has been on the specification of the economic model for a disaggregated demand system. The demand elasticity matrix of the system is computed in a sequential block-by-block fashion, where the estimation of each block is not affected by the ordering of commodity groups. To empirically estimate the economic model, additional stochastic specifications are necessary.

Stochastic Specification of a Disaggregated Demand System

The following presentation focuses on the development of constrained maximum likelihood estimation procedures for estimating the demand parameters of the within-group and cross-group demand subsystems. The procedures incorporate into estimation the parametric constraints derived from classical demand theory by a substitution approach. The approach, reducing the number of demand parameters from direct computation is a cost-effective technique. This approach is different from that used by Byron (*3*) and Court (*4*); they imposed the constraints by Lagrange multipliers which are required to compute all demand parameters directly.

Estimating the Within-Group Demand Subsystem

Given a demand structure (7) consisting of n commodities in a given commodity group, we can express the stochastic demand equation system for T sample observations as follows:

$$\begin{bmatrix} \overset{*}{q}_{11} \\ \vdots \\ \overset{*}{q}_{1T} \\ \vdots \\ \overset{*}{q}_{n1} \\ \vdots \\ \overset{*}{q}_{nT} \end{bmatrix} = \begin{bmatrix} p_{11},\ldots,p_{n1} & m_1 & & & 0 & \\ \vdots & \vdots & & & & \\ p_{1T},\ldots,p_{nT} & m_T & & & & \\ & & \ddots & & & \\ & & & & p_{11},\ldots,p_{n1} & m_1 \\ & 0 & & & \vdots & \vdots \\ & & & & p_{1T},\ldots,p_{nT} & m_T \end{bmatrix} \begin{bmatrix} e_1 \\ \vdots \\ e_{1n} \\ \delta_1 \\ \vdots \\ e_{n1} \\ \vdots \\ e_{nn} \\ \delta_n \end{bmatrix} + \begin{bmatrix} u_{11} \\ \vdots \\ u_{1T} \\ \vdots \\ u_{n1} \\ \vdots \\ u_{nT} \end{bmatrix} \qquad (12)$$

or, in an abbreviated form by making use of a Kronecker product (⊗),

$$y = (I_n \otimes X)\,\alpha + u \qquad (13)$$

where

y = column vector of nT observations, by stacking the adjusted relative change in quantity for each equation in (7),
I_n = n x n identity matrix,
X = T x (n+1) matrix containing the observations of the relative change in all prices and expenditures in a commodity group,
α = vector of n(n+1) parameters, and
u = column vector of nT random disturbances.

The symmetry condition provides n(n−1)/2 independent linear constraints on the parameters of the system (12):

$$e_{ji} = (w_i/w_j)\, e_{ij} + (\delta_i - \delta_j) w_i \quad j = 2,3,\ldots,(n-1) \quad i = 1,2,\ldots,j \qquad (14)$$

in which w_i is the expenditure weight of ith commodity.

We can express the constraints in matrix form as:

$$\alpha = R\,\beta \qquad (15)$$

where

α = column vector of all parameters of the system in (12),
β = vector of n(n+3)/2 parameters appearing on the right-hand side of (14),
and R = n(n+1) x n(n+3)/2 matrix of constraints.

Substituting the constraints (15), equation (13) becomes

$$y = [(I_n \otimes X)\, R]\,\beta + u. \qquad (16)$$

Assuming that the random disturbances in (16) at time t are distributed according to a multivariate normal N(O,Σ) and that a prior consistent estimate of Σ is given, say $\tilde{\Sigma}$, we can obtain the consistent estimator of β as

$$\tilde{\beta} = [R' (\tilde{\Sigma}^{-1} \otimes X'X)\, R]^{-1}\, [R' (\tilde{\Sigma}^{-1} \otimes X')\, y]. \qquad (17)$$

Because the estimate of disturbance covariance provided by ordinary least squares of the unconstrained model (13) is consistent, we may use this estimate as $\tilde{\Sigma}$ and obtain β from (17). The asymptotic covariance of β is then approximated by:

$$\tilde{\Sigma}_{\tilde{\beta}} = [R' (\tilde{\Sigma}^{-1} \otimes X'X)\, R]^{-1} \qquad (18)$$

In view of (15), we can obtain the consistent estimator of α and its standard error.

Estimating the Cross-Group Demand Subsystem

Given a pair of cross-group demand subsystems as defined in (9) and (11) for m+n commodities, we can express the stochastic equations for T sample observations as follows:

$$
\begin{bmatrix} \overset{*}{q}_{11} \\ \vdots \\ \overset{*}{q}_{1T} \\ \vdots \\ \overset{*}{q}_{m1} \\ \vdots \\ \overset{*}{q}_{mT} \\ \bar{q}_{m+1,1} \\ \vdots \\ \bar{q}_{m+1,T} \\ \vdots \\ \bar{q}_{m+n,1} \\ \vdots \\ \bar{q}_{m+n,T} \end{bmatrix}
=
\begin{bmatrix}
\overset{*}{p}_{m+1,1} \cdots \overset{*}{p}_{m+n,1} & & \\
\vdots & & \\
\overset{*}{p}_{m+1,T} \cdots \overset{*}{p}_{m+n,T} & 0 & \\
& \ddots & \\
0 & \overset{*}{p}_{m+1,1} \cdots \overset{*}{p}_{m+n,1} & \\
& \vdots & \\
& \overset{*}{p}_{m+1,T} \cdots \overset{*}{p}_{m+n,T} & \\
\bar{p}^{(m+1)}_{1,1} & \cdots\ \bar{p}^{(m+1)}_{n,1} & \\
0 & 0 & 0 \\
\bar{p}^{(m+1)}_{1,T} & \bar{p}^{(m+1)}_{n,T} & \\
& \ddots & \\
\bar{p}^{(m+n)}_{1,1} & & \bar{p}^{(m+n)}_{n,1} \\
0 & 0 & \\
\bar{p}^{(m+n)}_{1,T} & & \bar{p}^{(m+n)}_{n,T}
\end{bmatrix}
\begin{bmatrix} e_{1,m+1} \\ \vdots \\ e_{1,m+n} \\ \vdots \\ e_{m,m+1} \\ \vdots \\ e_{m,m+n} \end{bmatrix}
+
\begin{bmatrix} u_{11} \\ \vdots \\ u_{1T} \\ \vdots \\ u_{m1} \\ \vdots \\ u_{mT} \\ u_{m+1,1} \\ \vdots \\ u_{m+1,T} \\ \vdots \\ u_{m+n,1} \\ \vdots \\ u_{m+n,T} \end{bmatrix}
\tag{19}
$$

or in an abbreviated form,

$$y = X \beta + u \tag{20}$$

where

- y = column vector of (m+n)T observations, by stacking the adjusted relative change in quantity of the pair-wise group commodities as defined in (9) and (11),
- X = (m+n)T x mn matrix containing the observations of the adjusted relative change in price of the pair-wise group commodities as defined in (9) and (11),
- β = vector of mn parameters, and
- u = column vector of (m+n)T random disturbances.

Suppose that the random disturbances in (20) at time t are distributed according to a multivariate normal $N(O, \Sigma)$ with m+n dimensions. Then, given a prior consistent estimate of Σ, say $\tilde{\Sigma}$, the constrained maximum likelihood estimates of β are obtained by

$$\tilde{\beta} = [X' (\tilde{\Sigma}^{-1} \otimes I_T)\, X]^{-1}\, X' (\tilde{\Sigma}^{-1} \otimes I_T)\, y, \tag{21}$$

where $\otimes$ is a Kronecker product and I_T is a T x T identity matrix.

Again, we may use the consistent estimate of the disturbance covariance, provided by ordinary least squares of the unconstrained model (9) as $\tilde{\Sigma}$ in (21). The asymptotic covariance of β is then approximated by

$$\Sigma_{\tilde{\beta}} = [X'(\tilde{\Sigma}^{-1} \otimes I_T)X]^{-1} . \tag{22}$$

Finally, we can derive the parameters and standard errors in the demand subsystem for the Jth group commodities by applying the symmetric relations of (10).

Empirical Results of Demand Subsystems for Food Categories

I applied the statistical procedures developed in the preceding section to estimate a disaggregated food demand system for the United States. At the beginning of estimation, a composite food demand system is computed. Then, I computed the disaggregated demand system in block-by-block fashion. The empirical results are presented in two parts. This section contains the composite food demand system results and the diagonal blocks of disaggregated food demand system.

Appendix B explains the data sources used in this study. The price data are consumer price indexes for food and nonfood. The quantity data are defined as the "retail weight equivalent of civilian food disappearance." A difficulty with this quantity measurement is that many food commodities 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 estimates of actual consumption at the retail level. The correspondence between the price and quantity variables are certainly not ideal as assumed by the conceptual demand theory. However, given the limitations of the available data sources, the data compiled in this study are about as close a correspondence as one can achieve.

Composite Demand System of Food Categories

While the main objective is to obtain a disaggregated food demand system, the estimation of a composite demand model for food categories is required under the proposed estimation procedure. Continuous retail price series for individual food commodities are available only for 40 items and 31 observations covering 1953-83. Obviously, 31 observations is far less than the number of demand parameters in each demand equation, which includes 41 price elasticities and 1 expenditure elasticity. Thus, direct estimation of a demand equation is not feasible. Even though the number of demand parameters in the whole system can be reduced substantially under constrained estimation, the covariance matrix of residuals (required as prior information in the constrained maximum likelihood procedure) should be obtained from unconstrained estimation results.

In constructing commodity groups, there is a dichotomy between theory and empirical application. Hicks' composite-good theorem asserts that if a group of prices move in parallel, then the corresponding group of commodities can be treated as a single good (*10*). For econometric modeling, however, the usefulness of the theorem is rather limited. By grouping together commodities having highly correlated prices, we may introduce serious multicollinearity problems.

The criteria used for grouping food commodities in this study depend on the homogeneous characteristics of food commodities in consumers' budget and the goodness of statistical fit for the disaggregated food demand system. Based upon various experiments in model fitting, the following eight groups were established: (1) meats and other animal proteins, (2) staple foods, (3) fats and oils, (4) fresh fruits, (5) fresh vegetables, (6) processed fruits and vegetables, (7) desserts, sweeteners, and coffee, and (8) nonfood items. Table 1 shows a detailed listing of the 40 individual food items classified into each food category. Table 1 also includes the average values of per capita consumption for 1967-69 and the corresponding expenditure weights. Meats and staple foods are two major food categories with expenditure weights of 7.33 and 3.74 percent, respectively. Expenditure weights of more than 1 percent for individual food commodities are beef and veal (2.99), pork (1.71), wheat flour (1.60), fluid milk (1.56), and sugar (1.42).

In accordance with the commodity grouping, aggregate price and quantity variables are aggregate Laspeyres indexes derived from data on individual food commodities. More specifically, the aggregate quantity and price index at year t for a food category consisting of m commodities is calculated as follows:

$$Q_t = \sum_{i=1}^{m} (q_{it}/q_{io})\, w_{io}, \qquad (23)$$

$$P_t = \sum_{i=1}^{m} (p_{it}/p_{io})\, w_{io}, \qquad (24)$$

where Q_t and P_t are the aggregate quantity and price indexes at year t; q_{it} and p_{it} are disaggregate quantity and price indexes for the ith commodity at year t, and the subscript 'o' indicates the base year 1967; and w_{io} is the expenditure weight of the ith commodity in the base year.

Given the aggregate quantity and price indexes, we can now estimate a composite demand system of seven food categories and one nonfood category, subject to the parametric constraints of homogeneity, symmetry, and Engel aggregation. Table 2 gives information regarding the elasticity of the commodity category in the left column with respect to the category prices and expenditures at the top of the table. The direct-price elasticities for food categories, shown in the diagonal entries, are all negative, with magnitudes ranging between –0.08 and –0.34. The expenditure elasticities shown in the last column of the table are high for meats (0.45) and processed fruits and vegetables (0.63), but low for other food categories. The interdependent relationships among different categories are shown in the off-diagonal entries of the table. Again, the main function of this aggregated demand system is to provide a framework for estimating the demand parameters of the disaggregated food demand system.

Disaggregated Demand Subsystems for Each Composite Food Category

Recall the proposed estimation procedure in the preceding section where, after estimating a composite demand system, the parameters of the disaggregated food demand system are then obtained in a sequential manner group by group. To begin the estimation of within-group parameters, I adjusted the quantity variable by excluding the price effects of other commodities outside a given food category. These price effects are approximated by using cross-group price elasticities from the composite demand system. Then, I obtained the estimates of the parameters within each food category (including expenditure elasticities) by incorporating the symmetry constraints.

The major focus of the following discussion is on the explanation of price responses, expenditure responses, and interdependence relationships, such as the substitution or complementary effect between two foods. Strictly speaking, the substitution or complementary effects depend on the sign of the compensated cross-price elasticity, which measures the cross-price effect under a specific level of consumer satisfaction. The relationship of the compensated cross-price elasticity (say, $\overset{*}{e}_{ij}$) and the uncompensated cross-price elasticity (e_{ij}—given in the following tables) is as follows:

$$\overset{*}{e}_{ij} = e_{ij} + \delta_i w_j, \qquad (25)$$

where δ_i is the expenditure elasticity of ith commodity and w_j is the expenditure share of jth commodity. For food commodities, most of the estimated expenditure elasticities are less than 1 in absolute value, and their expenditure shares are relatively small, being in the range of 0.0003 to 0.0299. The

Table 1—Commodity grouping, expenditure weights, and abbreviated notations

Commodity group, group weight	Individual commodity		Value aggregate[1]	Weight
			Dollars	*Percent*
1. MEATS: Meats and other animal proteins; Group weight (7.331 percent)	(1) BEEF.V:	Beef and veal	73.00	2.994
	(2) PORK:	Pork	41.62	1.707
	(3) O.MEAT:	Other meats	9.85	.404
	(4) CHICKN:	Chicken	14.42	.591
	(5) TURKEY:	Turkey	4.13	.169
	(6) FISH:	Fresh and frozen fish	4.21	.173
	(7) C. FISH:	Canned and cured fish	4.17	.171
	(8) EGGS:	Eggs	18.97	.778
	(9) CHEESE:	Cheese	8.38	.344
2. STAPLE: Staple foods (3.742)	(10) F. MILK:	Fluid milk	38.08	1.562
	(11) O. MILK:	Evaporated and dry milk	3.98	.163
	(12) FLOUR:	Wheat flour	38.91	1.596
	(13) RICE:	Rice	5.64	.231
	(14) POTATO:	Potatoes	4.64	.190
3. FATS: Fats and oils (1.023)	(15) BUTTER:	Butter	4.36	.179
	(16) MARGAR:	Margarine	3.12	.128
	(17) O. FATS:	Other fats and oils	17.47	.716
4. FRUITS: Fresh fruits (.821)	(18) APPLES:	Apples	3.68	.151
	(19) ORANGE:	Oranges	3.75	.154
	(20) BANANA:	Bananas	2.87	.118
	(21) GRAPES:	Grapes	1.20	.049
	(22) GRAFRU:	Grapefruits	1.31	.054
	(23) O.FRUT:	Other fresh fruits	7.20	.295
5. VEGETA: Fresh vegetables (.829)	(24) LETTUC:	Lettuce	4.58	.188
	(25) TOMATO:	Tomatoes	4.12	.169
	(26) CELERY:	Celery	1.09	.045
	(27) ONIONS:	Onions	1.61	.066
	(28) CARROT:	Carrots	1.11	.046
	(29) CABAGE:	Cabbage	1.00	.041
	(30) O. VEGE:	Other fresh vegetables	6.70	.274
6. PRO. FV: Processed fruits and vegetables (1.898)	(31) JUICE:	Fruit juice	2.96	.121
	(32) C. TOMA:	Canned tomatoes	1.80	.074
	(33) C. PEAS:	Canned peas	.95	.039
	(34) COCKTL:	Canned fruit cocktail	.72	.030
	(35) D. BEAN:	Dried beans, peas, and nuts	7.72	.316
	(36) O. PRFV:	Other processed fruits and vegetables	32.15	1.318
7. DESSRT: Desserts, sweeteners, and coffee (2.990)	(37) SUGAR:	Sugar	34.73	1.424
	(38) SWEET:	Sweeteners	12.87	.528
	(39) COFFEE:	Coffee and tea	11.50	.472
	(40) FRZN. D:	Ice cream and other frozen dairy products	13.81	.566
8. N.FOOD: Nonfood (81.366)	(41) N.FOOD:	Nonfood	NA	81.366

NA = Not applicable.
[1]Value aggregate is the average value of per capita consumption for 1967-69.
Source: Compiled from (*17*, 1977 issue).

Table 2—Aggregated demand system for food groups and nonfood

Quantity \ Price	MEAT	STAPLE	FATS	FRUITS	VEGETA	PRO.FV	DESSRT	N.FOOD	EXPEND
MEAT	−0.3350	0.0119	0.0105	0.0096	−0.0087	0.0100	−0.0246	−0.1241	0.4504
	(.0349)	(.0194)	(.0068)	(.0110)	(.0064)	(.0116)	(.0128)	(.0776)	(.0731)
STAPLE	.0598	−.2270	−.0136	−.0505	.0586	−.0135	−.0195	.2519	−.0462
	(.0379)	(.0748)	(.0247)	(.0302)	(.0229)	(.0318)	(.0238)	(.0854)	(.0703)
FATS	.0953	−.0578	−.1216	−.0377	−.0779	.1327	.0010	−.1074	.1733
	(.0486)	(.0903)	(.0619)	(.0435)	(.0416)	(.0439)	(.0382)	(.1026)	(.0908)
FRUITS	.1251	−.2288	−.0443	−.2257	.0222	−.1182	.1554	.4013	−.0871
	(.0979)	(.1378)	(.0542)	(.1023)	(.0507)	(.0761)	(.0619)	(.2214)	(.1878)
VEGETA	−.0569	.2559	−.0962	.0198	−.0806	−.1122	−.0095	−.1008	.1804
	(.0552)	(.1025)	(.0509)	(.0498)	(.0679)	(.0502)	(.0389)	(.1187)	(.1095)
PRO.FV	.0250	−.0520	.0668	−.0570	−.0527	−.1434	−.0290	−.3911	.6334
	(.0449)	(.0626)	(.0236)	(.0329)	(.0221)	(.0462)	(.0295)	(.1022)	(.0911)
DESSRT	−.0320	−.0286	.0014	.0414	−.0017	−.0076	−.1244	.0855	.0660
	(.0320)	(.0304)	(.0133)	(.0174)	(.0111)	(.0192)	(.0242)	(.0866)	(.0789)
N.FOOD	−.0640	−.0339	−.0115	−.0063	−.0092	−.0193	−.0299	−.9961	1.1702
	(.0039)	(.0027)	(.0009)	(.0015)	(.0009)	(.0015)	(.0017)	(.0107)	(.0094)
WEIGHT	.0733	.0374	.0102	.0082	.0083	.0190	.0299	.8137	1.000

Note: For each pair of estimates, the upper part is the estimated elasticity, and the lower part (in parentheses) is the standard error. The abbreviated 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), DESSRT (desserts, sweeteners, and coffee), N.FOOD (nonfood), and EXPEND (expenditures).

sign of e^*_{ij} will probably be consistent with e_{ij} because the second term, $\delta_i w_j$, is negligible in most cases.[2] Thus, in the following tables, we may interpret the cross-price elasticities for two food commodities as being substitutes if the sign of the estimated cross-price elasticity is positive and complements if the sign is negative.

To understand the statistical properties of empirical estimates, an exact t-test for the statistical significance of an estimate is not applicable, because the estimation results satisfy only asymptotic properties. But for the purpose of discussion here, if an estimated elasticity is larger than its standard error in absolute value, the estimate is considered to be statistically significant and reliable as a price or expenditure response. On the other hand, the estimated elasticities with relatively large standard errors may imply that the estimates are not statistically precise as point estimates of the respective parameter.

Meats and Other Animal Proteins The category of meats and other animal proteins, including red meats, poultry, fish, eggs, and cheese, accounts for nearly 40 percent of consumers' food budget, and its importance in food consumption has long been recognized. Many empirical studies have analyzed the demand relationships for these commodities. However, few studies have brought these commodities together and analyzed their interdependent nature.

Table 3 contains a demand subsystem for meats and other animal proteins. The direct-price elasticities of red meats are beef and veal, −0.6166; pork, −0.7297; and other meats, −1.3712. The comparatively more elastic estimate found for other meats is probably due to the inclusion of lamb, mutton, and edible offal, which are consumed in very minor quantities compared with beef and pork. The expenditure elasticities for beef-veal and pork are almost the same at about 0.45, while the elasticity for other meats is numerically small and not significant. The estimated cross-price elasticities show significant substitution among red meats. For example, the quantity demanded of beef and veal could increase by 0.1087 percent because of a 1-percent increase in pork price, and 0.0714 percent because of a 1-percent increase in other meat prices. On the other hand, a 1-percent increase in the price of beef and veal could increase the quantity demanded for pork and other meats by 0.191 percent and 0.5409 percent, respectively.

The estimated direct-price elasticities for the two poultry meats are chicken, −0.5308, and turkey, −0.6797. Their expenditure

[2] I calculated the compensated cross-price elasticities for food commodities for the complete disaggregated demand elasticity matrix, and they support the consistency of signs. The sign is different for only six pairs of cross-price elasticities: pork-grapefruit, onions-canned tomatoes, juice-carrots, pork-coffee, beef-fluid milk, and other milk-sugar. However, these cross-price elasticities have relatively large standard errors.

Table 3—Disaggregated demand subsystem for meats and other animal proteins

Quantity \ Price	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	EXPEND
BEEF.V	–0.6166	0.1087	0.0714	0.0572	0.0115	–0.0112	0.0081	0.0084	–0.0296	0.4549
	(.0483)	(.0220)	(.0163)	(.0136)	(.0078)	(.0085)	(.0094)	(.0091)	(.0107)	(.0585)
PORK	.1910	–.7297	.0486	.0908	.0178	.0157	.0190	–.0147	–.0089	.4427
	(.0390)	(.0327)	(.0178)	(.0170)	(.0091)	(.0096)	(.0107)	(.0104)	(.0122)	(.0624)
O.MEAT	.5409	.2119	–1.3712	–.1633	.0251	.0430	–.0391	–.0151	.4068	.0607
	(.1214)	(.0754)	(.2045)	(.0675)	(.0634)	(.0883)	(.0787)	(.0526)	(.0891)	(.1123)
CHICKN	.2927	.2635	–.1128	–.5308	–.0487	.0820	–.0743	.0924	–.0394	.3645
	(.0698)	(.0492)	(.0461)	(.0608)	(.0323)	(.0322)	(.0363)	(.0307)	(.0411)	(.0863)
TURKEY	.2083	.1821	.0590	–.1701	–.6797	–.0894	.0742	–.0268	.1489	.3196
	(.1402)	(.0919)	(.1516)	(.1133)	(.1332)	(.1030)	(.1063)	(.0816)	(.1262)	(.1691)
FISH	–.1838	.1604	.1002	.2818	–.0870	.0142	–.0847	–.1189	.1501	.1155
	(.1476)	(.0946)	(.2060)	(.1100)	(.1004)	(.1615)	(.1298)	(.0853)	(.1353)	(.1783)
C.FISH	.1559	.1975	–.0922	–.2548	.0738	–.0855	.0350	–.0764	.1341	.0005
	(.1657)	(.1068)	(.1859)	(.1255)	(.1049)	(.1314)	(.1706)	(.0965)	(.1453)	(.2049)
EGGS	.0470	–.0242	–.0075	.0725	–.0052	–.0262	–.0167	–.1452	.0292	–.0283
	(.0354)	(.0229)	(.0274)	(.0234)	(.0177)	(.0191)	(.0213)	(.0225)	(.0251)	(.0445)
CHEESE	–.2618	–.0468	.4756	–.0690	.0727	.0747	.0656	.0613	–.3319	.5927
	(.0939)	(.0603)	(.1045)	(.0704)	(.0619)	(.0680)	(.0722)	(.0563)	(.1174)	(.1197)
WEIGHT	.0299	.0171	.0040	.0059	.0017	.0017	.0017	.0078	.0034	1.0000

Note: For each pair of estimates, the upper part is the estimated elasticity, and the lower part (in parentheses) is the standard error. The abbreviated notations are BEEF.V (beef and veal), O.MEAT (other meats), CHICKN (chicken), FISH (fresh and frozen fish), C.FISH (canned and cured fish), and EXPEND (expenditures).

elasticities are chicken, 0.3645, and turkey, 0.3196. Turkey is being increasingly used in processed foods and sold as parts. Smaller turkeys also have been produced. Thus, turkey consumption nowadays is throughout the year and not restricted to holidays.

These changes support the similarity of elasticity estimates between chicken and turkey. However, the cross-price elasticity between chicken and turkey suggesting a complementary relationship is not expected from conventional wisdom. The estimated cross-price elasticities between poultry and red meats (except for other meats) show significant substitution relationships. In particular, the cross-price elasticities of beef with respect to the prices of chicken and turkey are significant at 0.0572 and 0.0115, respectively. The cross-price elasticities of pork with respect to the prices of chicken and turkey are also found to be significant at 0.0908 and 0.0178, respectively. The results support a widely held view about the substitution between red meats and poultry.

I separated fish consumption into fresh-frozen fish and canned-cured fish. Both the estimated direct-price and expenditure elasticities for these food items are not statistically significant, and the direct-price elasticities have the wrong sign. One possible explanation is that the correspondence between the price and quantity data series as discussed below is not as close as is desirable. One problem is aggregation, in that a wide variety of fish species are included in the aggregate ''fish'' category. Besides, the retail prices of fish were not defined consistently over the years. Before the early sixties, the prices referred to only two items: fresh-frozen fish, and fresh-canned tuna. Beginning in 1964, the prices of frozen shrimp and canned sardines were added. After 1977, the price series includes additional seafoods. Another explanation of the insignificant estimates is that much fish is consumed away from home, where demand for fish is influenced by menu prices instead of the price of raw fish.

The consumers' response to the changes in the price of eggs is reflected in a direct-price elasticity of –0.1452. The results also indicate that eggs are substitutable for beef-veal and chicken. Although there is some indication of a negative egg consumption response to income level changes, the estimate is insignificant. Over the last two decades, per capita egg consumption has been decreasing. One often expressed reason for the decline relates to medical and dietary concerns resulting from the perceived linkage between heart disease and cholesterol levels.

ıeese consumption includes many varieties with American eddar cheese being a major item. For example, per capita ɪnsumption of American cheddar cheese in 1983 was 9.11 ɪunds, 44 percent of total cheese consumption. Unfortuɪtely, the only retail price available for use in estimation is at for American processed cheese slices. The results of using is price series are not considered to be a reliable estimate the "true" price-quantity demand response. To better repreɪnt the aggregate cheese price, the wholesale price of Wisconn cheddar (assembly point, 40 pound block) obtained from (8) was used in the analysis as a proxy for the average retail ıeese price. The results show the direct-price and expenditure lasticities of −0.3319 and 0.5927, respectively. The crossrice elasticity of cheese with respect to the price of beef and eal is significant at −0.2618, a complementary relationship ıat may in part reflect such popular complementary preparaions as cheeseburgers.

Staple Foods Fluid milk, evaporated-dry milk, and starchy foods that provide basic nutrients and energy are classified n the staple food category. Most of these staple foods are characterized by declining per capita consumption over the sample period. In particular, the fluid milk consumption index (1967 = 100) decreased from 115.7 in 1953 to 82.2 in 1983. The index for evaporated-dry milk consumption decreased from 122.1 to 58.7 over the same period.

Table 4 presents the estimated demand subsystem for staple foods. Given the declining consumption, it is not surprising to find that all expenditure elasticities are negative, with the exception of potatoes which is positive but not significant. The expenditure elasticities for fluid milk and evaporated-dry milk are quite close at −0.2209 and −0.2664, respectively, while the elasticity of wheat flour is the lowest in absolute value at −0.1333. The negative expenditure elasticities may imply that the commodities in this category are "inferior goods," with consumption of these staple foods decreasing as consumers' income increases.

As for direct-price elasticity, the processed milk products such as evaporated-dry milk are comparatively more elastic (−0.8255) than fluid milk (−0.2588). For starchy food items, the direct-price elasticity of potatoes is −0.3688, while relatively low price elasticities are estimated for wheat flour (−0.1092) and rice (−0.1467). Among the estimated cross-price elasticities, fluid milk is a substitute for evaporated-dry milk but a complement to potatoes. A substitution relationship is also found between wheat flour and rice.

Fats and Oils Empirical results of the demand subsystem for butter, margarine, and other fats and oils are contained in table 5. The aggregate price index of fats and oils is used for the "other fats and oils," because of the lack of price data for this category.

Butter usage steadily decreased over the years, while margarine consumption increased over most of the sample period, decreasing slightly in the early eighties. The estimated cross-price elasticity of butter with respect to the price of margarine is 0.0477, indicating that the two table spreads are substitutes, although the standard error is large. Because this estimate is not quite statistically significant nor is the cross-price elasticity of margarine with respect to the price of butter, the perceived substitution relationship for table spread use may not be as strong as expected. The estimated direct-price

Table 4—Disaggregated demand subsystem for staple foods

Quantity \ Price	F.MILK	O.MILK	FLOUR	RICE	POTATO	EXPEND
F.MILK	−0.2588 (.1205)	0.0743 (.0411)	−0.0565 (.0817)	0.0387 (.0368)	−0.0230 (.0168)	−0.2209 (.0686)
O.MILK	.7125 (.3939)	−.8255 (.2642)	−.0679 (.2976)	.0001 (.1284)	.0349 (.0537)	−.2664 (.2230)
FLOUR	−.0567 (.0798)	−.0072 (.0302)	−.1092 (.1026)	.0503 (.0382)	−.0019 (.0168)	−.1333 (.0701)
RICE	.2638 (.2509)	.0003 (.0910)	.3512 (.2668)	−.1467 (.1438)	.0187 (.0569)	−.3664 (.2301)
POTATO	−.1946 (.1389)	.0293 (.0460)	−.0207 (.1420)	.0216 (.0689)	−.3688 (.0689)	.1586 (.2225)
WEIGHT	.0156	.0016	.0160	.0023	.0019	1.0000

Note: For each pair of estimates, the upper part is the estimated elasticity and the lower part (in parentheses) is the standard error. The abbreviated notations are F.MILK (fluid milk), O.MILK (evaporated and dry milk), POTATO (potatoes), and EXPEND (expenditures).

and expenditure elasticities of margarine are, respectively, -0.2674 and 0.1112. The demand for butter is relatively inelastic in price response, with a direct-price elasticity of -0.1670, but not statistically significant.

Demand for other fats and oils, mainly shortening and cooking oils, increased substantially over the sample period mainly because of the sharp growth in demand for vegetable oils. The estimated direct-price and expenditure elasticities of the other fats and oils are -0.2191 and 0.3691, respectively. Because the major portion of other fats and oils is vegetable-type oils, their estimated cross-price elasticities indicate that they are substitutable for margarine but complementary to butter.

Fresh Fruits Retail price indexes are available for apples, oranges, bananas, grapes, and grapefruit. These items are treated as individual fruits. A variety of other fruits are grouped together, and the aggregate retail price of fresh fruits is used, because separate retail prices are not available.

Table 5—Disaggregated demand subsystems for fats and oils

Quantity \ Price	BUTTER	MARGAR	O.FATS	EXPEND
BUTTER	-0.1670 (.1748)	0.0477 (.0666)	-0.1226 (.1190)	0.0227 (.1915)
MARGAR	.0665 (.0934)	-.2674 (.1379)	.1845 (.1714)	.1112 (.1073)
O.FATS	-.0313 (.0296)	.0327 (.0306)	-.2191 (.0496)	.3691 (.0531)
WEIGHT	.0018	.0013	.0072	1.000

Note: For each pair of estimates, the upper part is the estimated elasticity and the lower part (in parentheses) is the standard error. The abbreviated notations are MARGAR (margarine), O.FATS (other fats and oils), and EXPEND (expenditures).

Table 6 contains the empirical results of the demand subsystem for fresh fruits. The price responses of grapes and oranges are elastic with direct-price elasticities of -1.3780 and -0.9996, respectively. For all other fruits, the direct-price elasticities range between -0.2 and -0.4. The expenditure elasticities for oranges, grapes, and grapefruit are of similar magnitude, ranging between 0.44 and 0.49. The negative expenditure elasticity for apples, though it may be difficult to justify, reflects the consumption pattern in the sample period; that consumption pattern was high at the beginning, decreased drastically in 1960, and thereafter remained low, the opposite of the pattern of per capita expenditure. The estimates of cross-price response indicate that apples are a substitute for oranges, bananas, and grapefruit and that oranges are complementary to grapes. Both bananas and grapes are complementary to grapefruit. Based on the relative size of the standard errors, the elasticity estimates for the other fruit category have a relatively low degree of precision, possibly because of the unavoidable lumping together of the variety of items.

Fresh Vegetables Fresh vegetables include lettuce, tomatoes, celery, onions, carrots, cabbage, and other fresh vegetables. The aggregate retail price index of fresh vegetables is used for the "other fresh vegetables," because data are not available for this category. Table 7 shows the estimated demand subsystem.

Lettuce and tomatoes are two major items with a total expenditure share of 43 percent of fresh vegetables. While the per capita consumption of tomatoes has increased slightly, lettuce

Table 6—Disaggregated demand subsystem for fresh fruits

Quantity \ Price	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	EXPEND
APPLES	-0.2015 (.1469)	0.1400 (.1119)	0.1510 (.0940)	-0.0445 (.0637)	0.1016 (.0533)	-0.0446 (.3175)	-0.3514 (.2126)
ORANGE	.1360 (.1097)	-.9996 (.1465)	-.0746 (.0899)	-.1132 (.0660)	-.0175 (.0538)	.3843 (.3496)	.4866 (.2587)
BANANA	.1928 (.1202)	-.0965 (.1173)	-.4002 (.1334)	.0148 (.0717)	-.1024 (.0564)	.2630 (.3306)	-.0429 (.1899)
GRAPES	-.1382 (.1963)	-.3556 (.2074)	.0350 (.1728)	-1.3780 (.1829)	-.2154 (.1032)	1.7077 (.5820)	.4407 (.3263)
GRAFRU	.2828 (.1491)	-.0498 (.1535)	-.2244 (.1233)	-.1955 (.0937)	-.2191 (.1067)	-.6022 (.4243)	.4588 (.2636)
O.FRUT	-.0229 (.1624)	.2019 (.1823)	.1055 (.1322)	.2840 (.0966)	-.1098 (.0776)	-.2357 (.5471)	-.3401 (.2360)
WEIGHT	.0015	.0015	.0012	.0005	.005	.0030	1.0000

Note: For each pair of estimates, the upper part is the estimated elasticity and the lower part (in parentheses) is the standard error. The abbreviated notations are GRAFRU (grapefruit), O.FRUT (other fresh fruits), ORANGE (oranges), BANANA (bananas), and EXPEND (expenditures).

›nsumption has steadily increased over the years. Using the ıdex, with base year of 1967, lettuce consumption increased 'om 78.4 percent in 1953 to 121.1 in 1983. Although dif- cult to document, much of this growth may have been in the way-from-home market. The relative insensitivity to price hanges supports this hypothesis. Lettuce is quite inelastic with rice and expenditure elasticities of –0.1371 and 0.2344. The stimated price and expenditure elasticities for tomatoes are 0.5584 and 0.4619, respectively. Price and expenditure esponses for other fresh vegetables are inelastic. The stimated cross-price elasticities indicate that lettuce is a ubstitute for celery, carrots, and cabbage, while tomatoes and elery have a substitution relationship with cabbage.

Processed Fruits and Vegetables Despite a wide variety of processed fruits and vegetables, fruit juice, canned tomatoes, canned peas, fruit cocktail, dried beans, and peas are the only distinct items having retail price data available. All others are grouped, and an aggregate price index is used to represent the "other processed fruits and vegetables." Table 8 contains the estimated demand subsystem for this category.

The consumption of processed fruits and vegetables has grown rapidly, particularly fruit juices—a major item in this category. The processed fruits and vegetables quantity index (1967 = 100) increased from 68.3 in 1953 to 187.1 in 1983. The estimated direct-price and expenditure elasticities for juice are, respectively, –0.5612 and 1.1254. Fruit cocktail demand is also quite responsive to both price and expenditure, with a direct-price elasticity of –0.7323 and an expenditure elasticity of 0.7354. The estimated cross-price elasticities for processed fruits do not show any significant interdependent relationships with other commodities in this group.

Canned tomatoes and canned peas are the only individual processed vegetables considered here. The estimated direct-price elasticity for canned tomatoes is –0.3811 and for canned peas is –0.6926. The expenditure elasticities are also significant for canned tomatoes (0.7878) and canned peas (0.3295). Based on the estimated cross-price elasticities, they are substitutes. Consistent with the grouping in the Consumer Price Index, dried beans, peas, and nuts are grouped together. The estimated direct-price and expenditure elasticities for this category are –0.1248 and 0.5852, respectively.

Desserts, Sweeteners, and Coffee Based on the consumption patterns, sugar, sweeteners, ice cream and other frozen dairy products, and coffee are grouped together in a dessert category. Table 9 contains the empirical results of this demand subsystem.

Sugar, including cane and beet, is a major item in this category. The available quantity data, measured at approximately the wholesale level of distribution, includes household consumption and commercial use. However, because of lack of detailed quantity and price data, there is no way to estimate demands for different uses. Sugar consumption was quite stable before the early seventies, but drastically decreased thereafter, probably because of dietary considerations as consumers shifted to lower calorie foods. Another factor could be the

Table 7—Disaggregated demand subsystem for fresh vegetables

Quantity \ Price	LETTUC	TOMATO	CELERY	ONIONS	CARROT	CABAGE	O.VEGE	EXPEND
LETTUC	–0.1371 (.0656)	0.0148 (.0383)	0.0409 (.0180)	–0.0230 (.0290)	0.0881 (.0366)	0.0563 (.0160)	0.0599 (.0846)	0.2344 (.1154)
TOMATO	.0161 (.0426)	–.5584 (.0624)	–.0026 (.0235)	–.0163 (.0250)	.0220 (.0399)	.0950 (.0175)	.0291 (.0805)	.4619 (.0904)
CELERY	.1708 (.0751)	–.0094 (.0884)	–.2516 (.0636)	.0021 (.0437)	–.0179 (.0728)	.0879 (.0332)	–.0882 (.1303)	.1632 (.1501)
ONIONS	–.0655 (.0826)	–.0411 (.0642)	.0015 (.0298)	–.1964 (.0693)	–.0327 (.0639)	.0144 (.0280)	.3230 (.1545)	.1603 (.2045)
CARROT	.3610 (.1497)	.0818 (.1466)	–.0173 (.0712)	–.0467 (.0916)	–.0388 (.1816)	–.0479 (.0605)	.0432 (.2654)	–.1529 (.3365)
CABAGE	.2594 (.0734)	.3931 (.0724)	.0967 (.0365)	.0235 (.0451)	–.0537 (.0679)	–.0385 (.0405)	–.2547 (.1334)	–.3767 (.1577)
O.VEGE	.0409 (.0578)	.0182 (.0495)	–.0145 (.0213)	.0774 (.0370)	.0070 (.0443)	–.0382 (.0199)	–.2102 (.1436)	.2837 (.1526)
WEIGHT	.0019	.0017	.0004	.0007	.0005	.0004	.0027	1.0000

Note: For each pair of estimates, the upper part is the estimated elasticity and the lower part (in parentheses) is the standard error. The abbreviated notations are LETTUC (lettuce), TOMATO (tomatoes), CARROT (carrots), CABAGE (cabbage), O.VEGE (other fresh vegetables), and EXPEND (expenditures).

Table 8—Disaggregated demand subsystem for processed fruits and vegetables

Quantity \ Price	JUICE	C.TOMA	C.PEAS	COCKTL	D.BEAN	O.PRFV	EXPEND
JUICE	-0.5612 (.1006)	0.0066 (.0306)	0.0127 (.0207)	0.0139 (.0278)	-0.0441 (.0615)	0.2572 (.2281)	1.1254 (.2505)
C.TOMA	.0112 (.0500)	-.3811 (.1072)	.2490 (.0638)	-.0067 (.0818)	-.0588 (.0418)	.1562 (.2087)	.7878 (.1454)
C.PEAS	.0404 (.0643)	.4728 (.1211)	-.6926 (.1746)	.0745 (.1747)	-.0261 (.0544)	-.2508 (.3250)	.3295 (.1616)
COCKTL	.0565 (.1121)	-.0166 (.2017)	.0967 (.2271)	-.7323 (.3677)	.0801 (.0914)	-.2446 (.5729)	.7354 (.2788)
D.BEAN	-.0162 (.0235)	-.0136 (.0098)	-.0033 (.0067)	.0076 (.0087)	-.1248 (.0313)	.1010 (.0795)	.5852 (.1167)
O.PRFV	.0242 (.0208)	.0089 (.0117)	-.0075 (.0096)	-.0055 (.0130)	.0242 (.0190)	-.2089 (.0921)	.6311 (.0675)
WEIGHT	.0012	.0007	.0004	.0003	.0032	.0132	1.0000

Note: For each pair of estimates, the upper part is the estimated elasticity and the lower part (in parentheses) is the standard error. The abbreviated notations are C.TOMA (canned tomatoes), C.PEAS (canned peas), COCKTL (canned fruit cocktail), D.BEAN (dried beans, peas, and nuts), O.PRFV (other processed fruits and vegetables), and EXPEND (expenditures).

Table 9—Disaggregated demand subsystem for desserts, sweeteners, and coffee

Quantity \ Price	SUGAR	SWEET	COFFEE	FRZN.D	EXPEND
SUGAR	-0.0521 (.0172)	-0.0075 (.0135)	0.0104 (.0084)	0.0038 (.0068)	-0.1789 (.0627)
SWEET	-.0214 (.0359)	-.0045 (.0895)	-.0932 (.0318)	.0217 (.0411)	-.0928 (.1241)
COFFEE	.0274 (.0255)	-.1052 (.0357)	-.1868 (.0294)	-.0220 (.0174)	.0937 (.1027)
FRZN.D	.0069 (.0168)	.0197 (.0383)	-.0179 (.0145)	-.1212 (.0848)	.0111 (.0580)
WEIGHT	.0142	.0053	.0047	.0057	1.0000

Note: For each pair of estimates, the upper part is the estimated elasticity and the lower part (in parentheses) is the standard error. The abbreviated notations are SWEET (sweeteners), FRZN.D (ice cream and other frozen dairy products), and EXPEND (expenditures).

substitution of other sweeteners for sugar in processed products. The estimated direct-price and expenditure elasticities for sugar are -0.0521 and -0.1789, respectively. Sweeteners include syrup, honey, and cocoa (both as a beverage and as a nonbeverage ingredient such as in confectionery items). The results indicate that price and expenditure responses for sweeteners are not significant.

Coffee consumption has decreased over the years. Its direct-price elasticity is estimated to be -0.1868, and the estimated expenditure elasticity is not significant. The estimated cross-price elasticities show that coffee is complementary with sweeteners and ice cream, but not with sugar, an item that does not necessarily reflect the quantity used in coffee drinks. Finally, the estimated direct-price elasticity of ice cream and other frozen dairy products is -0.1212, but the expenditure response is not significant.

Empirical Results of the Complete Disaggregated Demand System

This section estimates various paired cross-group demand elasticities and completes the estimation of the complete disaggregated demand system. Subsequently, I will address implementation and verification of the demand system.

The Demand Elasticity Matrix

After estimating demand parameters within each food category, I obtained the cross-price elasticities across different categories in a sequential manner for two groups at a time, subject to symmetry and homogeneity constraints. Because the estimation of demand elasticities for any pair of cross-groups is not affected by the ordering of commodity groups, this study starts estimation with the cross-group between meats and staple foods.

At the beginning of estimation, I adjusted the relative changes of all food commodity prices and expenditure variables by subtracting the relative change of nonfood price from them. Then, I adjusted the quantities of individual commodities in either the group of meats or staple foods by subtracting the price and expenditure effects due to the commodities outside the corresponding cross-group. The prior information for the quantity adjustment comes from two sources: one is the estimated emand elasticities for within-group demand subsystems (in his case, the estimated price and expenditure elasticities in he respective groups of meats and staple foods), the other is he aggregate estimates from the composite demand system. Then, the cross-price elasticities in the pair of cross-groups ire estimated simultaneously by applying the symmetry estriction.

For illustrative purposes, table 10 presents the estimation results for the cross-groups of the disaggregated demand subsystem corresponding to the commodity groups for meats and staple foods. "Meats" includes beef and veal, pork, other meats, chicken, turkey, fresh fish, canned and cured fish, eggs, and cheese. "Staples" includes fluid milk, evaporated and dry milk, flour, rice, and potatoes. The values of each row express the estimated demand elasticities with price variables across the top and the quantity variables down the left-hand side. The results provide essential information regarding the interdependent relationships among commodities, not only inside the group, but also across categories in the different groups.

Following similar estimation procedures for computing the cross-price elasticities between commodity groups of meats and staple foods, we can estimate the cross-price elasticities of food commodities for the other cross-groups in the row and column related to the meat group. Then, the remaining unknown demand elasticities for the groups in the second row related to the commodities of staple foods and their symmetric counterparts are completed. Thus, continuing such a row-column group operation, one can obtain all the cross-price elasticities for food commodities sequentially, group by group. Given the complete estimates of price and expenditure elasticities for food commodities, one can obtain the elasticities for nonfood by applying the Engel aggregation, homogeneity, and symmetry constraints. Thus, the entire demand elasticity matrix is completed.

The empirical estimates for the complete disaggregated food demand system are presented in matrix form at the end of this report for 40 food commodities and 1 nonfood commodity. The average expenditure weights for all commodities for the period 1967-69 used in estimation are also listed in the bottom row of the table for easy identification of the relative importance of each food commodity. Because all demand elasticities are estimated by mean of constrained maximum likelihood procedures, one can easily verify that the theoretical constraints of symmetry, homogeneity, and Engel aggregation are satisfied. The numerous estimates of cross-price elasticities across different categories preclude a detailed discussion here. The estimated cross-price elasticities emphasize the importance of the inherent economic interdependence among the various food demands and underscore the possible error in ignoring these relationships in traditional partial demand analysis.

Implementing and Verifying the Demand System

The demand system serves at least two major functions: one is to provide a quantitative representation of the economic structure of food demands; the other is to provide a quantitative model for forecasting and analyzing food consumption behavior. The first function is carried out by the assessment of the sign, magnitude, and precision of the various estimated demand elasticities discussed previously. This section focuses on the second function which is an evaluation of the potential analytic and forecasting capability of the demand system.

Recall that the demand system for n commodities can be represented by

$$\underset{(nx1)}{\dot{q}_t} = \underset{(nxn)}{E_p}\underset{(nx1)}{\dot{p}_t} + \underset{(nx1)}{\delta}\underset{(1x1)}{\dot{m}_t} \qquad (26)$$

where $\dot{q}_t$, $\dot{p}_t$, and $\dot{m}_t$ are relative changes in quantities, prices, and expenditure at year t, respectively; E_p is an n x n price elasticity matrix, and δ is a vector of expenditure elasticities. The model is static in the statistical sense because there are no lagged endogenous variables appearing in the equation. Thus, the demand system may serve as a basis for projecting changes in quantities consumed for food commodities in the short run. The implementation of this demand system is rather straightforward. For conducting outlook, we may update the information on relative changes in prices and expenditure, and forecast the quantity demanded. For program analysis, we may assume various scenarios of changes in prices and expenditure and conduct simulation experiments for the evaluation of program effects because of these changes.

The immediate forecasting results from the model are in terms of relative changes in quantities demanded. In practice, it is also desirable to present the forecasting results in terms of quantity levels. For this purpose, we can easily transform the projected relative changes into quantity levels (say, a vector of q_t) on the basis of quantity level available in the previous year, q_{t-1} as follows:

$$\underset{(nx1)}{q_t} = (\underset{(nxn)}{I} + \underset{(nxn)}{\dot{D}_q})\underset{(nx1)}{q_{t-1}} \qquad (27)$$

where $\dot{D}_q$ is a diagonal matrix with the elements of the projected vector $\dot{q}_t$ in the diagonal. In case of an ex ante forecast when the lagged quantity level is unknown, the projected quantity in the previous year should be substituted.

To evaluate the forecasting performance of the model, an ex post simulation is conducted here for comparing the difference between actual and simulated values over the sample period. Another possible approach, not used here, is to compare the forecasts outside the sample period with available actual data. The problem with this 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

Table 10—Disaggregated demand subsystem for meats and staple foods

Quantity \ Price	Meats and other animal protein products									Staple foods				
	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
Meats:														
BEEF.V	-0.6166 (.0483)	0.1087 (.0220)	0.0714 (.0163)	0.0572 (.0136)	0.0115 (.0078)	-0.0112 (.0085)	0.0081 (.0094)	0.0084 (.0091)	-0.0296 (.0107)	-0.0005 (.0141)	-0.0018 (.0065)	-0.0301 (.0193)	0.0383 (.0084)	0.0059 (.0087)
PORK	.1910 (.0390)	-.7297 (.0327)	.0486 (.0178)	.0908 (.0170)	.0178 (.0091)	.0157 (.0096)	.0190 (.0107)	-.0147 (.0104)	-.0089 (.0122)	-.0325 (.0167)	-.0164 (.0069)	.0390 (.0215)	.0030 (.0095)	-.0096 (.0091)
O.MEAT	.5409 (.1214)	.2119 (.0754)	-1.3712 (.2045)	-.1633 (.0675)	.0251 (.0634)	.0430 (.0883)	-.0391 (.0787)	-.0151 (.0526)	.4068 (.0891)	-.1493 (.1108)	.0664 (.0734)	.3692 (.1338)	-.1782 (.0504)	-.0029 (.0254)
CHICKN	.2927 (.0698)	.2635 (.0492)	-.1128 (.0461)	-.5308 (.0608)	-.0487 (.0323)	.0820 (.0322)	-.0743 (.0363)	.0924 (.0307)	-.0394 (.0411)	.1788 (.0533)	.0347 (.0230)	.0783 (.0660)	-.1309 (.0275)	.0304 (.0209)
TURKEY	.2083 (.1402)	.1821 (.0919)	0590 (.1516)	-.1701 (.1133)	-.6797 (.1332)	-.0894 (.1030)	.0742 (.1063)	-.0268 (.0816)	.1489 (.1262)	-.3749 (.1413)	-.0991 (.0682)	.2418 (.1703)	-.0872 (.0659)	.1361 (.0332)
FISH	-.1838 (.1476)	.1604 (.0946)	.1002 (.2060)	.2818 (.1100)	-.0870 (.1004)	.0142 (.1615)	-.0847 (.1298)	-.1189 (.0853)	.1501 (.1353)	-.2258 (.1640)	.0680 (.0829)	-.1278 (.1897)	-.0717 (.0735)	.0024 (.0379)
C.FISH	.1559 (.1657)	.1975 (.1068)	-.0922 (.1859)	-.2548 (.1255)	.0738 (.1049)	-.0855 (.1314)	.0350 (.1706)	-.0764 (.0965)	.1341 (.1453)	.2885 (.2079)	-.1356 (.1039)	-.4308 (.2468)	.0374 (.0912)	.0860 (.0489)
EGGS	.0470 (.0354)	-.0242 (.0229)	-.0075 (.0274)	.0725 (.0234)	-.0052 (.0177)	-.0262 (.0191)	-.0167 (.0213)	-.1452 (.0225)	.0292 (.0251)	-.0418 (.0323)	.0201 (.0132)	-.1506 (.0374)	.0333 (.0154)	-.0016 (.0108)
CHEESE	-.2618 (.0939)	-.0468 (.0603)	.4756 (.1045)	-.0690 (.0704)	.0727 (.0619)	.0747 (.0680)	.0656 (.0722)	.0613 (.0563)	-.3319 (.1174)	.4531 (.1088)	-.0675 (.0479)	-.1000 (.1292)	.0080 (.0512)	-.0042 (.0303)
Staples:														
F.MILK	.0194 (.0270)	-.0242 (.0183)	-.0375 (.0287)	.0711 (.0202)	-.0396 (.0153)	-.0244 (.0182)	.0320 (.0228)	-.0193 (.0161)	.1026 (.0240)	-.2588 (.1205)	.0743 (.0411)	-.0565 (.0817)	.0387 (.0368)	-.0230 (.0168)
O.MILK	-.0117 (.1188)	-.1595 (.0725)	.1660 (.1819)	.1297 (.0835)	-.1018 (.0707)	.0729 (.0880)	-.1418 (.1090)	.0979 (.0632)	-.1395 (.1010)	.7125 (.3939)	-.8255 (.2642)	-.0679 (.2976)	.0001 (.1284)	.0349 (.0537)
FLOUR	-.0388 (.0362)	.0515 (.0230)	.0942 (.0339)	.0319 (.0245)	.0264 (.0180)	-.0134 (.0206)	-.0459 (.0264)	-.0726 (.0182)	-.0191 (.0278)	-.0567 (.0798)	-.0072 (.0302)	-.1092 (.1026)	.0503 (.0382)	-.0019 (.0168)
RICE	.5207 (.1083)	.0357 (.0699)	-.3100 (.0882)	-.3306 (.0704)	-.0626 (.0482)	-.0528 (.0551)	.0283 (.0675)	.1149 (.0520)	.0153 (.0762)	.2638 (.2509)	.0003 (.0910)	.3512 (.2668)	-.1467 (.1438)	.0187 (.0569)
POTATO	.1020 (.1378)	-.0813 (.0815)	-.0065 (.0539)	.0959 (.0651)	.1214 (.0296)	.0021 (.0345)	.0772 (.0440)	-.0081 (.0443)	-.0062 (.0548)	-.1946 (.1389)	.0293 (.0460)	-.0207 (.1420)	.0216 (.0689)	-.3688 (.0689)

Note: The figures in parentheses are the standard errors. The abbreviated notations are BEEF.V (beef and veal), O.MEAT (other meats), CHICKN (chicken), C.FISH (canned and cured fish), F.MILK (fluid milk), and O.MILK (evaporated and dry milk).

f only a few available observations could be misleading. ecause the dependent variable is stochastic, we might rroneously conclude that forecasting performance is poor if ne or more of a very few observations is far away from the nean value, even though the model accurately predicts the nean value over a large sample. On the other hand, the ex ost simulation conducted here gives the average neasurements of forecasting efficiency in relation to the bserved values over the sample period. Thus, at this stage, he approach used represents the best means of evaluating orecasting performance of the estimated demand system.

For initial verification of the demand system here, the actual relative changes of prices and expenditures are used in the demand system to generate the forecast of relative change in consumption for a given year. The procedure is then repeated to cover the whole sample period, and a series of projected relative quantity changes are obtained. To transform the relative quantity changes into levels, the actual quantity of the preceding year is used as a basis for the calculation. The error between actual and simulated values gives information about the accuracy of the forecast for that year. One can also derive the projected quantity levels on the basis of the projected quantity of the preceding year as a stringent test of model performance in the dynamic fashion. However, the forecasting results thus obtained would be sensitive to a particular initial year chosen, and the forecasting errors are cumulative over years. This approach is not used here.

I used three measurements of average forecasting performance over the sample period. One, labeled 'RMS-A', measures the ratio of root-mean-square error to the sample mean of a projected variable for a period of T years, measured in percentage terms:

$$\text{RMS-A} = [(1/T) \sum_{t=1}^{T} (y_t - \overset{*}{y}_t)^2]^{1/2}/\bar{y} \times 100,$$

where y_t, $\overset{*}{y}_t$, and $\bar{y}$ are, respectively, the actual, simulated, and sample mean of per capita consumption.

Another measurement, labeled 'RMS-B', is a common use of mean-square percentage error calculated as follows:

$$\text{RMS-B} = [\sum_{t=1}^{T} (y_t - \overset{*}{y}_t)^2 / \sum_{t=1}^{T} y_t^2]^{1/2} \times 100.$$

Both the RMS-A and the RMS-B provide similar statistics on the basis of root-mean-square error for evaluating the accuracy of forecasts over the entire sample period.

As another measure, we may evaluate how well the model simulates turning points in the historical data. A simple way is to compare the sign of the actual relative change in quantity demanded to the corresponding simulated relative change. The turning point errors reflect the number of signs in the projected quantity changes not consistent with the actual quantity changes.

Table 11 summarizes the three measures of forecasting performance in the last three columns of the table. For convenience, I have also listed the estimated direct-price and expenditure elasticities. The average errors over 30 sample observations, measured in terms of RMS-A, range between 0.96 percent and 7.63 percent. Furthermore, for 30 of the 41 commodities, the error is less than 5 percent. The RMS-B measure gives quite similar results. The average error ranges between 0.94 percent and 7.52 percent. Again, 30 of the 41 commodities have an average error of less than 5 percent. Graphic presentation of the actual and simulated results often provide a better intuitive feel of forecasting performance and help to ascertain the consistency of the error measurements in table 11. The graphic results are presented in appendix C. The last column of table 11 shows the turning point errors. The number of sign errors is less than or equal to one-half of a total 30 sample observations for all commodities. The number of turning point errors is between 1 and 5 for 14 commodities; between 6 and 10 for 17 commodities; and between 10 and 15 for 10 commodities.

The results of the ex post simulation provide evidence that the estimated demand parameters adequately reflect consumers' responses to changes in prices and income over the sample period. The RMS-A percentage errors are relatively small for a number of individual food items that have expenditure weights of more than 0.5 percent of the consumer budget. The errors for these items are beef and veal, 2.43; pork, 2.88; chicken, 2.93; eggs, 1.87; fluid milk, 1.64; wheat flour, 1.78; sugar, 2.47; sweeteners, 3.79; and frozen dairy products, 1.33. One can reasonably conclude that the conformity of the estimated complete disaggregated demand system with the sample observations appears quite good.

The estimated demand system can be used for a wide range of applications to evaluate the effects of retail price changes on quantities of food purchased. All these applications depend on the purpose and issue that one needs to address. Because the primary purpose of this report is to provide information about the structure of demand for food in the United States and to provide an instrument for general use in outlook and policy analysis, there is no intent here to focus on any particular forecast or any specific policy analysis.

Table 11—Summary of major elasticities and model performance[1]

Commodity	Direct price elasticity	Expenditure elasticity	RMS-A error[2]	RMS-B error[2]	TP error[3]
			Percent		
(1) Beef and veal	-0.6166 (0.0483)	0.4549 (0.0585)	2.43	2.41	9
(2) Pork	-.7297 (.0327)	.4427 (.0624)	2.88	2.88	2
(3) Other meats	-1.3712 (.2045)	-.0607 (.1123)	4.50	4.46	13
(4) Chicken	-.5308 (.0608)	.3645 (.0863)	2.93	2.84	2
(5) Turkey	-.6797 (.1332)	.3196 (.1691)	4.24	4.15	2
(6) Fresh and frozen fish	.0142 (.1615)	.1155 (.1783)	3.31	3.28	5
(7) Canned and cured fish	.0350 (.1706)	.0005 (.2049)	3.95	3.95	4
(8) Eggs	-.1452 (.0225)	-.0283 (.0445)	1.87	1.86	11
(9) Cheese	-.3319 (.1174)	.5927 (.1197)	4.93	4.68	9
(10) Fluid milk	-.2588 (.1205)	-.2209 (.0686)	1.64	1.63	15
(11) Evaporated and dry milk	-.8255 (.2642)	-.2664 (.2230)	2.56	2.47	7
(12) Wheat flour	-.1092 (.1026)	-.1333 (.0701)	1.78	1.78	15
(13) Rice	-.1467 (.1438)	-.3664 (.2301)	5.02	5.00	12
(14) Potatoes	-.3688 (.0689)	.1586 (.2225)	5.84	5.70	7
(15) Butter	-.1670 (.1748)	.0227 (.1915)	3.18	3.08	6
(16) Margarine	-.2674 (.1379)	.1112 (.1073)	1.64	1.64	4
(17) Other fats and oils	-.2191 (.0496)	.3691 (.0531)	2.27	2.25	8
(18) Apples	-.2015 (.1469)	-.3514 (.2126)	6.04	6.00	9
(19) Oranges	-.9996 (.1465)	.4866 (.2587)	7.63	7.52	6
(20) Bananas	-.4002 (.1334)	-.0429 (.1899)	4.05	4.03	4
(21) Grapes	-1.3780 (.1829)	.4407 (.3263)	6.34	6.18	7
(22) Grapefruits	-.2191 (.1067)	.4588 (.2636)	7.24	7.17	7
(23) Other fresh fruits	-.2357 (.5471)	-.3401 (.2360)	5.38	5.36	7
(24) Lettuce	-.1371 (.0656)	.2344 (.1154)	3.34	3.32	9
(25) Tomatoes	-.5584 (.0624)	.4619 (.0904)	2.59	2.59	4
(26) Celery	-.2516 (.0636)	.1632 (.1501)	2.36	2.36	2
(27) Onions	-.1964 (.0693)	.1603 (.2045)	6.01	5.98	7
(28) Carrots	-.0388 (.1816)	-.1529 (.3365)	6.37	6.34	5
(29) Cabbage	-.0385 (.0405)	-.3767 (.1577)	3.69	3.68	3
(30) Other fresh vegetables	-.2102 (.1436)	.2837 (.1526)	3.46	3.46	11
(31) Fruit juice	-.5612 (.1006)	1.1254 (.2505)	6.82	6.47	6
(32) Canned tomatoes	-.3811 (.1072)	.7878 (.1454)	4.63	4.56	5
(33) Canned peas	-.6926 (.1746)	.3295 (.1616)	4.56	4.51	3
(34) Canned fruit cocktail	-.7323 (.3677)	.7354 (.2788)	6.96	6.91	6
(35) Dried beans, peas, and nuts	-.1248 (.0313)	.5852 (.1167)	4.59	4.58	13
(36) Other processed fruits and vegetables	-.2089 (.0921)	.6311 (.0675)	2.58	2.56	8
(37) Sugar	-.0521 (.0172)	-.1789 (.0627)	2.47	2.46	11
(38) Sweeteners	-.0045 (.0895)	-.0928 (.1241)	3.79	3.78	10
(39) Coffee and tea	-.1868 (.0294)	.0937 (.1027)	3.36	3.34	13
(40) Ice cream and other frozen dairy products	-.1212 (.0848)	.0111 (.0580)	1.33	1.33	11
(41) Nonfood	-.9875 (.0125)	1.1873 (.0043)	.96	.94	2

[1] The figures in parentheses are the standard errors of estimated elasticities.

[2] Forecasting errors are measured in two forms:

$$\text{RMS-A} = [\sum_{t=1}^{T} (y_t - \overset{*}{y}_t)^2/T]^{1/2}/\bar{y} \times 100, \text{ and RMS-B} = [\sum_{t=1}^{T} (y_t - \overset{*}{y}_t)^2 / \sum_{t=1}^{T} y_t^2]^{1/2} \times 100,$$

in which y_t, $\overset{*}{y}_t$ and $\bar{y}$ are respectively actual, predicted, and sample mean of the index of per capita consumption.

[3] TP error is the number of signs in the projected changes not consistent with the actual changes of a total 30 observations.

Conclusion

This study develops and implements a unique approach for estimating a large-scale, complete demand system from a limited sample of time series observations. The procedures are firmly linked to the classical theory of consumer demand by directly incorporating its principal properties of homogeneity, symmetry, and Engel aggregation into the estimation without relying on restrictive separability assumptions. I implemented a constrained maximum likelihood method. The method provides estimators of the demand parameters that are asymptotically efficient and consistent with corresponding estimators of the respective standard errors that can be used to evaluate the precision of the estimates. Moreover, the elasticity estimates are not affected by the ordering of the commodities in the demand matrix. The estimation procedures, which circumvent the problem of insufficient degrees of freedom and alleviate the problem of multicollinearity, can be applied to all large-scale complete demand systems that contain commodity definitions and specifications tailored to specific end uses.

The developed procedures have been successfully applied to the estimation of a U.S. food demand system consisting of 40 foods and 1 nonfood component. The demand parameters, including 1,722 price and expenditure elasticities, are directly estimated from annual data covering the period 1953-83. Partial assessment of the results, in terms of coefficient signs, magnitudes, and standard errors, indicates that the demand estimates explain well the price and expenditure effects. Obviously, the demand system provides a useful source for specific elasticities of price and expenditure for a particular commodity of interest. In addition, the cross-price elasticities provide a direct means of assessing the nature and magnitude of economic interdependence among commodities.

Validation of the estimated demand system was examined by means of simulation over the sample period. A preliminary evaluation of forecasting performance based on root-mean-square error and turning points indicates that there is a fairly close correspondence between simulated value and sample observation. Consequently, in addition to assessing the price and expenditure effects, the demand system can be used as a shortrun forecasting device for food consumption, given prices and expenditure, as demonstrated. Another potential way of using the demand system is to combine it with a compatible supply component model for longer term forecasts and projections. The demand system can also be used for policy analysis on the program effects of price changes on quantities of food purchased. In this regard, we may assume various scenarios of program effect changes.

To implement the estimated demand system, one must recognize the inherent characteristics of the estimates. First, for making the estimation of the demand system manageable, the model is estimated using a functional form which assumes constant elasticities. This permits ease of interpretation and eliminates confusion generated by different "units of measurement" across commodities. The model specification is a tradeoff, however, between empirical interest and theoretical rigidity because the assumption of constant elasticity is well-known to be theoretically restrictive. Second, by following the classical demand system framework, the estimated demand system is specified from the point of view of consumers' behavior but without explicitly recognizing the supply conditions prevailing during the sample period. That is, I assumed prices to be independent or exogenous variables and not influenced by consumption levels. Third, the estimation results are conditional on the available time-series data. The correspondence between the observed price and quantity variables is not always as close as assumed by conceptual demand theory.

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Appendix A

Review of the Brandow and the George and King Procedures

The purpose of this review is to provide a better understanding about the evolution of methodology issues regarding the estimation of complete disaggregated demand systems. In fact, the noteworthy work of Brandow (*1*) and George and King (*9*) provided my motivation to develop an alternative approach to improve their procedures.

For easy illustration of their procedures, a demand elasticity matrix for the case of (n-1) food commodities and one nonfood commodity can be represented as the following:

$$\begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \\ \cdot \\ \cdot \\ \dot{q}_n \end{bmatrix} = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1n} & f_1 \\ e_{21} & e_{22} & \cdots & e_{2n} & f_2 \\ \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdots & \cdot & \cdot \\ e_{n1} & e_{n2} & \cdots & e_{nn} & f_n \end{bmatrix} \begin{bmatrix} \dot{p}_1 \\ \dot{p}_2 \\ \cdot \\ \dot{p}_n \\ \dot{m} \end{bmatrix}$$

where variables are relative changes of quantities (q_i's), prices p_i's and expenditure ($\dot{m}$) parameters are e_{ij}'s (the demand elasticity of the ith commodity with respect to the price change of the jth commodity), and f_i's (income elasticity of the ith commodity).

The Brandow Procedures

Brandow constructed a demand system for 24 foods and 1 nonfood commodity. The basic data used are prior estimates of direct-price elasticities (e_{ii}), income elasticities (f_i), and expenditure shares (w_i) for (n-1) food commodities. The sequential calculation procedures are as follows:

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

$$f_n = (1 - \sum_{i=1}^{n-1} w_i f_i)/w_n.$$

(2) Cross-price elasticities for individual food commodities with respect to nonfood price were calculated using the block additivity assumption, in which each of the cross-price elasticities is proportional to its income elasticity: $e_{in} = r\, f_i$, where the proportional factor r is assumed to be 0.33.

On the other hand, according to an equation by Frisch (*8*) based on the block additivity assumption, the cross-price elasticity can be linked with expenditure share of nonfood (w_n), income elasticities (f_i's), and a money flexibility measure θ as follows:

$$e_{in} = -\, f_i\, w_n\, (1 + f_n/\theta), \qquad \text{for } i=1,2,..,(n-1).$$

The equality of two cross-price elasticities gives the proportional factor $r = -\, w_n\, (1+f_n/\theta)$. Thus, for the given values of w_n, f_n, and r selected by Brandow (*1*), he obtained the implied money flexibility estimate −0.86.

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

$$e_{nj} = (w_j/w_n)\, e_{jn} + (f_j - f_i)\, w_j, \text{for } j=1,2,..,(n-1).$$

(4) Cross-price elasticities for individual commodities 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:

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

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

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

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

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

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

$$e_{1j} = (w_j/w_1)\, e_{j1} + (f_j - f_1)\, w_j, i=2,3,..,(n-1).$$

(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 completed the demand elasticity matrix by repeating the column-row steps.

Remarks on the Brandow Procedures

(1) The demand elasticity matrix generated by the synthetic approach may not closely reflect actual data, since most of the demand elasticities are not estimated directly from sample observations. Thus, it 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 estimates.

(2) The prior information on direct price elasticities and income elasticities for individual food commodities 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.

(3) The cross-price elasticities for individual food commodities in relation to the nonfood commodity are derived under an assumption of block additivity (or want independence) between each individual food and nonfood, and a fixed proportion (33 percent) of the corresponding income elasticity. These assumptions are quite arbitrary.

(4) To obtain the column vector of cross-price elasticities in step (4.b) of the Brandow procedure, he assumed each individual 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 constructed a demand matrix for 49 food commodities and 1 nonfood commodity. All food commodities were grouped into 16 major categories. The income elasticities for foods were obtained from cross-section household survey data. Some of the direct, cross-price elasticities within each commodity 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 Brandow procedure and used the money flexibility estimate of –0.86. However, George and King deviated from the Brandow procedures in step 4 for obtaining the cross-price elasticities of individual food commodities in a commodity group with respect to individual food commodity prices outside the group. For a grouping of G categories, they proposed to obtain the demand elasticities inside a commodity category, say I, as follows:

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

$$R_i = -(e_{in} + f_i + \sum_{J=1}^{I} \sum_{j\varepsilon J} e_{ij}), \qquad \text{for } i\ \varepsilon\ I.$$

(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 equation and assuming $\theta = -0.86$ as follows:

$$k_{ij} = -f_i\, w_j\, (1 + f_j/\theta), \text{for } j\ \varepsilon\ J,\ J\ \varepsilon\ (I+1, G).$$

Then the cross-price elasticities were obtained as

$$e_{ij} = R_i\, (k_{ij} / \sum_{J=I+1}^{G} \sum_{j\varepsilon J} k_{ij}), \text{for } j\ \varepsilon\ J,\ J\ \varepsilon\ (I+1, G).$$

(3) Given a column block of cross-price elasticities, they calculated the corresponding row block by the symmetry relation. Repetition of the column block-row block steps were used to complete the demand elasticity matrix.

Remarks on the George and King Procedures

(1) The George and King procedures are quite parallel to those used by Brandow. Thus, the general drawbacks of the synthetic approach also apply to George and King's study.

(2) Some of the demand elasticities in each food commodity 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.

(3) The cross-price elasticities of individual foods with respect to the price change of nonfood are derived from the Frisch equation by making use of a money flexibility estimate of −0.86 obtained from Brandow. In addition to the rigid assumption of block additivity used, 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 commodity with respect to the price of nonfood is 33 percent of the corresponding income elasticity of that food.

(4) The procedures to generate the cross-price elasticities outside a commodity group are quite subjective. The weights are derived from the Frisch equation, in which the implicit assumption of want independence among food commodities 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, one finds the sum of the unknown cross-price elasticities R_i are all positive, while the weights k_{ij}'s are uniformly negative.[1] 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 commodities in the demand matrix.

Appendix B: Data Sources

The basic data required for estimating the complete disaggregated demand system are per capita quantity and price of each commodity, and per capita consumption expenditure. The expenditure weight of each commodity at the base year is also needed for constructing aggregate price and quantity indexes and introducing parametric constraints in the estimation.

I obtained the consumer price indices for food items and nonfood from the U.S. Department of Labor (*20*). I obtained data for personal consumption expenditures, published by the Department of Commerce (*19*). Per capita consumption expenditure is total consumption expenditure divided by the civilian population of 50 States on July 1 of each year. I compiled data for food consumption and expenditure weights from the U.S. Department of Agriculture (*17*). The value aggregates of food items for 1967-69 are compiled from table 3 of the 1979 issue of (*17*); these value aggregates are the only data available for use in this study. The expenditure weights between food and nonfood categories for the period are calculated from (*19*). Given the expenditure weight for food, this weight is proportionally allocated to each individual food item in accordance with its value in the 1967-69 period. I calculated the quantity index for the nonfood sector from the current value of the nonfood per capita expenditure obtained from (*19*) and divided it by the consumer price index of all items less food.

Some retail prices for grapes, grapefruits, celery, onions, carrots, cabbage, canned tomatoes, and dried beans were not reported in 1979. To construct continuous price series for these fruits and vegetables, I estimated a set of price linkage equations between retail and farm prices for 1959-78. The farm prices are obtained from the U.S. Department of Agriculture (*16*). On the basis of these linkage equations, the 1979 retail prices for those commodities are then derivable by plugging in the farm prices of that year in the equations.

Appendix table 1—Retail and farm price linkage for some fruits and vegetables

Commodity	Estimated coefficients		R^2	D.W.
	α	β		
Grapes	23.92	0.7549	0.90	1.31
	(9.11)	(.0597)		
Grapefruits	32.82	.5894	.65	.82
	(16.15)	(.1054)		
Celery	-6.34	1.1312	.94	1.55
	(8.21)	(.0714)		
Onions	26.58	.7721	.75	1.78
	(13.48)	(.1072)		
Carrots	3.75	1.0882	.94	1.99
	(7.25)	(.0664)		
Cabbage	18.95	.8498	.73	1.47
	(15.57)	(.1266)		
Canned tomatoes	10.19	1.1044	.86	1.00
	(10.38)	(.1067)		
Dried beans	42.33	.6588	.56	2.49
	(24.97)	(.1410)		

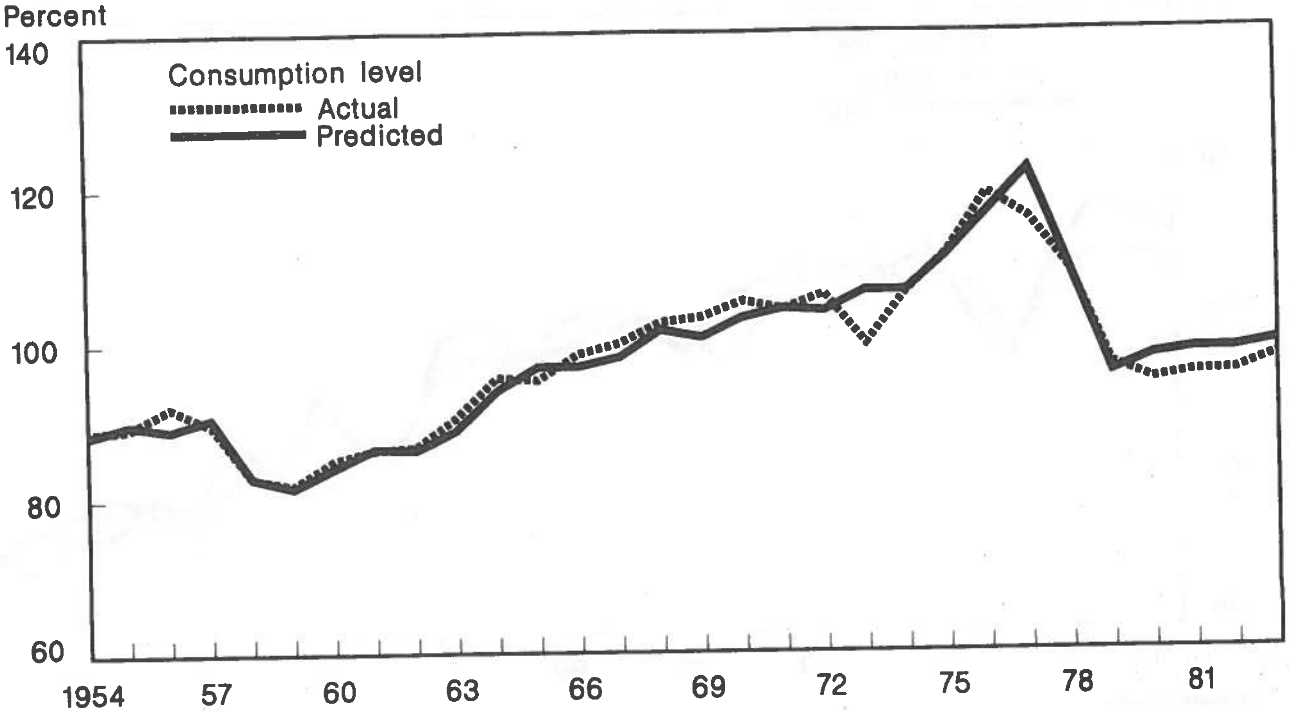
Note: The equation of retail and farm price linkage is defined as $P_r = \alpha + \beta P_f$, where P_r and P_f are retail and farm price indices (1967=100), respectively. Figures in parentheses are estimated standard errors.

[1]The values of R_i are 0.020032 (beef), 0.110177 (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 commodity is positive, and the income elasticities for commodities outside the meat commodity group are less than the money flexibility (−0.86) in absolute value.

Appendix C: Graphic Comparison of Actual and Predicted Consumption

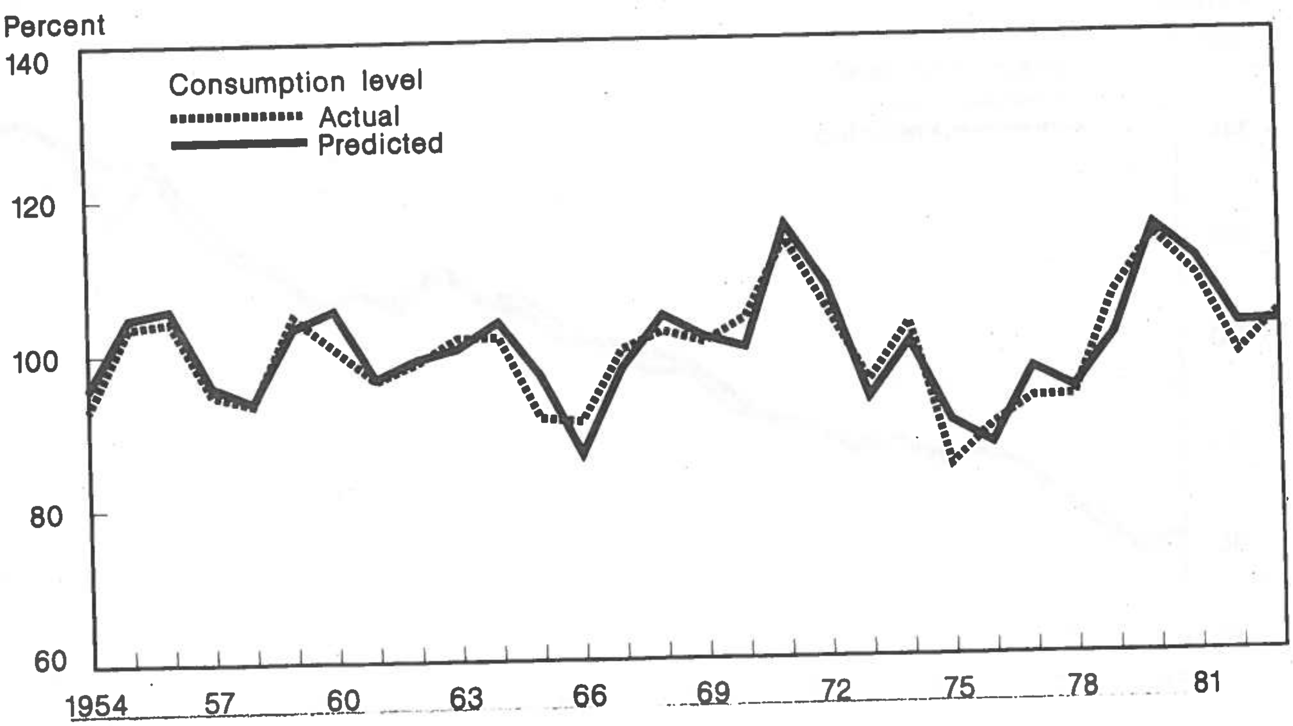
Appendix Figure 1

Beef and Veal



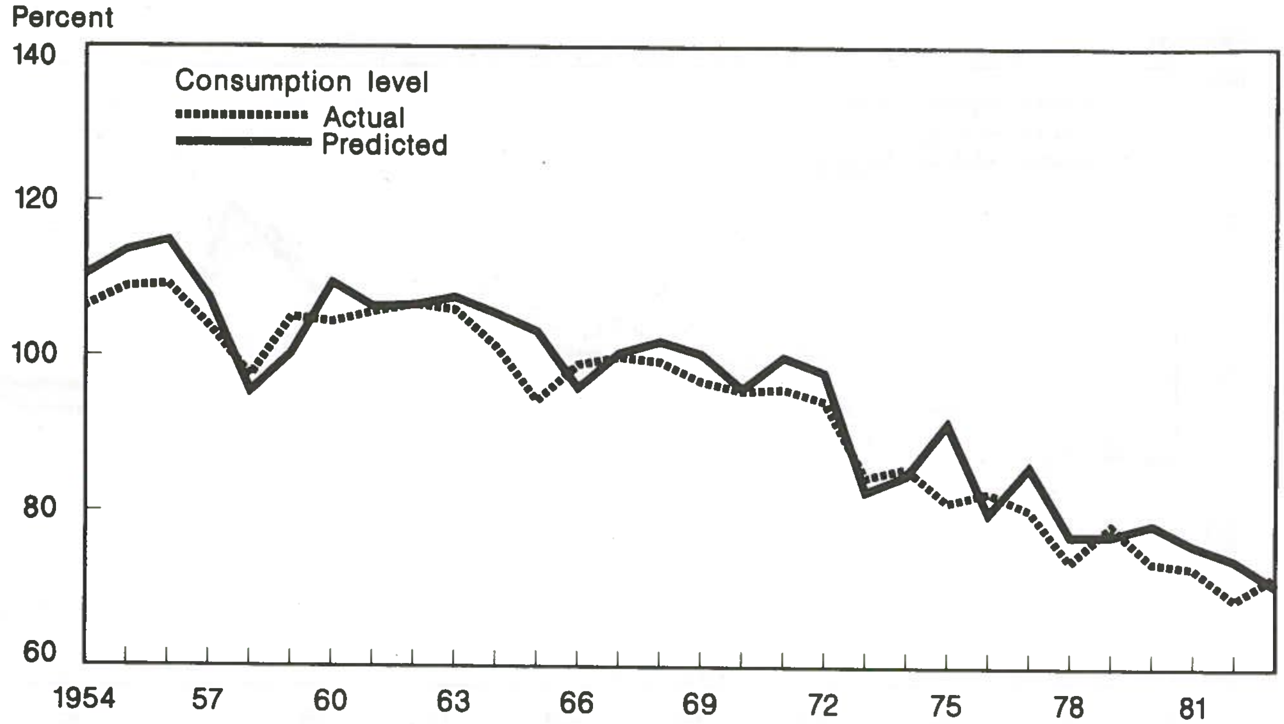
Appendix Figure 2

Pork



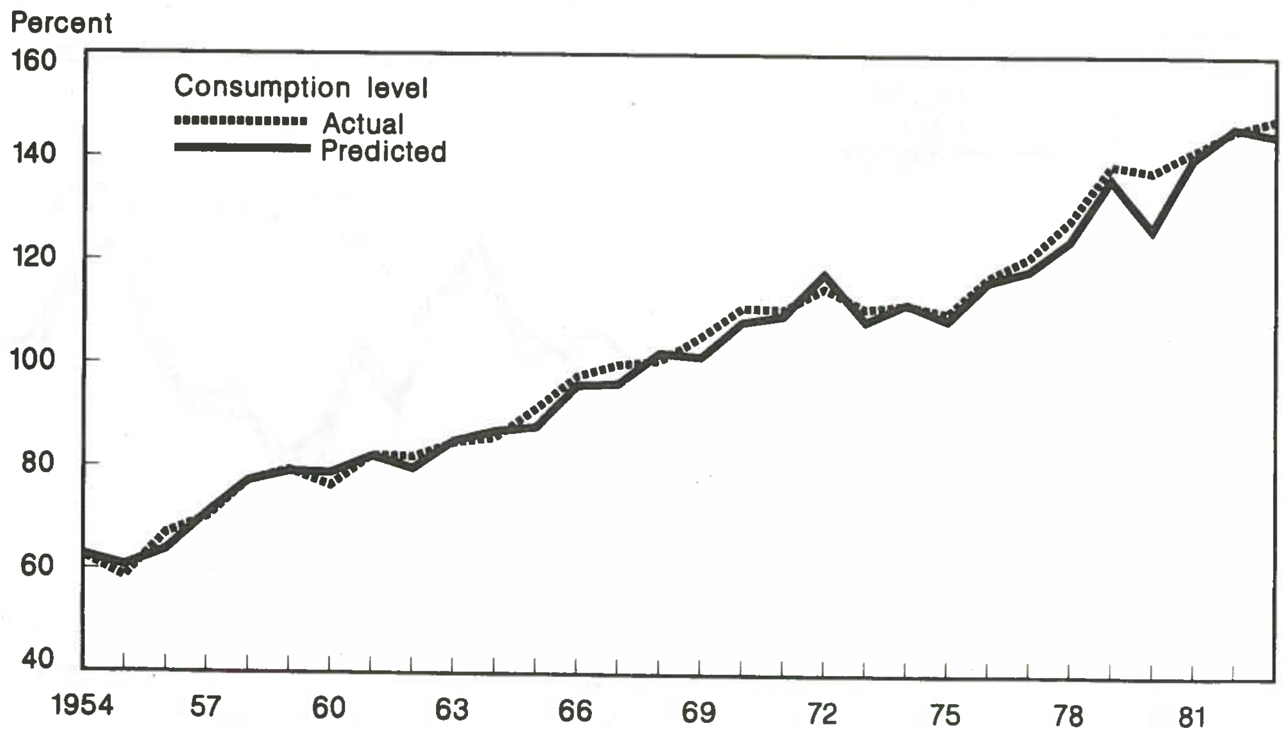
Appendix Figure 3

Other Meat



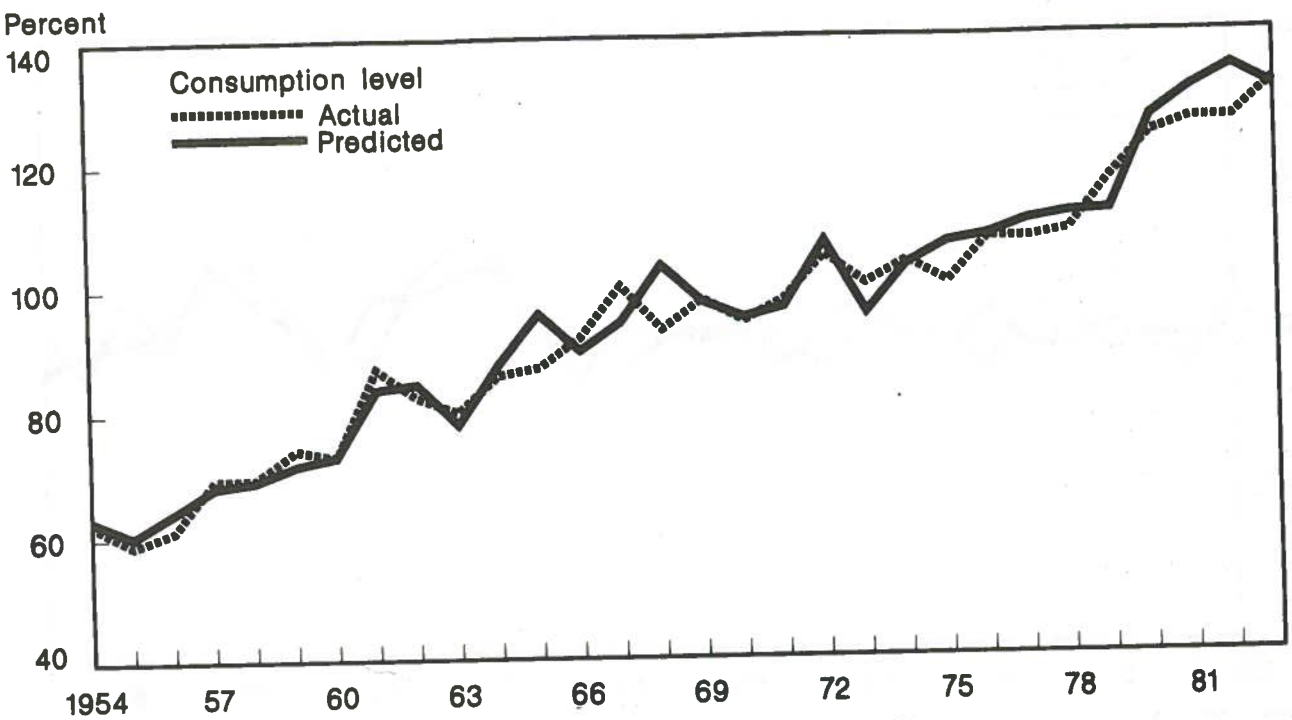
Appendix Figure 4

Chicken



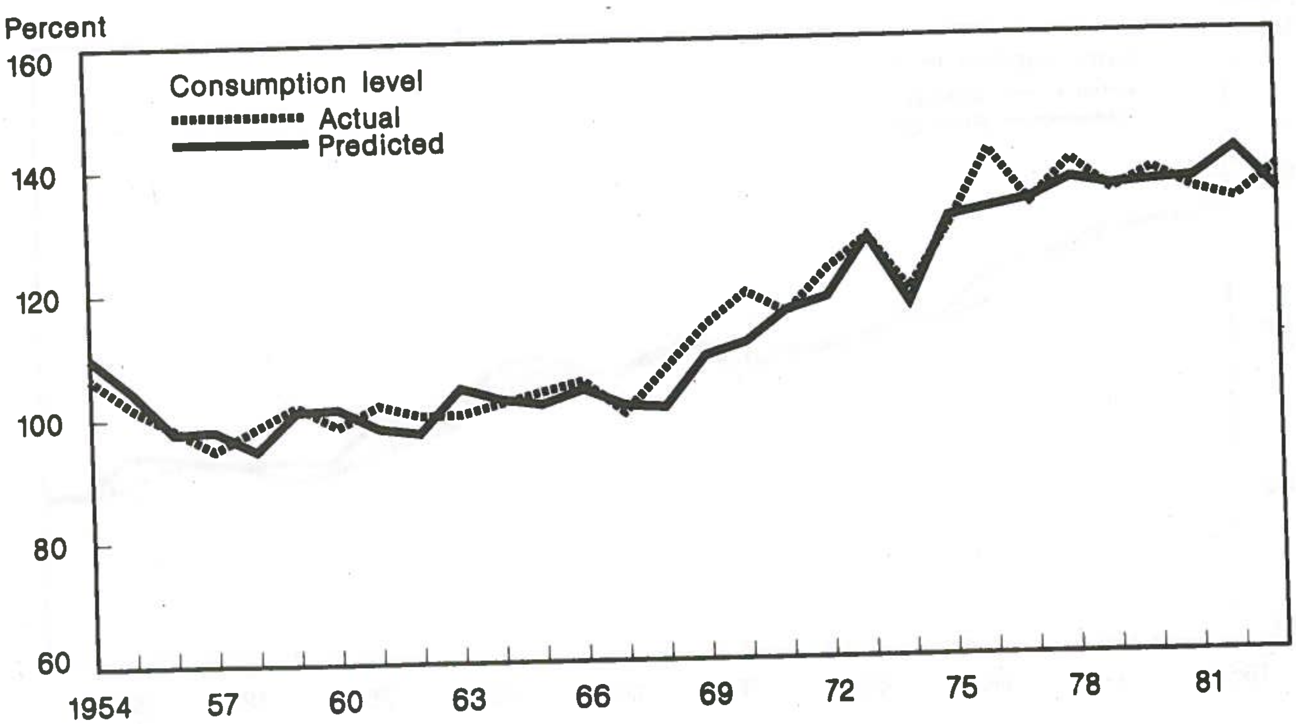
Appendix Figure 5

Turkey



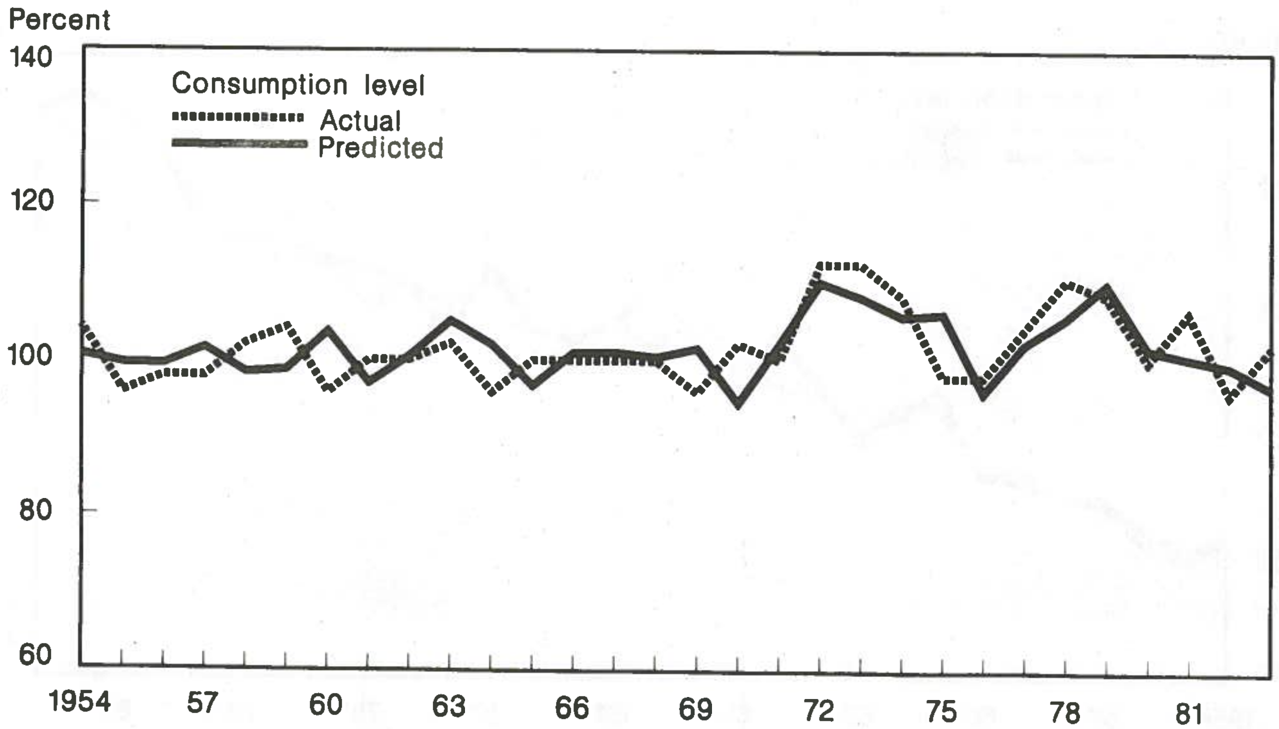
Appendix Figure 6

Fresh and Frozen Fish



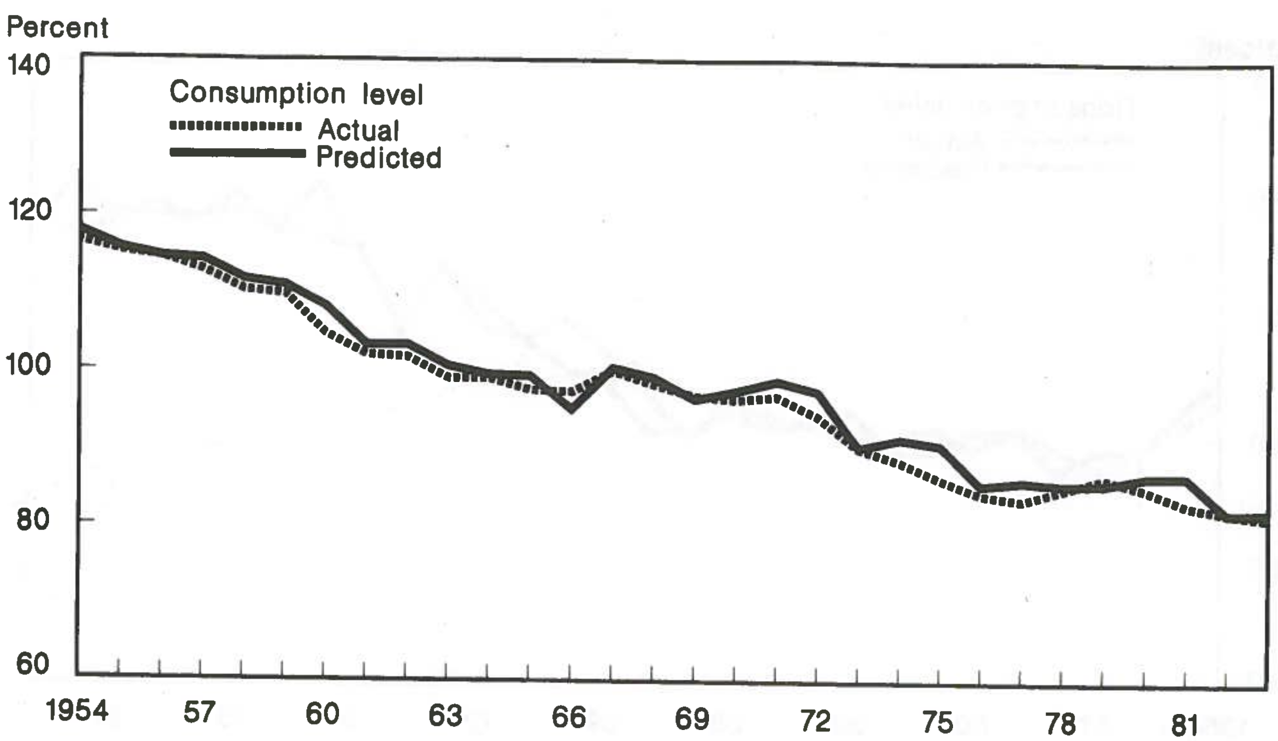
Appendix Figure 7

Canned and Cured Fish



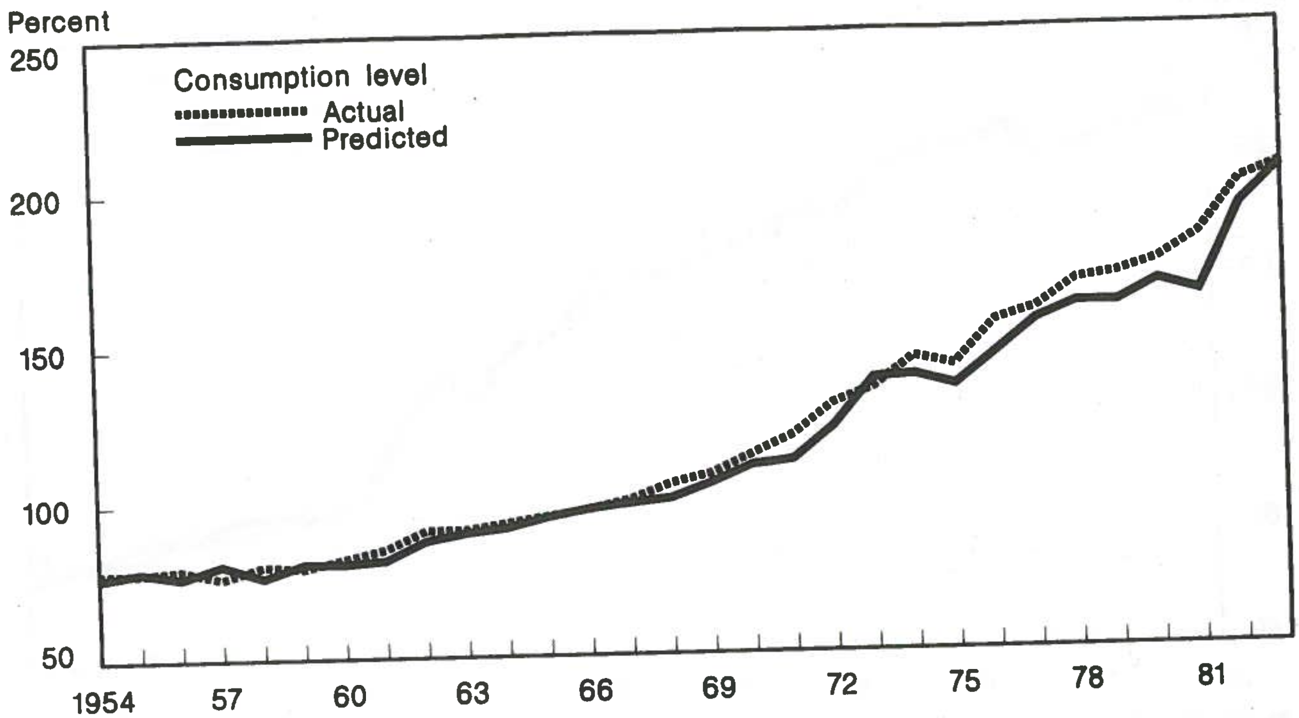
Appendix Figure 8

Eggs



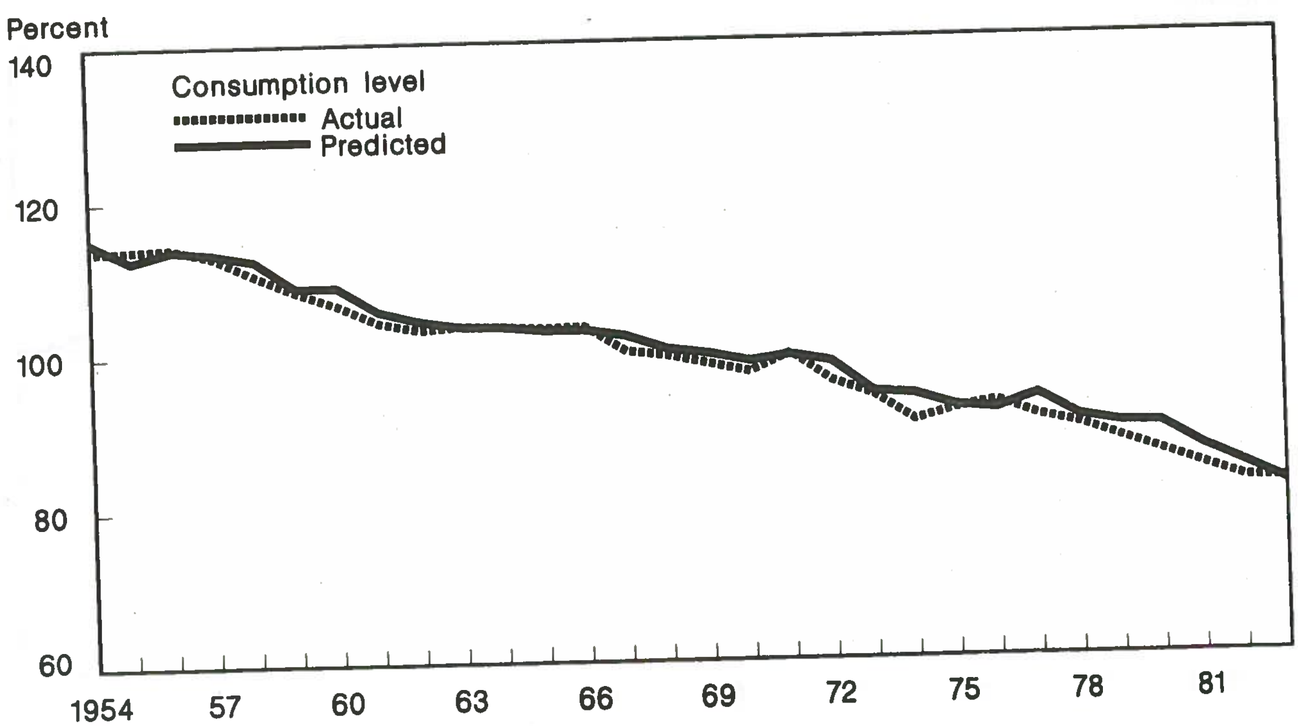
Appendix Figure 9

Cheese



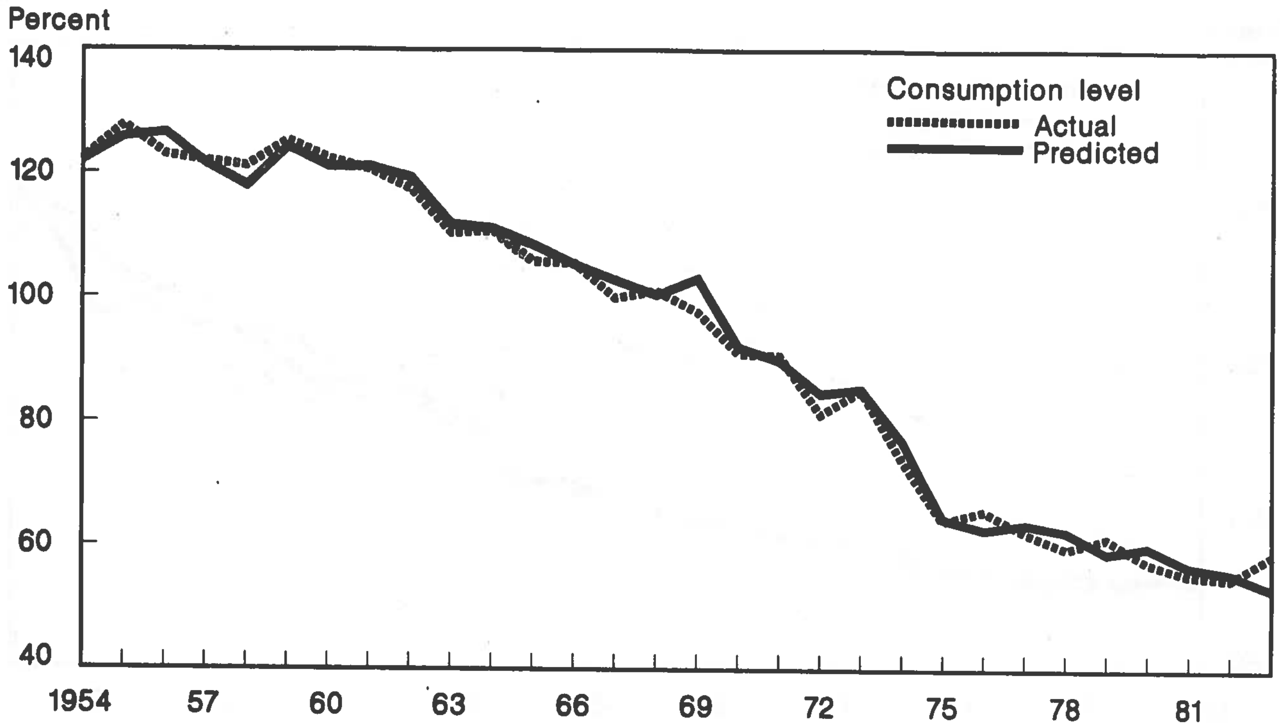
Appendix Figure 10

Fluid Milk



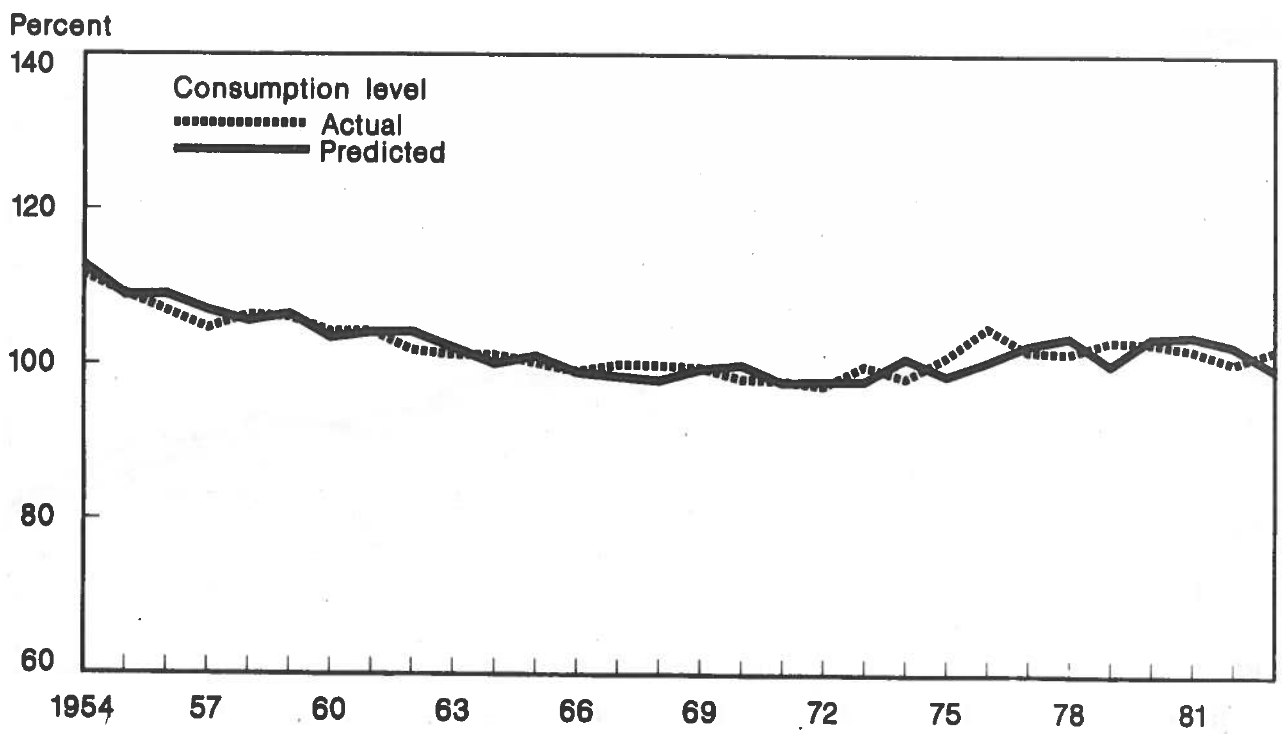
Appendix Figure 11

Evaporated and Dry Milk

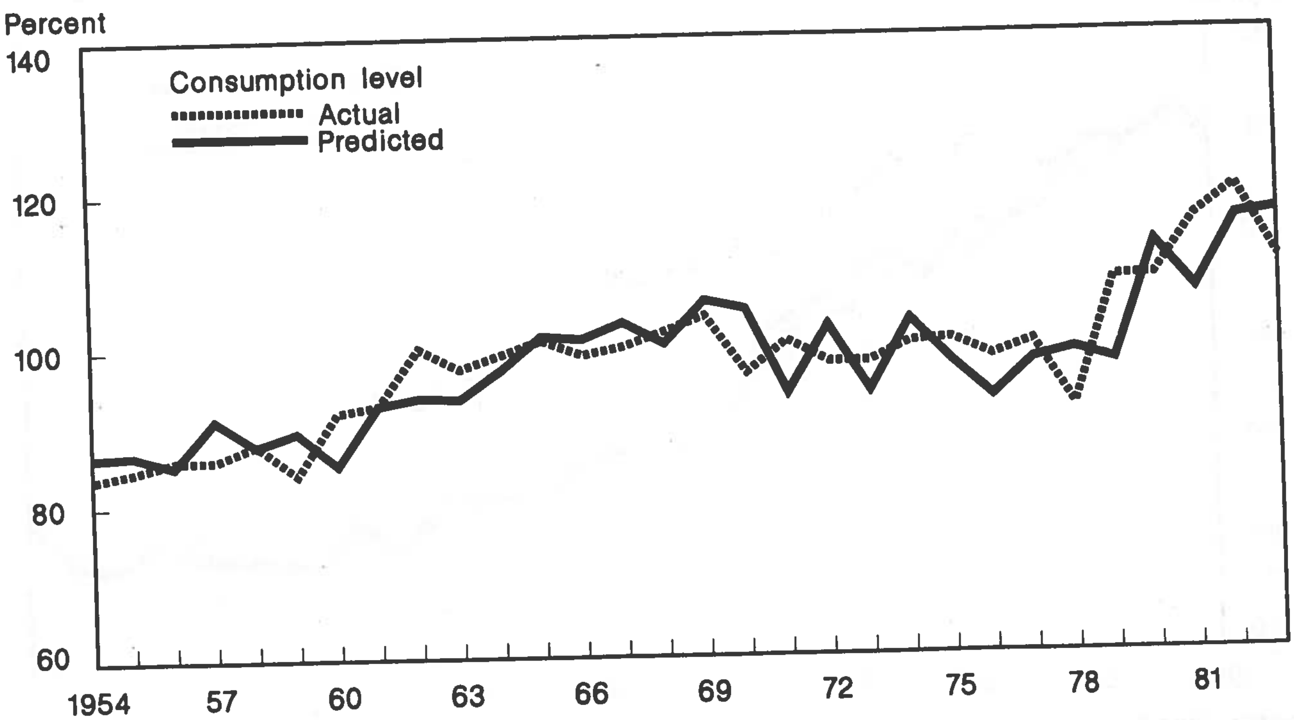


Appendix Figure 12

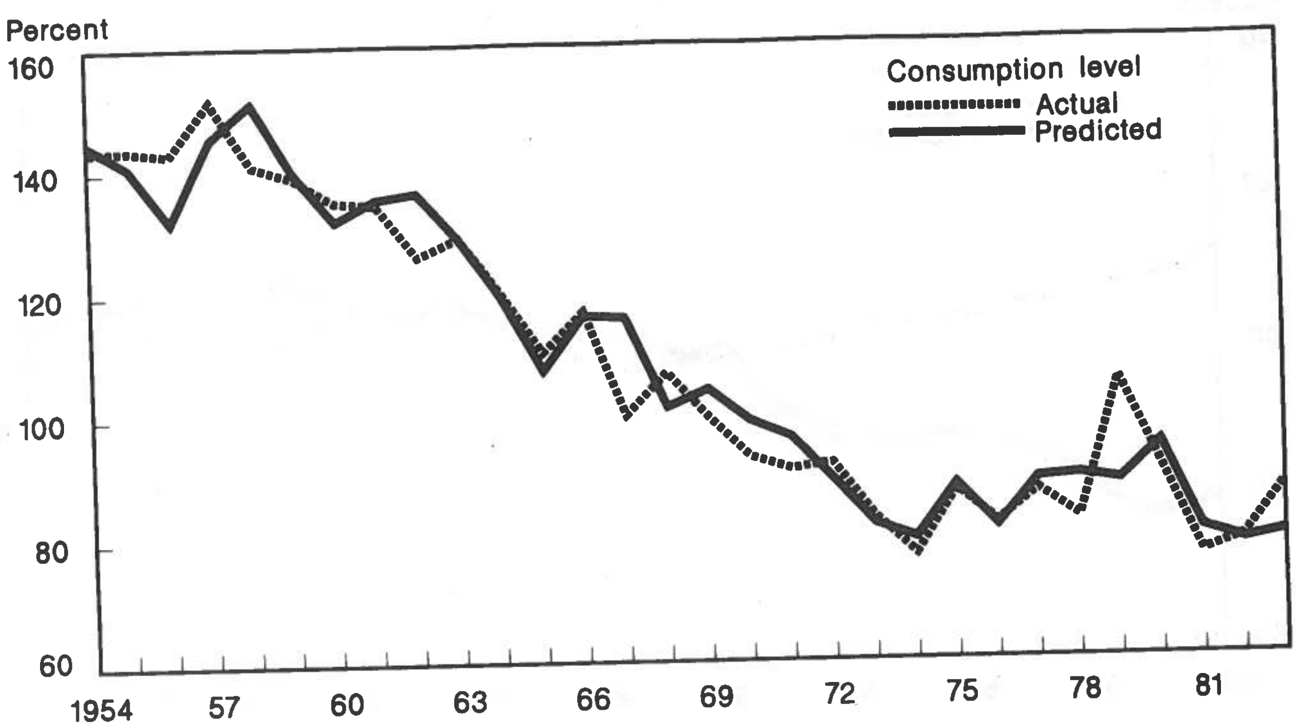
Wheat Flour



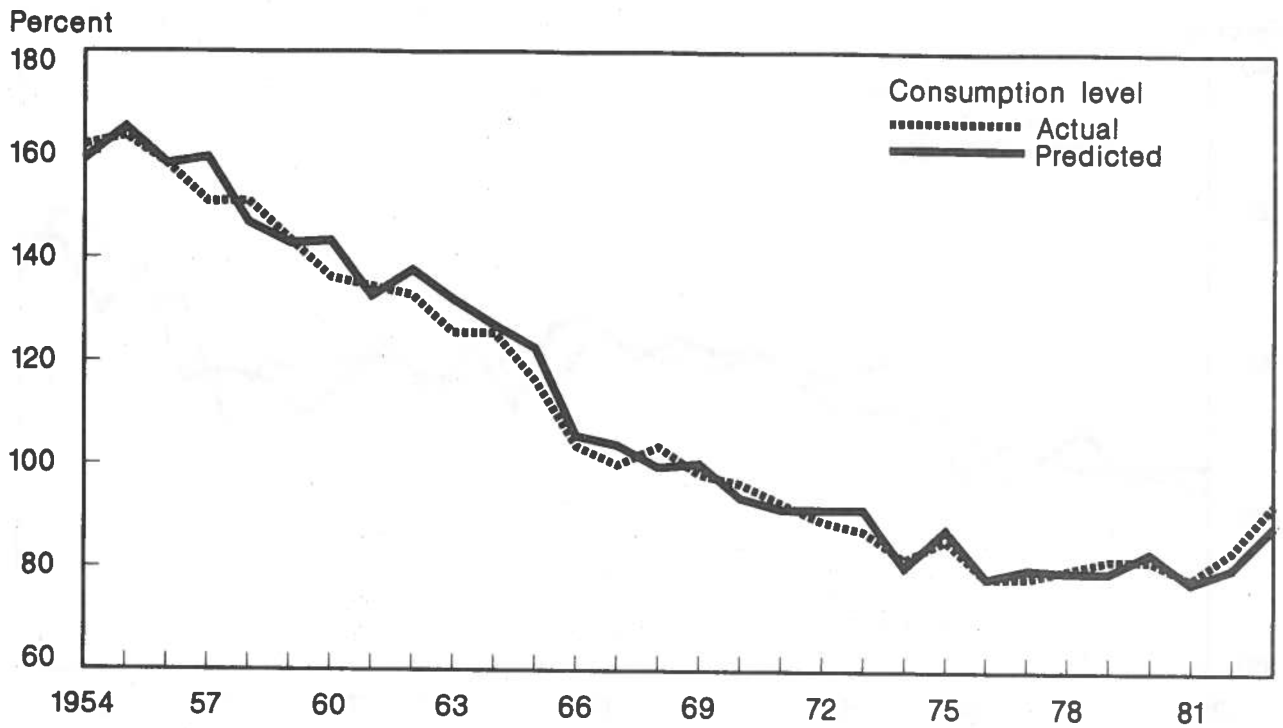
Appendix Figure 13
Rice



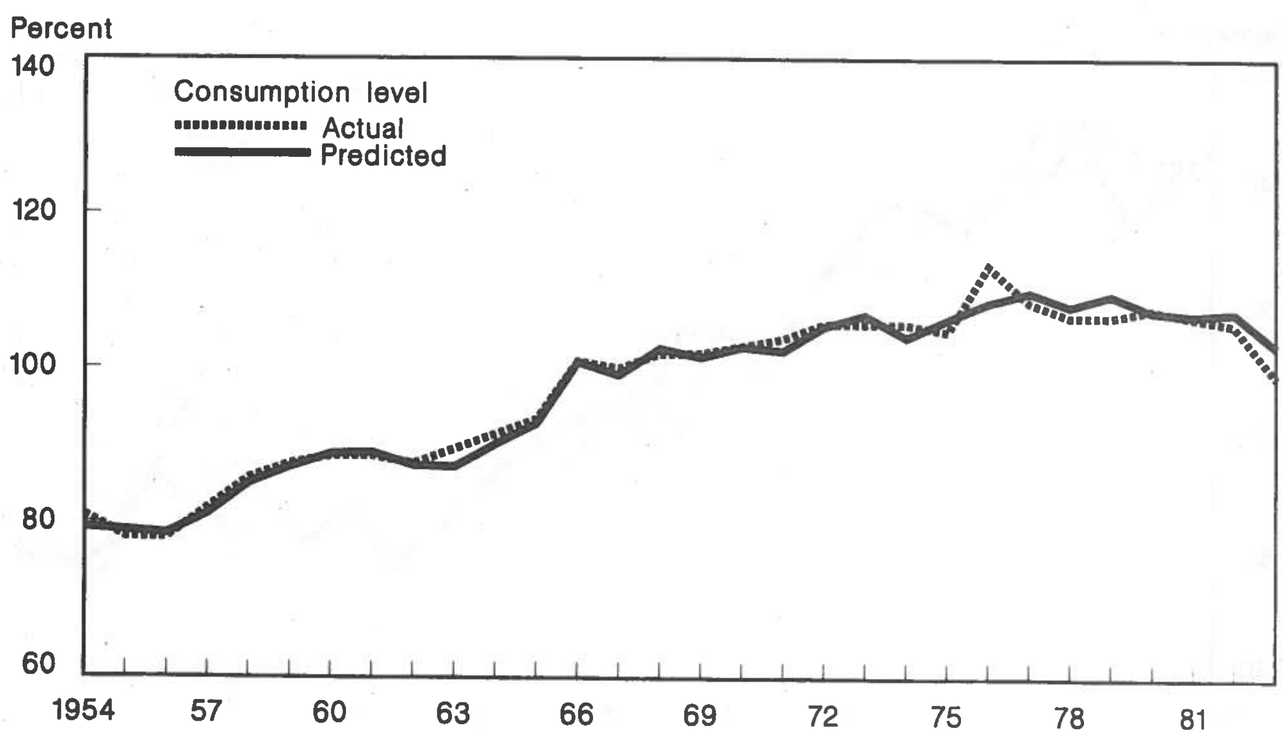
Appendix Figure 14
Potatoes



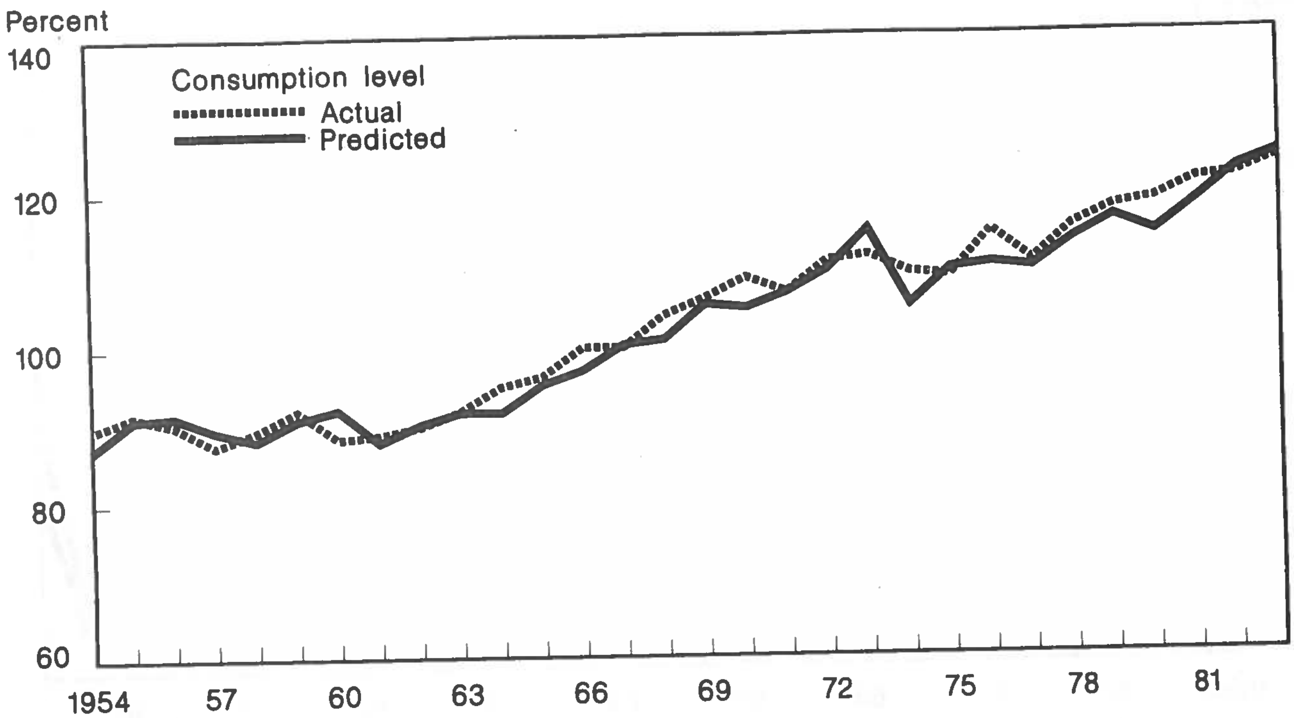
Appendix Figure 15
Butter



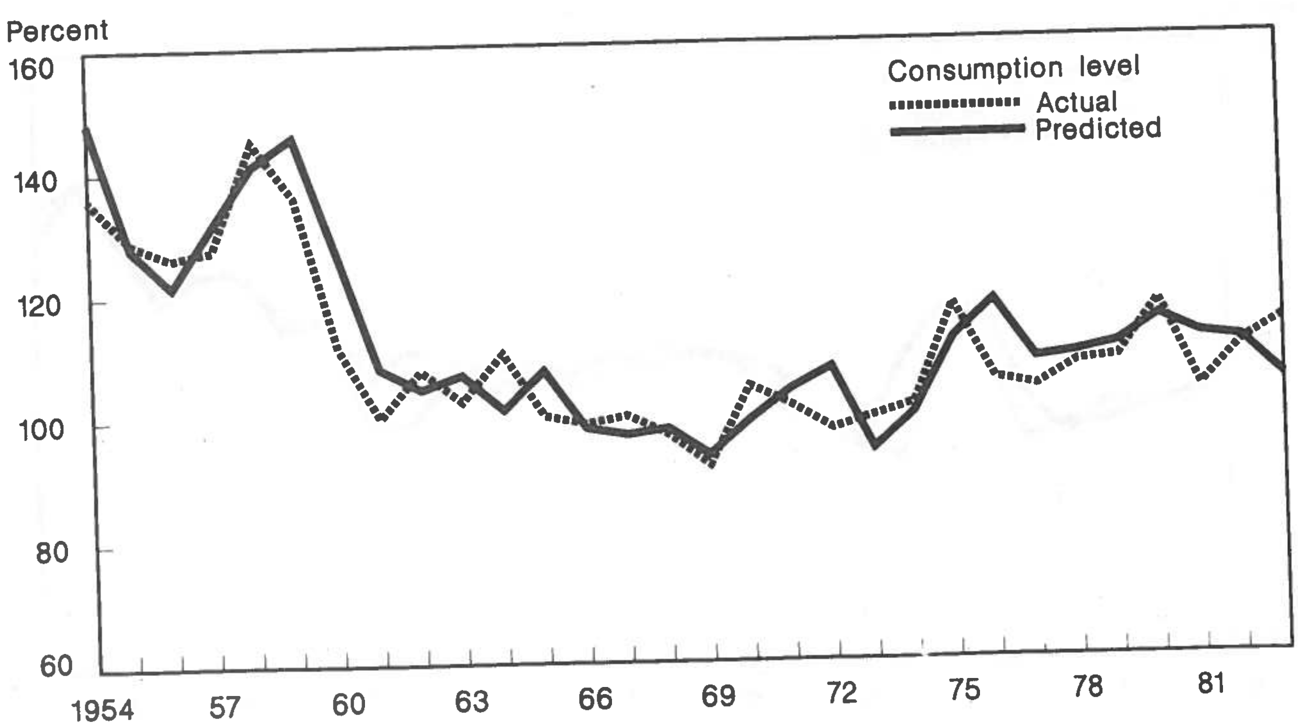
Appendix Figure 16
Margarine



Appendix Figure 17
Other Fats and Oils

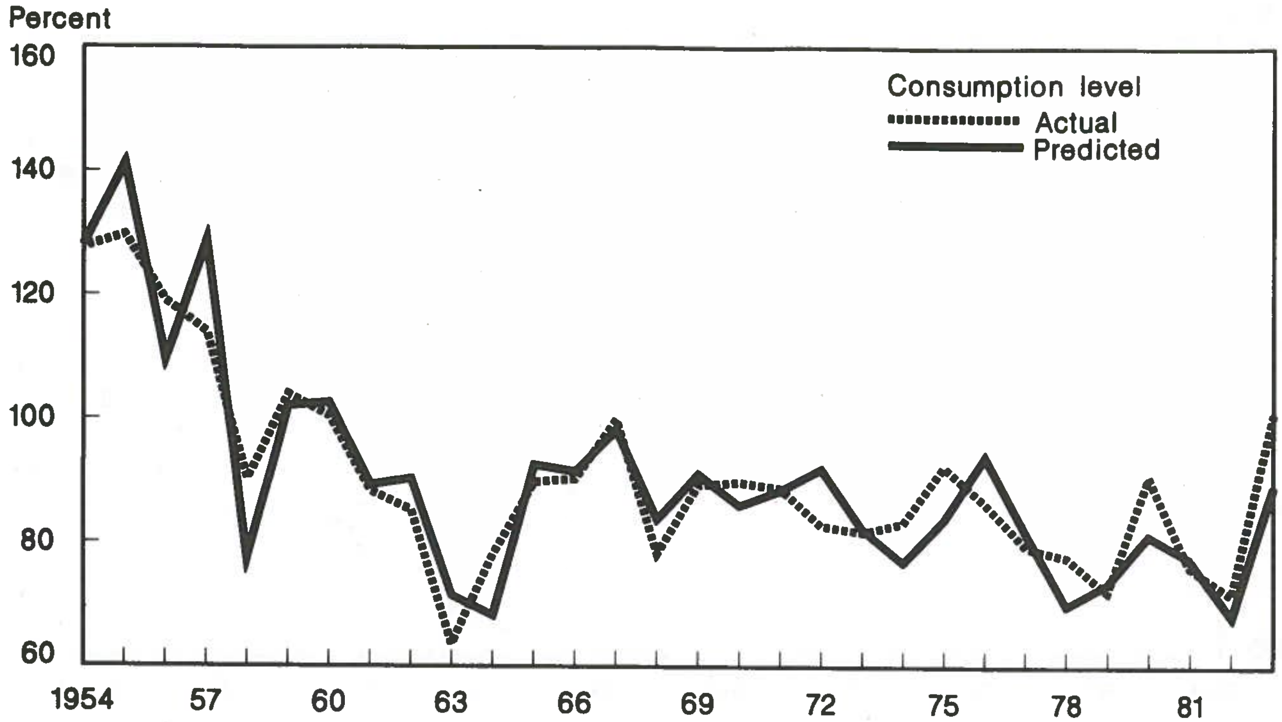


Appendix Figure 18
Apples



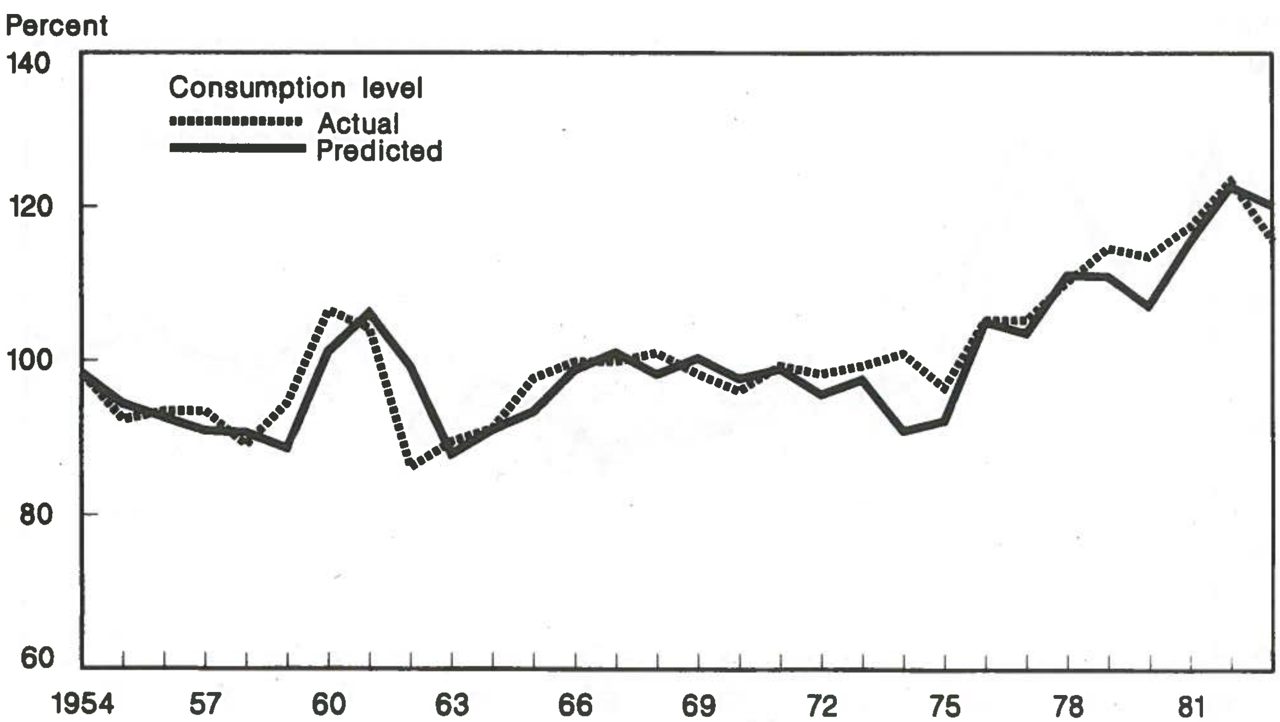
Appendix Figure 19

Oranges



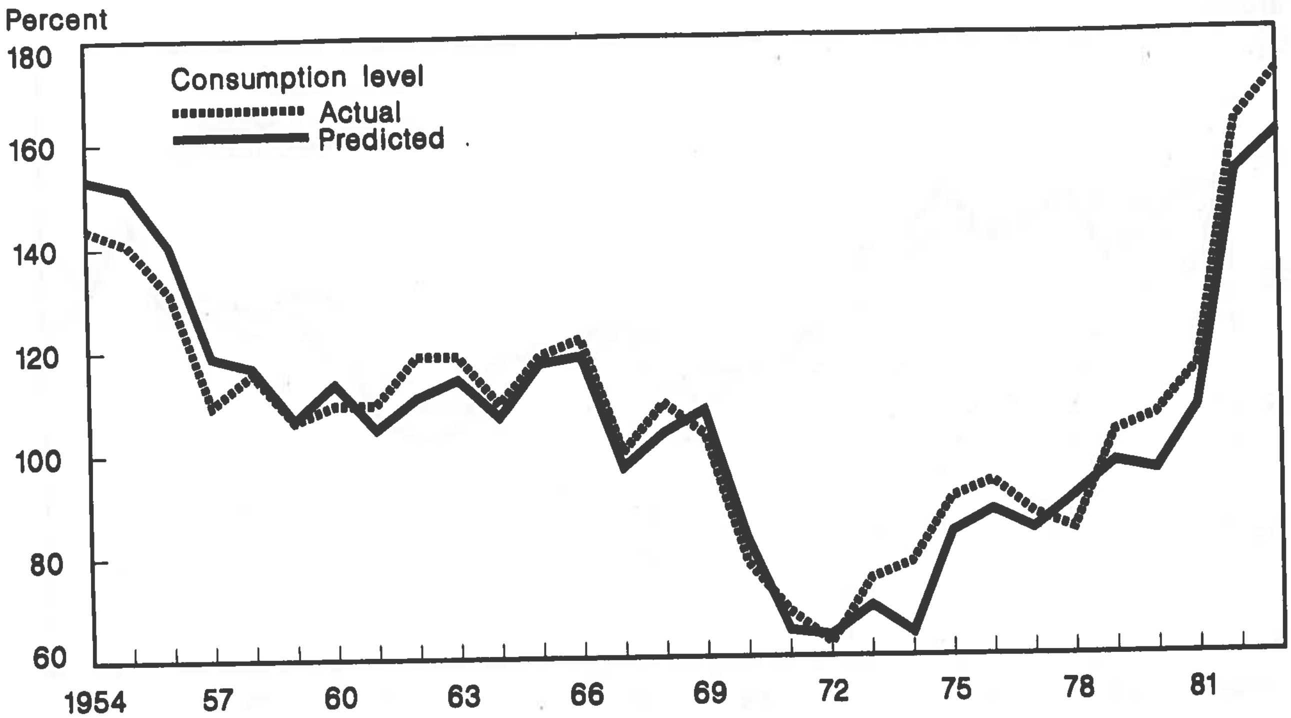
Appendix Figure 20

Bananas



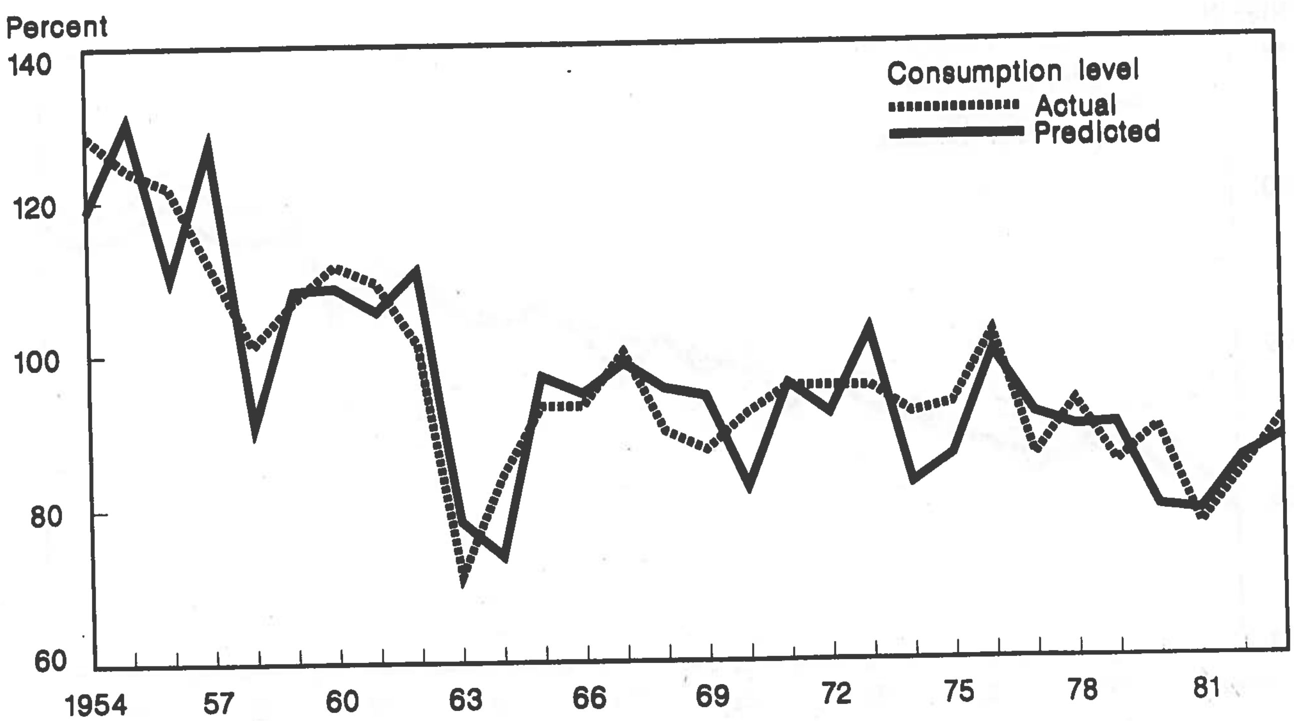
Appendix Figure 21

Grapes



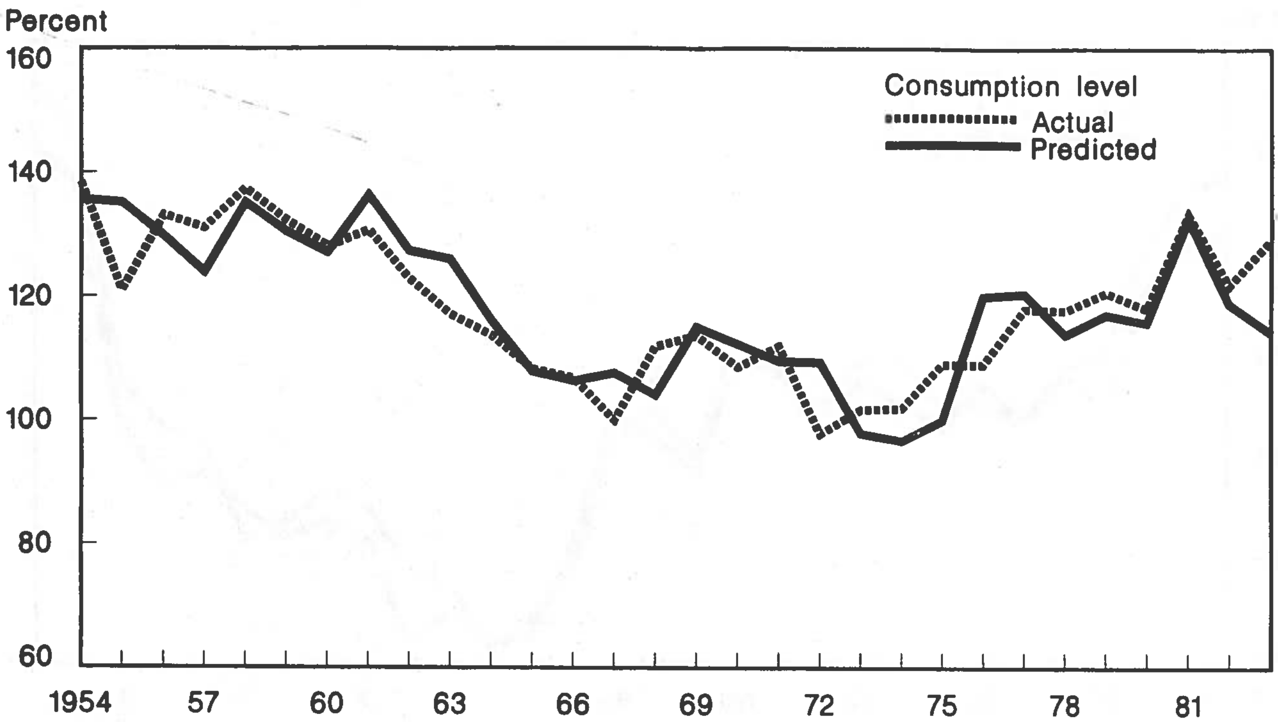
Appendix Figure 22

Grapefruits



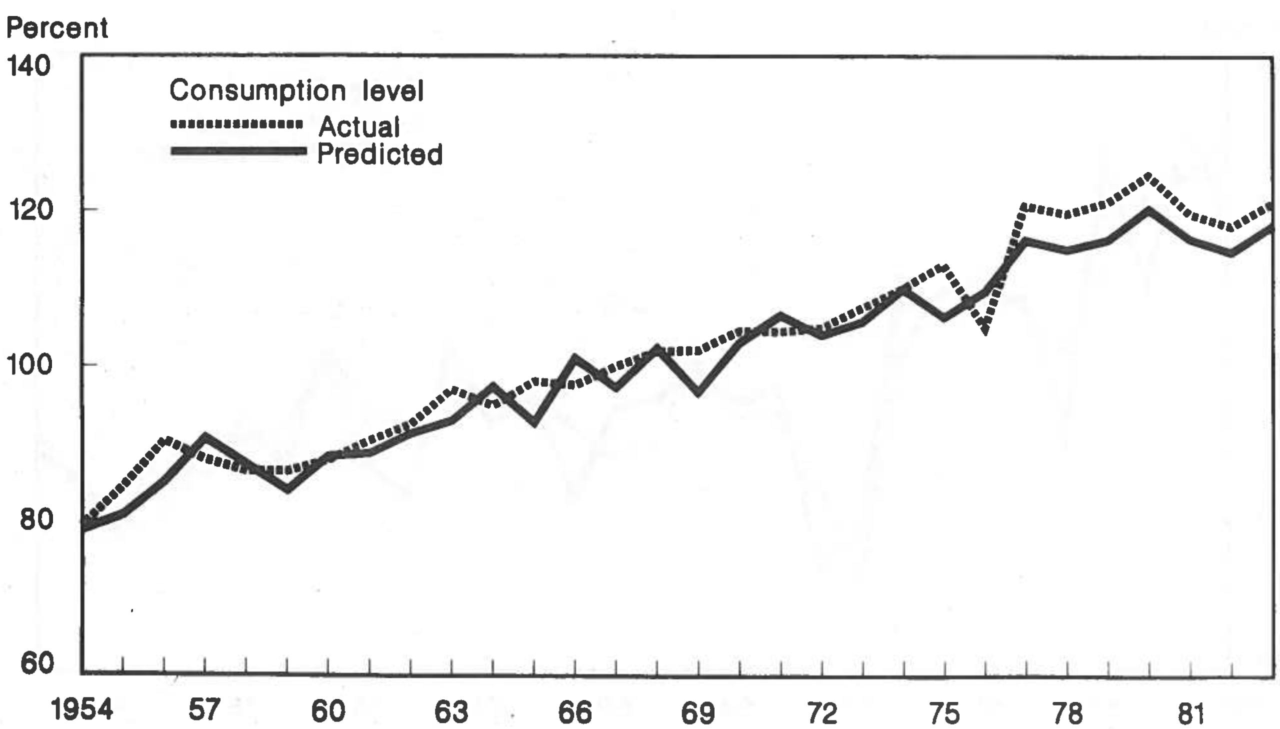
Appendix Figure 23

Other Fresh Fruits



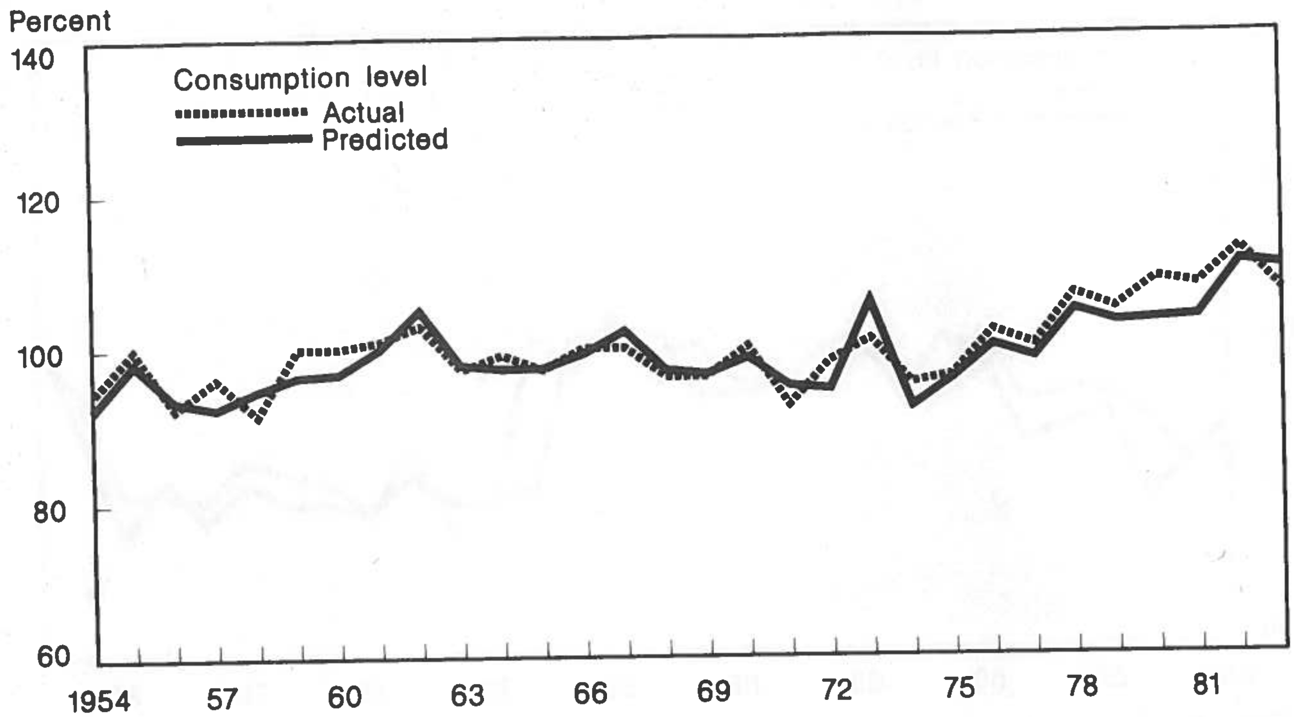
Appendix Figure 24

Lettuce



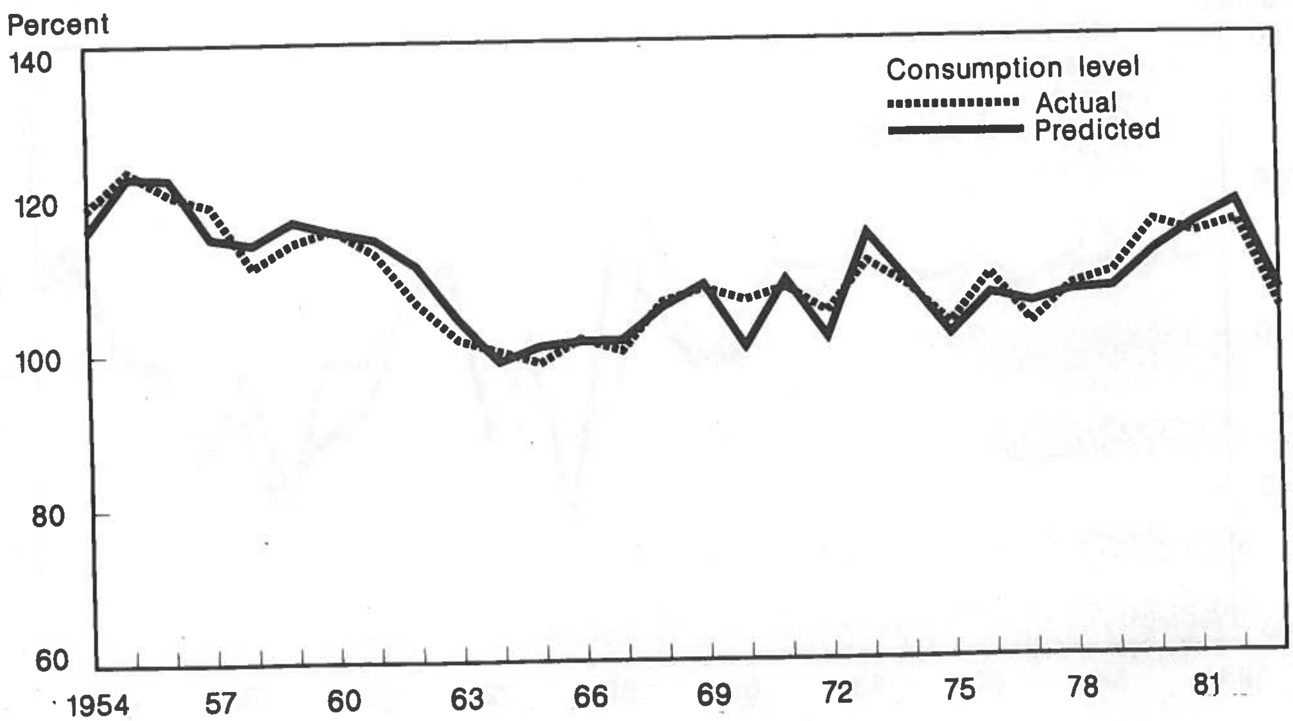
Appendix Figure 25

Tomatoes



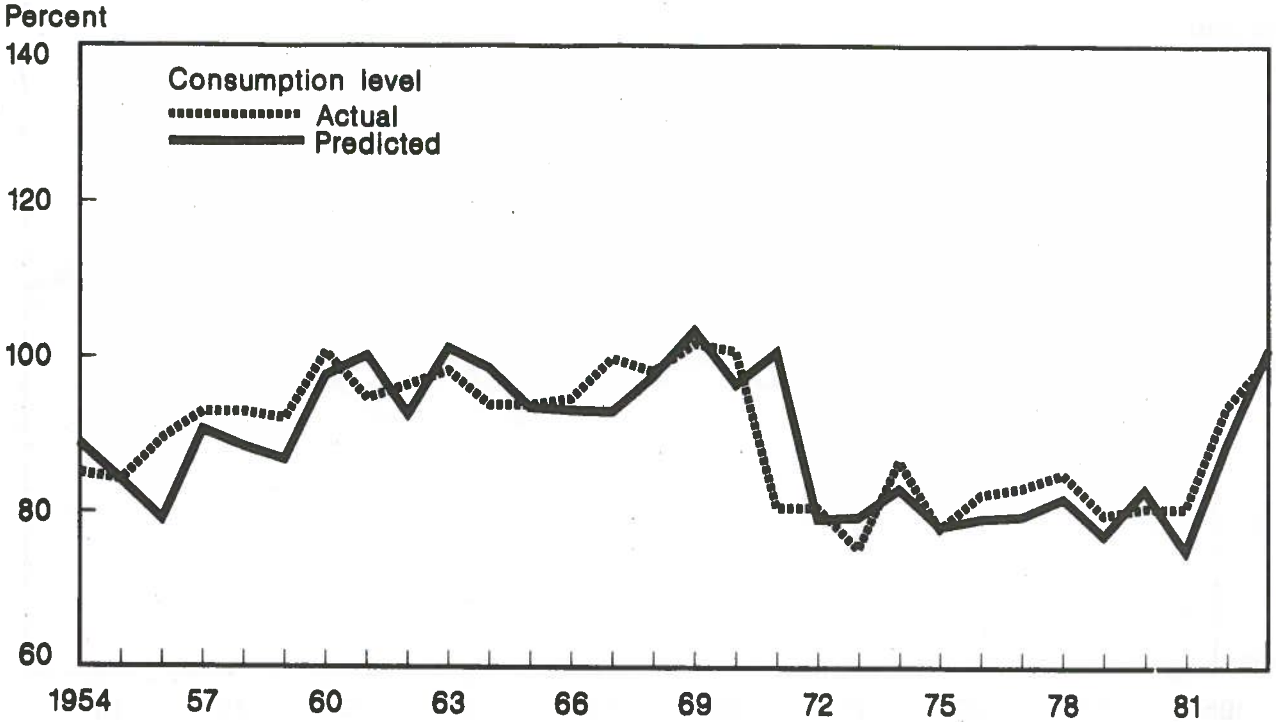
Appendix Figure 26

Celery



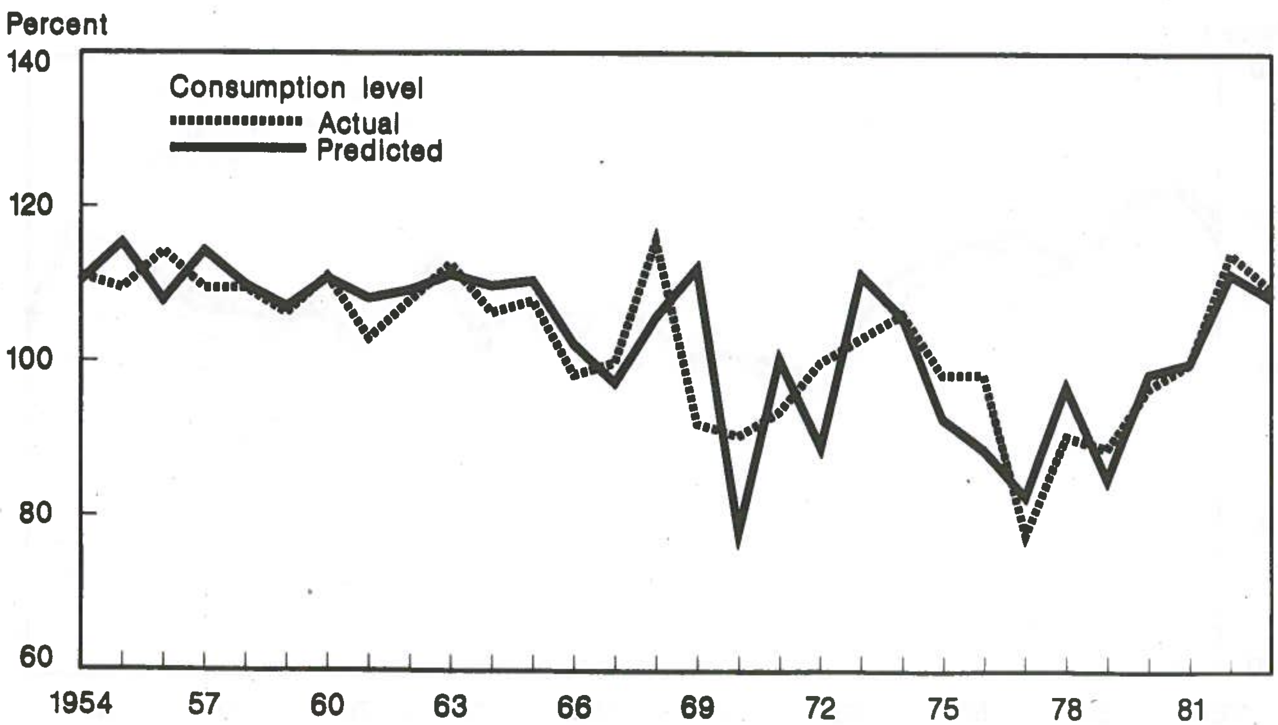
Appendix Figure 27

Onions



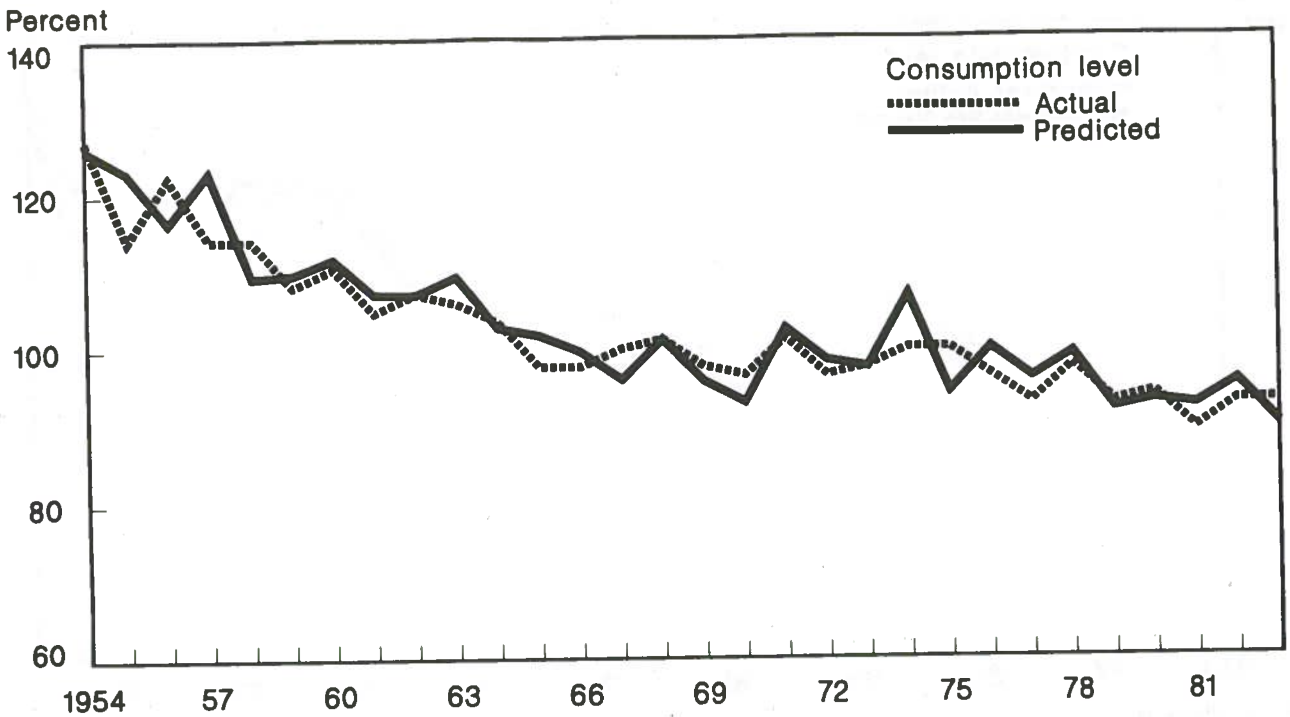
Appendix Figure 28

Carrots



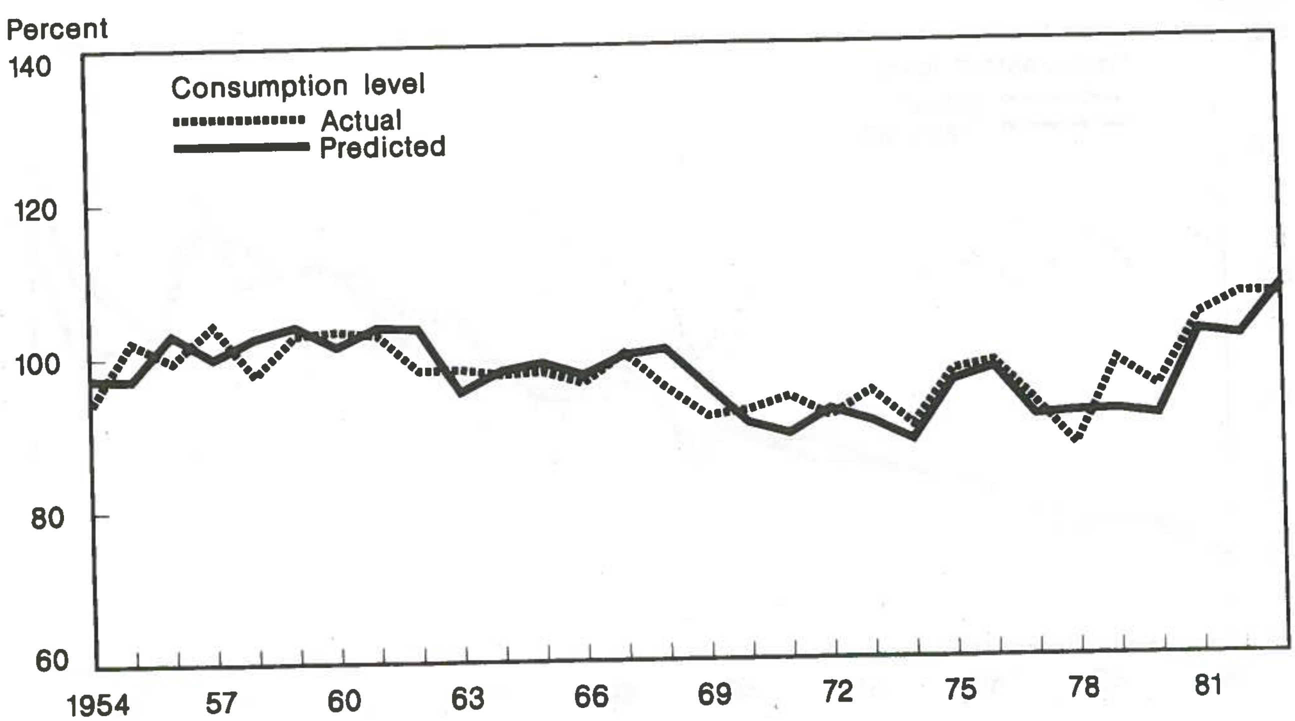
Appendix Figure 29

Cabbage



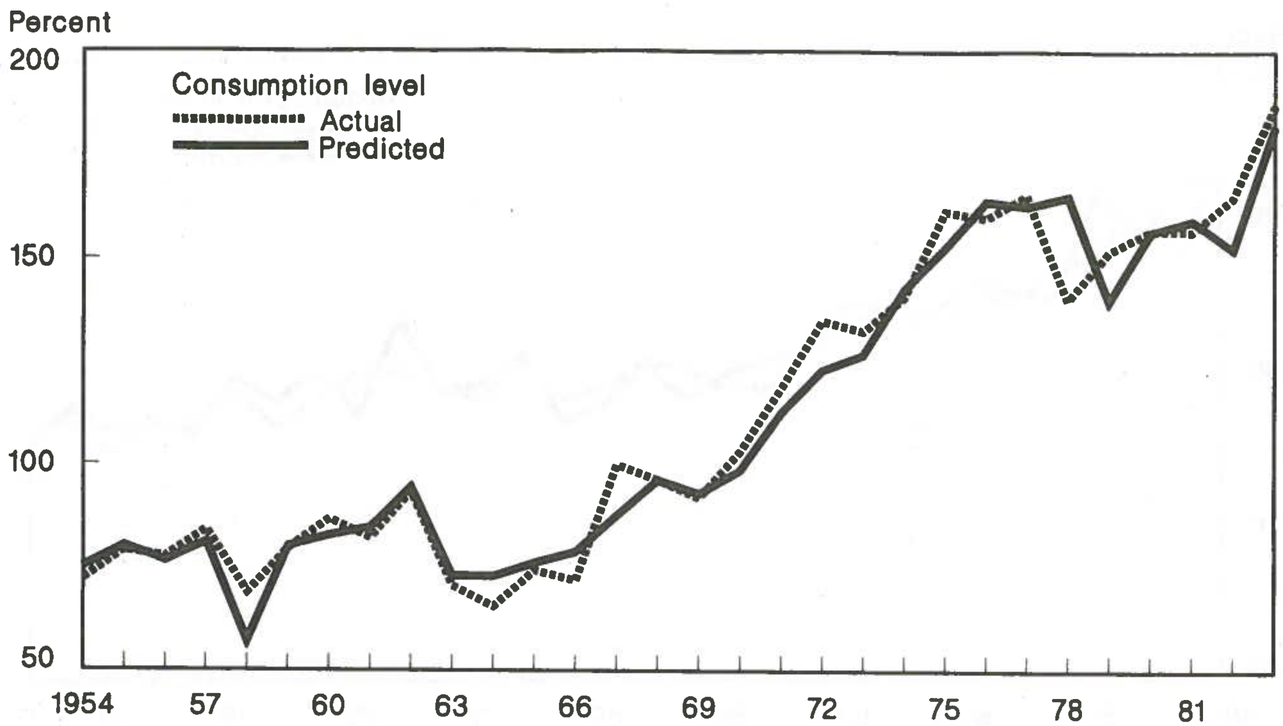
Appendix Figure 30

Other Fresh Vegetables



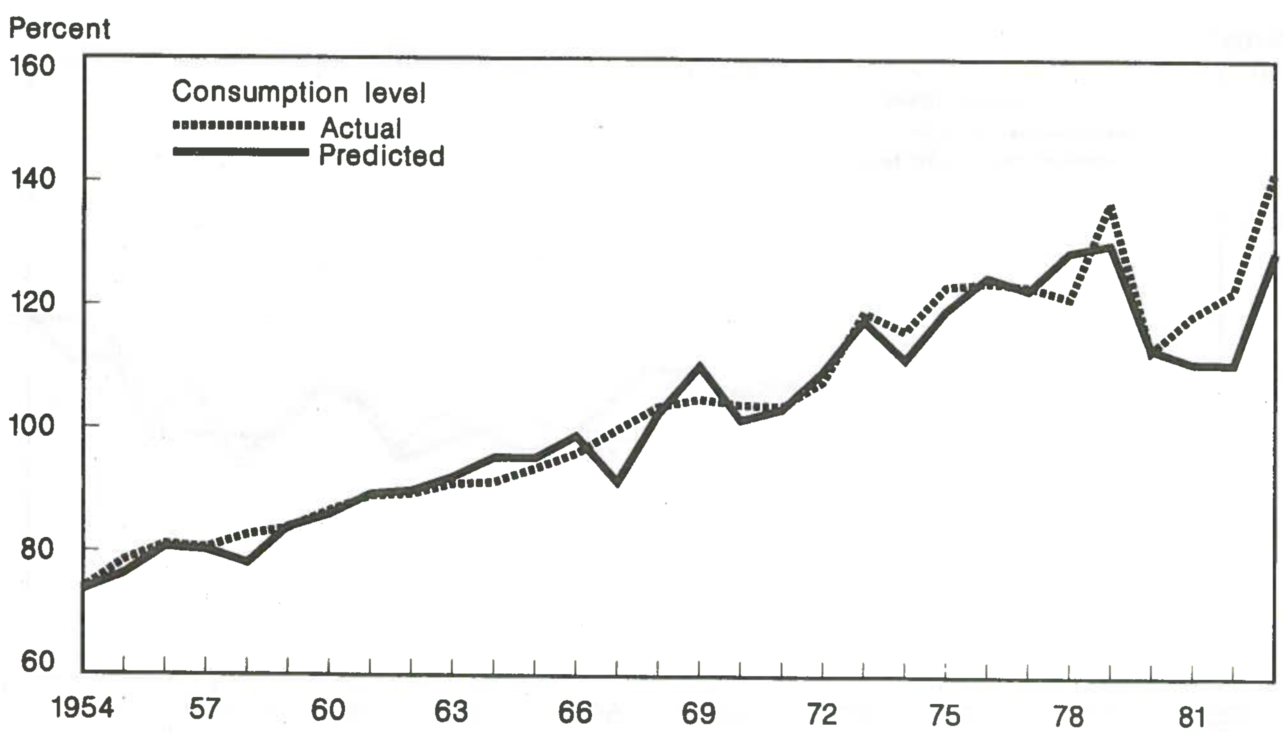
Appendix Figure 31

Fruit Juice



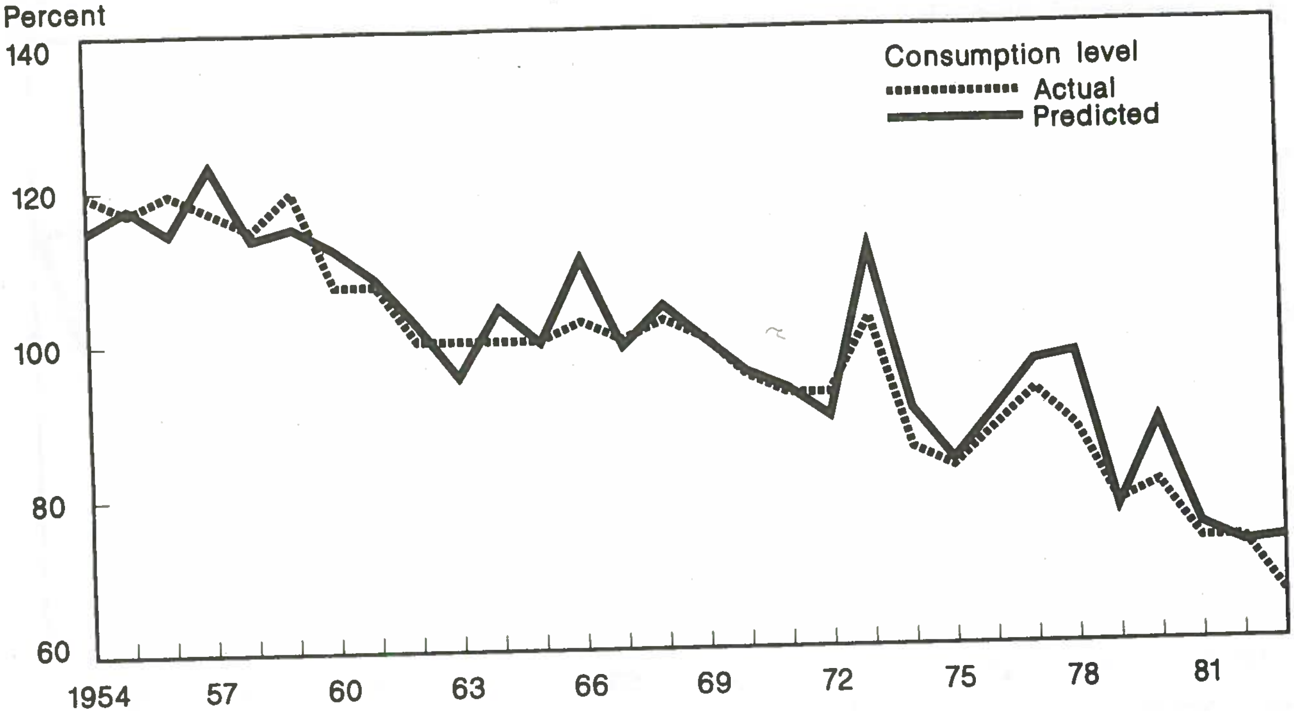
Appendix Figure 32

Canned Tomatoes



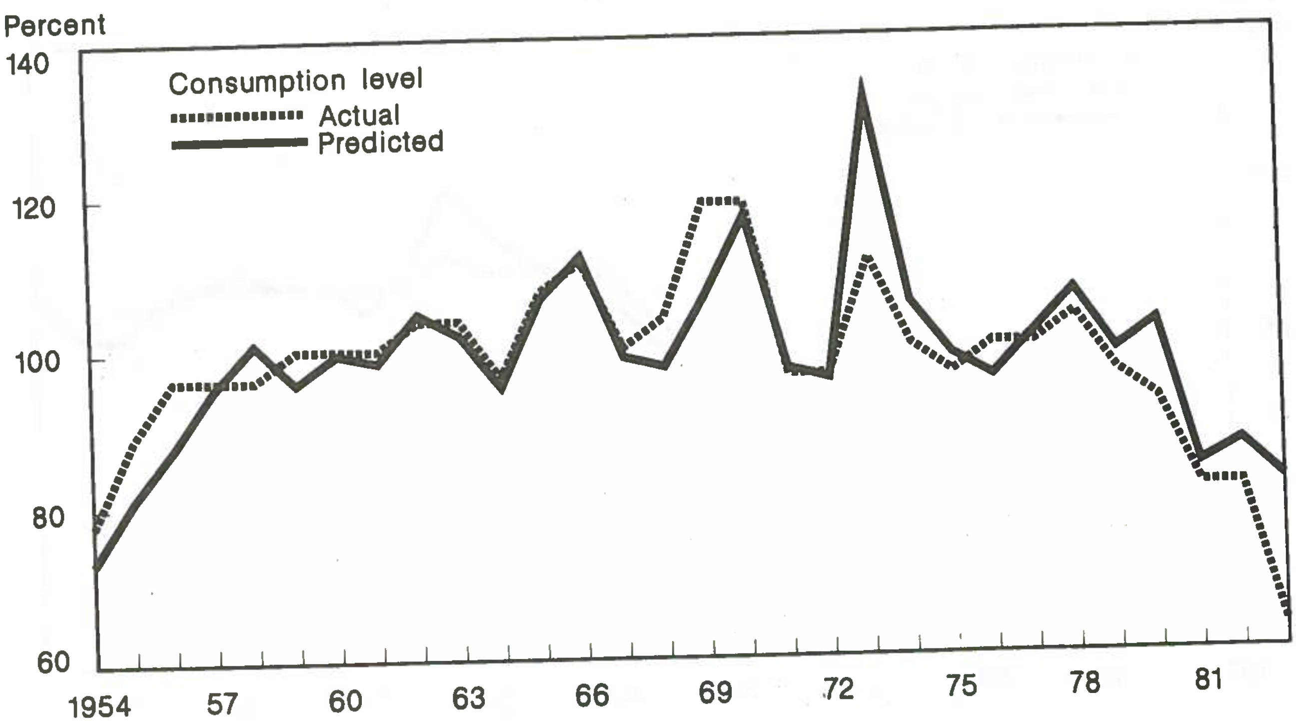
Appendix Figure 33

Canned Peas



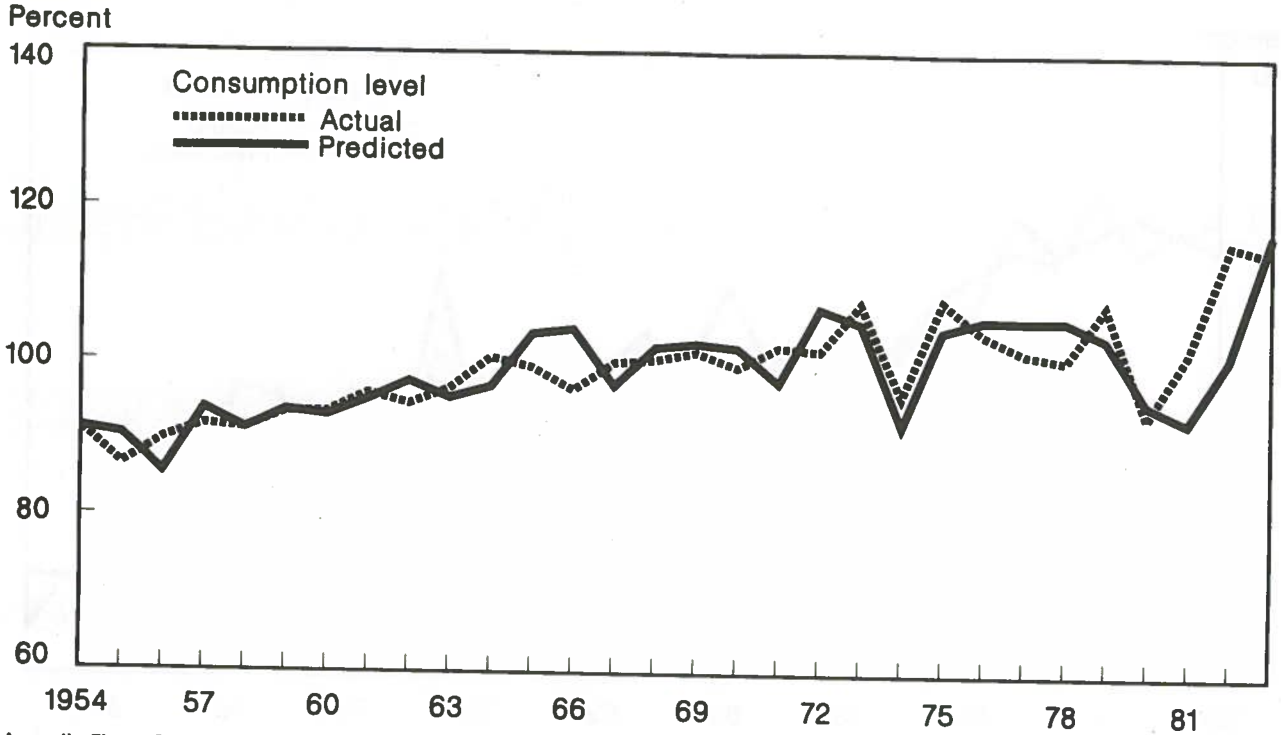
Appendix Figure 34

Canned Fruit Cocktail



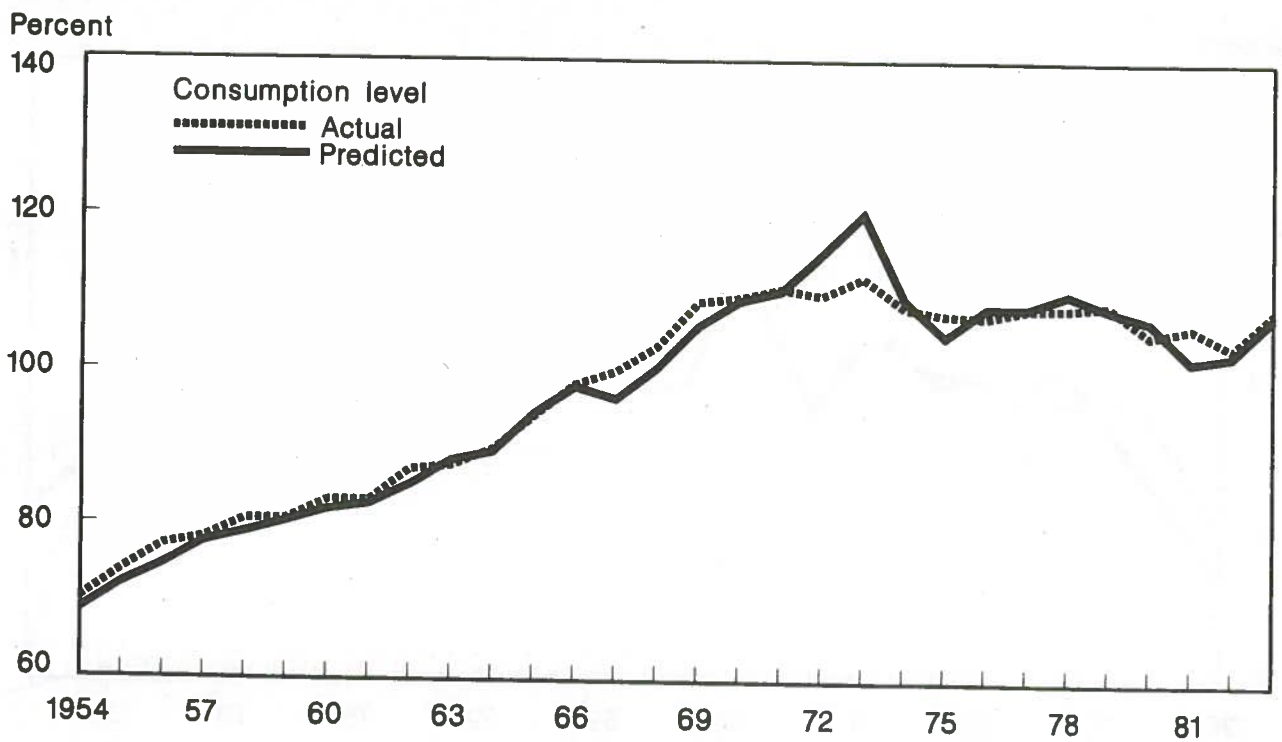
Appendix Figure 35

Dried Beans, Peas, and Nuts



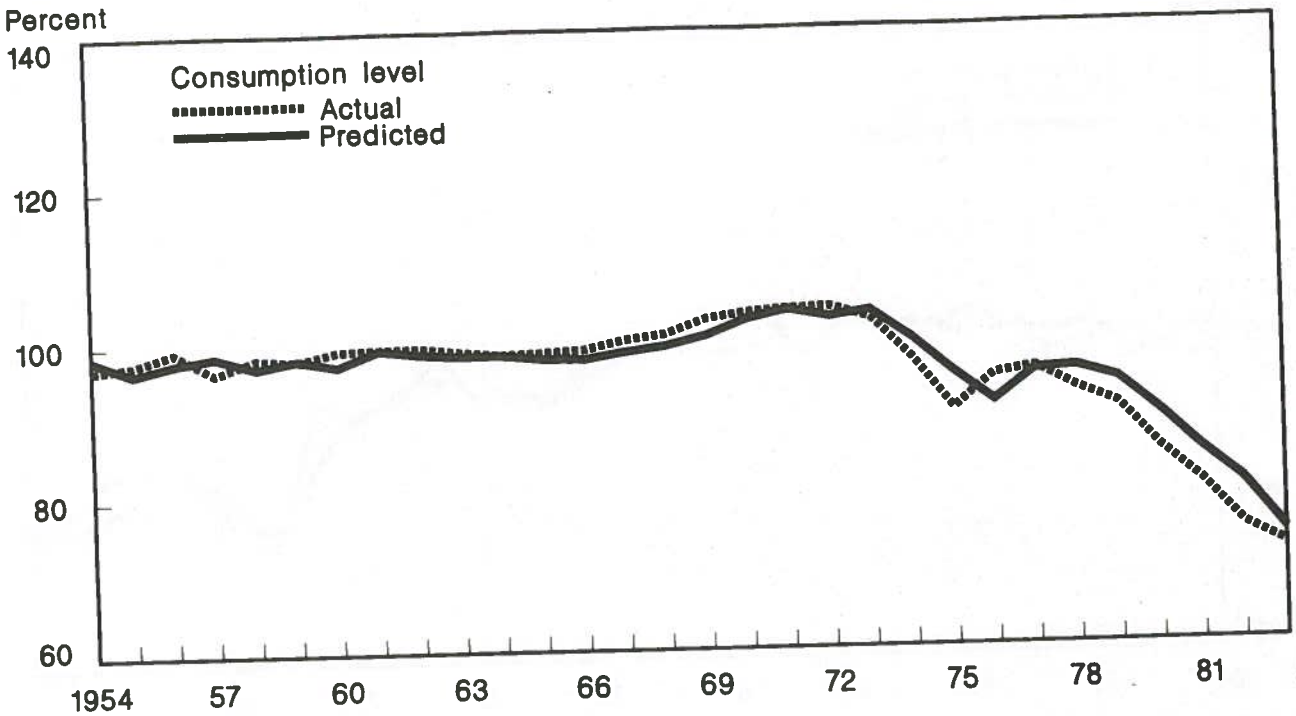
Appendix Figure 36

Other Processed Fruits and Vegetables



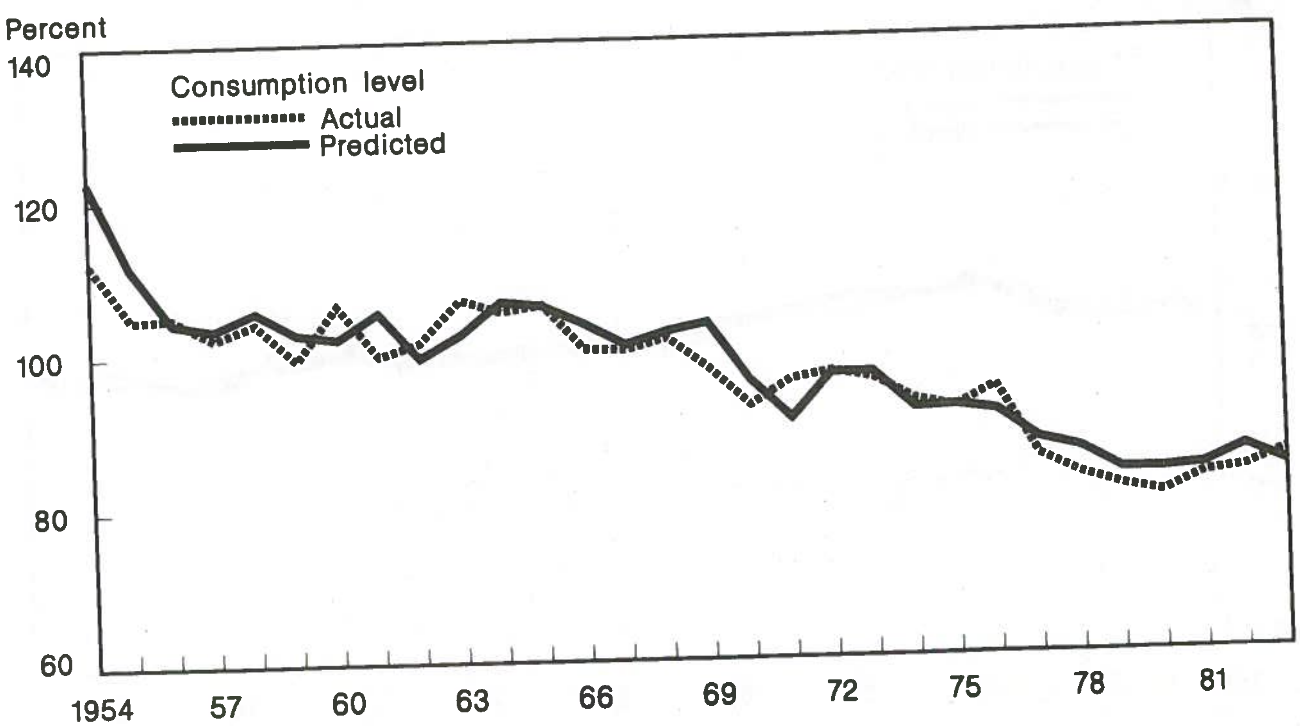
Appendix Figure 37

Sugar



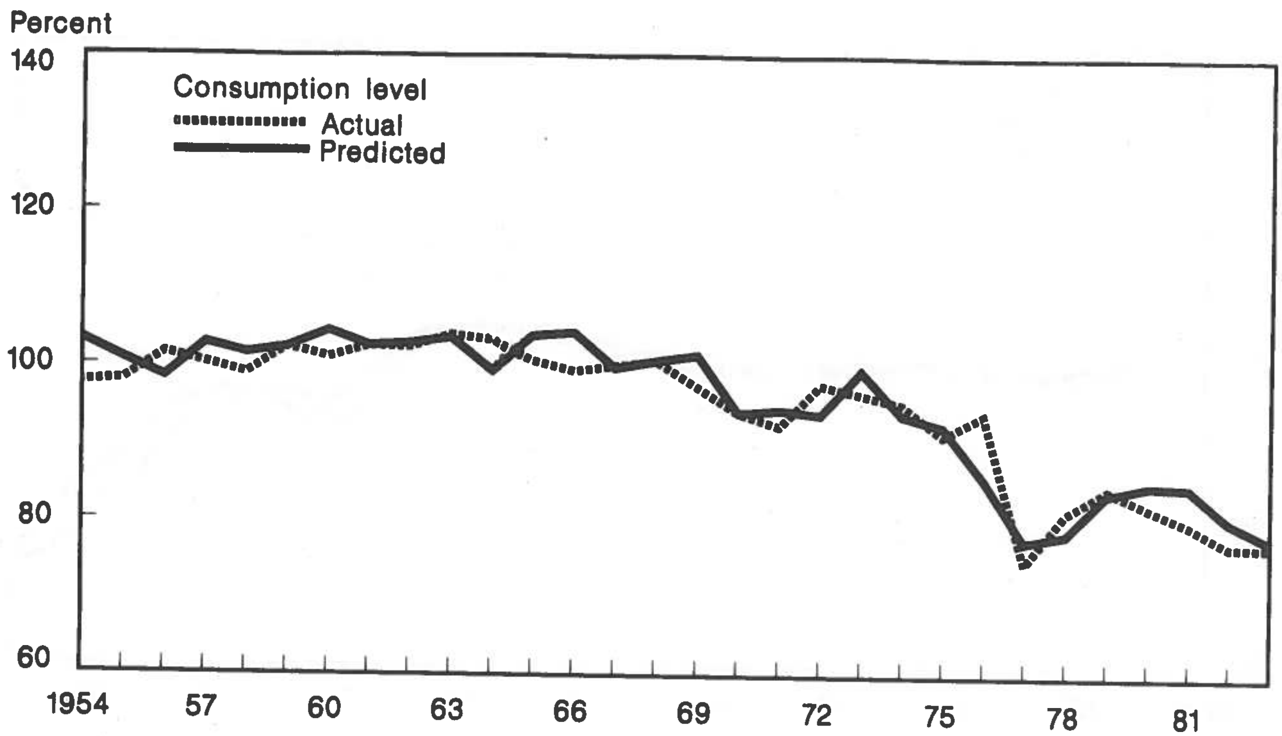
Appendix Figure 38

Sweeteners



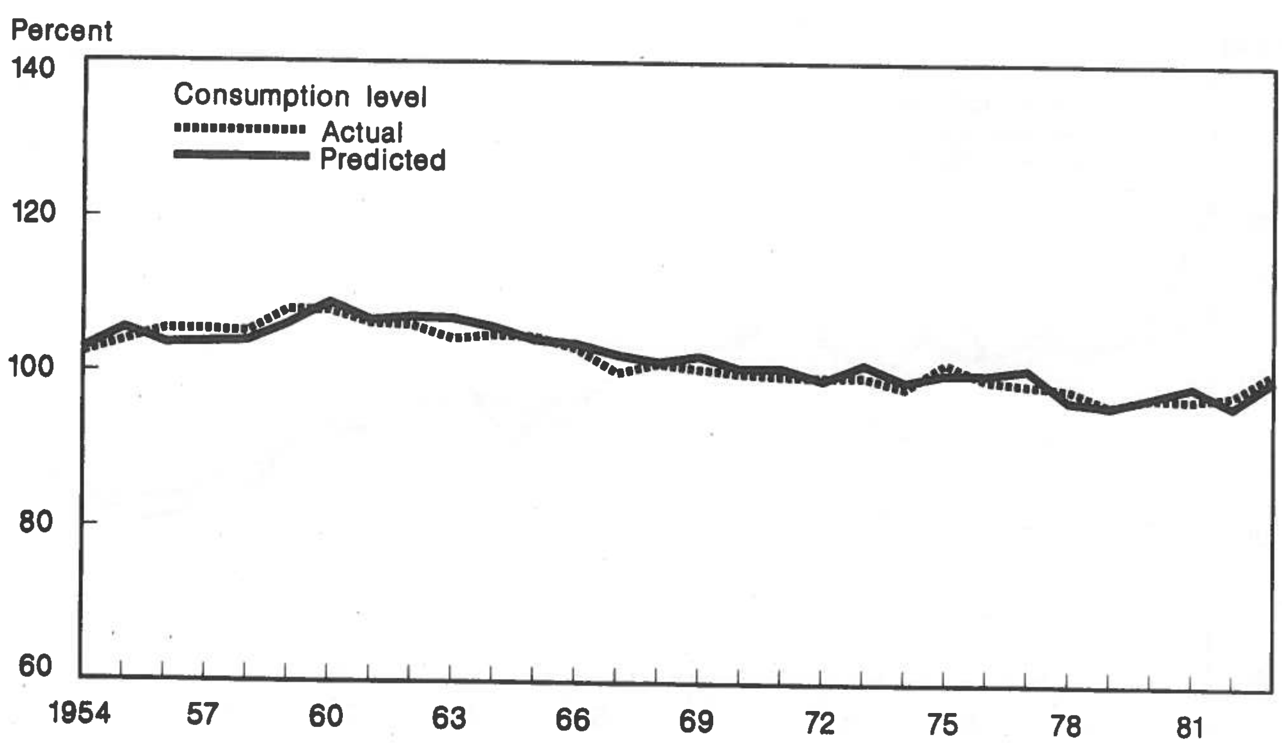
Appendix Figure 39

Coffee



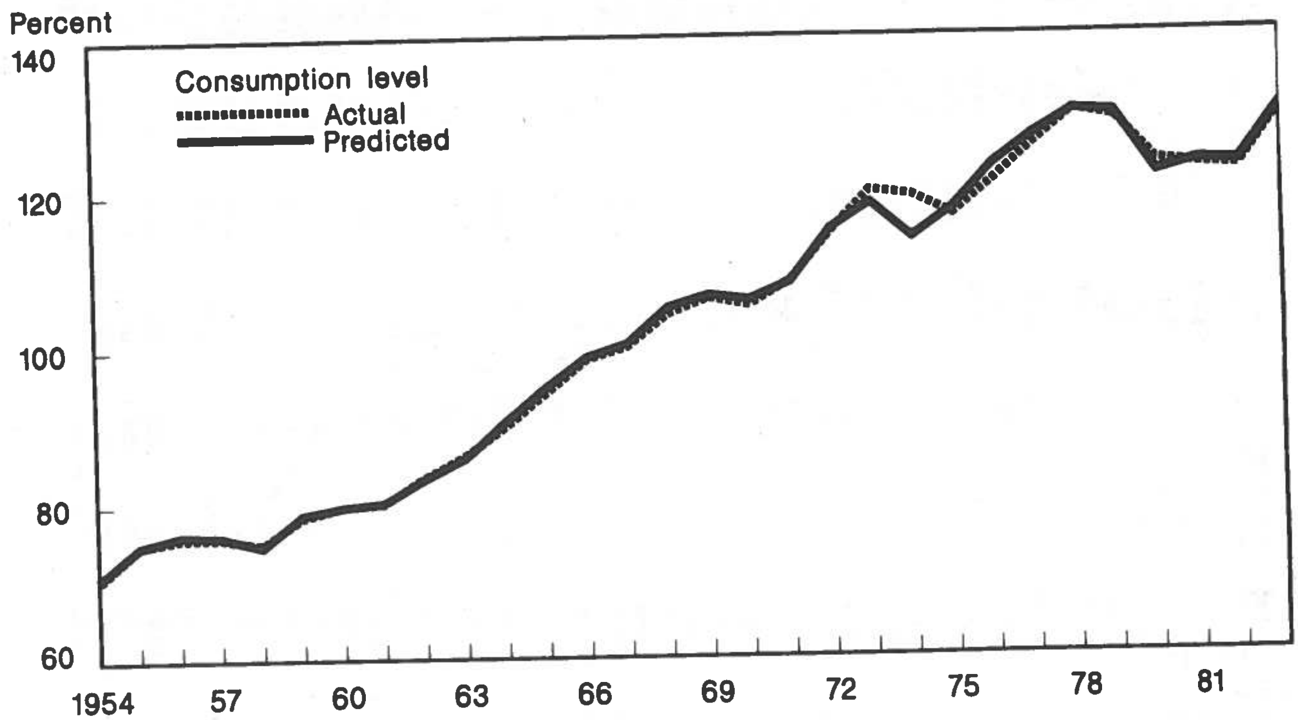
Appendix Figure 40

Ice Cream and Other Frozen Dairy Products



Appendix Figure 41

Nonfood



Appendix D:

Disaggregated Food Demand System for the United States

Quantity \ Price	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
BEEF.V	-0.6166	0.1087	0.0714	0.0572	0.0115	-0.0112	0.0081	0.0084	-0.0296	-0.0005	-0.0018	-0.0301	0.0383	0.0059
	(.0483)	(.0220)	(.0163)	(.0136)	(.0078)	(.0085)	(.0094)	(.0091)	(.0107)	(.0141)	(.0065)	(.0193)	(.0084)	(.0087)
PORK	.1910	-.7297	.0486	.0908	.0178	.0157	.0190	-.0147	-.0089	-.0325	-.0164	.0390	.0030	-.0096
	(.0390)	(.0327)	(.0178)	(.0170)	(.0091)	(.0096)	(.0107)	(.0104)	(.0122)	(.0167)	(.0069)	(.0215)	(.0095)	(.0091)
O.MEAT	.5409	.2119	-1.3712	-.1633	.0251	.0430	-.0391	-.0151	.4068	-.1493	.0664	.3692	-.1782	-.0029
	(.1214)	(.0754)	(.2045)	(.0675)	(.0634)	(.0883)	(.0787)	(.0526)	(.0891)	(.1108)	(.0734)	(.1338)	(.0504)	(.0254)
CHICKN	.2927	.2635	-.1128	-.5308	-.0487	.0820	-.0743	.0924	-.0394	.1788	.0347	.0783	-.1309	0304
	(.0698)	(.0492)	(.0461)	(.0608)	(.0323)	(.0322)	(.0363)	(.0307)	(.0411)	(.0533)	(.0230)	(.0660)	(.0275)	(.0209)
TURKEY	.2083	.1821	.0590	-.1701	-.6797	-.0894	.0742	-.0268	.1489	-.3749	-.0991	.2418	-.0872	.1361
	(.1402)	(.0919)	(.1516)	(.1133)	(.1332)	(.1030)	(.1063)	(.0816)	(.1262)	(.1413)	(.0682)	(.1703)	(.0659)	(.0332)
FISH	-.1838	.1604	.1002	.2818	-.0870	.0142	-.0847	-.1189	.1501	-.2258	.0680	-.1278	-.0717	.0024
	(.1476)	(.0946)	(.2060)	(.1100)	(.1004)	(.1615)	(.1298)	(.0853)	(.1353)	(.1640)	(.0829)	(.1897)	(.0735)	(.0379)
C.FISH	.1559	.1975	-.0922	-.2548	.0738	-.0855	.0350	-.0764	1341	.2885	-.1356	-.4308	.0374	.0860
	(.1657)	(.1068)	(.1859)	(.1255)	(.1049)	(.1314)	(.1706)	(.0965)	(.1453)	(.2079)	(.1039)	(.2468)	(.0912)	(.0489)
EGGS	.0470	-.0242	-.0075	.0725	-.0052	-.0262	-.0167	-.1452	.0292	-.0418	.0201	-.1506	.0333	-.0016
	(.0354)	(.0229)	(.0274)	(.0234)	(.0177)	(.0191)	(.0213)	(.0225)	(.0251)	(.0323)	(.0132)	(.0374)	(.0154)	(.0108)
CHEESE	-.2618	-.0468	.4756	-.0690	.0727	.0747	.0656	.0613	-.3319	.4531	-.0675	-.1000	.0080	-.0042
	(.0939)	(.0603)	(.1045)	(.0704)	(.0619)	(.0680)	(.0722)	(.0563)	(.1174)	(.1088)	(.0479)	(.1292)	(.0512)	(.0303)
F.MILK	.0194	-.0242	-.0375	.0711	-.0396	-.0244	.0320	-.0193	.1026	-.2588	.0743	-.0565	.0387	-.0230
	(.0270)	(.0183)	(.0287)	(.0202)	(.0153)	(.0182)	(.0228)	(.0161)	(.0240)	(.1205)	(.0411)	(.0817)	(.0368)	(.0168)
O.MILK	-.0117	-.1595	.1660	.1297	-.1018	.0729	-.1418	.0979	-.1395	.7125	-.8255	-.0679	.0001	.0349
	(.1188)	(.0725)	(.1819)	(.0835)	(.0707)	(.0880)	(.1090)	(.0632)	(.1010)	(.3939)	(.2642)	(.2976)	(.1284)	(.0537)
FLOUR	-.0388	.0515	.0942	.0319	.0264	-.0134	-.0459	-.0726	-.0191	-.0567	-.0072	-.1092	.0503	-.0019
	(.0362)	(.0230)	(.0339)	(.0245)	(.0180)	(.0206)	(.0264)	(.0182)	(.0278)	(.0798)	(.0302)	(.1026)	(.0382)	(.0168)
RICE	.5207	.0357	-.3100	-.3306	-.0626	-.0528	.0283	.1149	.0153	.2638	.0003	.3512	-.1467	.0187
	(.1083)	(.0699)	(.0882)	(.0704)	(.0482)	(.0551)	(.0675)	(.0520)	(.0762)	(.2509)	(.0910)	(.2668)	(.1438)	(.0569)
POTATO	.1020	-.0813	-.0065	.0959	.1214	.0021	.0772	-.0081	-.0062	-.1946	.0293	-.0207	.0216	-.3688
	(.1378)	(.0815)	(.0539)	(.0651)	(.0296)	(.0345)	(.0440)	(.0443)	(.0548)	(.1389)	(.0460)	(.1420)	(.0689)	(.0689)
BUTTER	-.0620	-.0420	.0931	.3620	-.0339	-.0961	-.2270	-.0387	-.4609	.0138	.0803	.0701	-.1058	-.0613
	(.1102)	(.0731)	(.1517)	(.0896)	(.0804)	(.0897)	(.0986)	(.0654)	(.1109)	(.1787)	(.1033)	(.2155)	(.0827)	(.0357)
MARGAR	-.0163	.0956	.2134	-.1150	-.1140	.0784	.1359	.0098	.1097	.2008	-.0656	.0992	-.0643	-.0009
	(.0754)	(.0470)	(.1394)	(.0471)	(.0431)	(.0591)	(.0721)	(.0359)	(.0573)	(.1392)	(.1050)	(.1579)	(.0605)	(.0244)
O.FATS	.0317	.0599	-.0069	.0423	.0463	-.0530	-.0159	.0146	-.0708	-.0048	.0113	-.0475	.0003	-.0080
	(.0446)	(.0283)	(.0398)	(.0290)	(.0188)	(.0217)	(.0272)	(.0191)	(.0278)	(.0565)	(.0293)	(.0736)	(.0260)	(.0186)
APPLES	.2080	.1972	.0280	-.0511	.1127	.1329	-.0892	-.3068	.1489	-.2484	.1727	-.1409	.1091	-.0923
	(.1262)	(.0773)	(.1012)	(.0838)	(.0575)	(.0660)	(.0705)	(.0573)	(.0832)	(.2104)	(.0729)	(.2268)	(.0937)	(.0614)
ORANGE	.2020	-.0837	-.0154	.2616	.0312	.0252	-.2844	-.1742	-.0347	.0909	.0499	.0628	-.0515	-.0114
	(.1894)	(.1071)	(.1170)	(.0934)	(.0611)	(.0709)	(.0769)	(.0603)	(.0814)	(.1925)	(.0788)	(.2162)	(.0922)	(.0633)
BANANA	-.3249	-.1456	.4970	-.1711	.1190	.0199	.0926	.0226	-.0131	-.4257	-.2625	.0023	.0025	.1021
	(.1346)	(.0850)	(.1471)	(.1002)	(.0775)	(.0868)	(.0960)	(.0731)	(.1069)	(.2242)	(.1051)	(.2564)	(.0966)	(.0493)
GRAPES	-.0537	.2002	-.1067	-.3609	.0367	-.0480	.3789	.4365	-.2821	-.2107	-.0812	.3497	-.1068	-.0982
	(.1982)	(.1235)	(.2518)	(.1491)	(.1293)	(.1488)	(.1627)	(.1171)	(.1865)	(.3660)	(.1669)	(.4017)	(.1534)	(.0727)

See note at end of table.

Disaggregated Food Demand System for the United States—Continued

Quantity \ Price	BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
BEEF.V	-0.0045	-0.0011	0.0070	0.0093	0.0104	-0.0134	-0.0009	-0.0040	0.0005	-0.0044	-0.0095	0.0020	-0.0111	0.0027
	(.0066)	(.0032)	(.0107)	(.0064)	(.0097)	(.0053)	(.0032)	(.0034)	(.0137)	(.0045)	(.0038)	(.0014)	(.0035)	(.0034)
PORK	-.0052	.0067	.0246	.0162	-.0075	-.0106	.0057	-.0002	-.0272	-.0186	-.0067	-.0008	.0005	-.0041
	(.0077)	(.0035)	(.0119)	(.0068)	(.0097)	(.0059)	(.0035)	(.0035)	(.0153)	(.0049)	(.0043)	(.0017)	(.0037)	(.0037)
O.MEAT	.0412	.0677	-.0100	.0099	-.0052	.1450	-.0127	.0513	-.0829	.0715	.1067	-.0360	.0505	.0027
	(.0672)	(.0442)	(.0705)	(.0378)	(.0446)	(.0430)	(.0305)	(.0215)	(.1145)	(.0250)	(.0332)	(.0160)	(.0170)	(.0256)
CHICKN	.1090	-.0252	.0513	-.0141	.0684	-.0346	-.0299	.0505	-.0698	.0301	.0221	.0128	-.0037	.0383
	(.0271)	(.0102)	(.0352)	(.0214)	(.0243)	(.0200)	(.0124)	(.0113)	(.0536)	(.0164)	(.0156)	(.0057)	(.0109)	(.0119)
TURKEY	-.0364	-.0866	.1965	.0997	.0287	.0827	.0107	-.0840	-.2811	-.0046	.0397	-.0389	.0309	-.0355
	(.0852)	(.0326)	(.0796)	(.0514)	(.0557)	(.0541)	(.0375)	(.0286)	(.1430)	(.0444)	(.0485)	(.0182)	(.0309)	(.0375)
FISH	-.0997	.0580	-.2174	.1153	.0230	.0134	-.0134	.0726	-.3232	-.0450	-.1245	-.0399	-.0426	-.1014
	(.0929)	(.0437)	(.0897)	(.0576)	(.0631)	(.0592)	(.0421)	(.0328)	(.1645)	(.0494)	(.0554)	(.0216)	(.0336)	(.0402)
C.FISH	-.2376	.1019	-.0640	-.0793	-.2553	.0639	.1088	.0083	.6178	.0628	.1842	.0577	.0432	-.0083
	(.1032)	(.0540)	(.1140)	(.0622)	(.0692)	(.0662)	(.0466)	(.0348)	(.1817)	(.0501)	(.0632)	(.0257)	(.0352)	(.0454)
EGGS	-.0088	.0018	.0163	-.0600	-.0337	.0034	.0277	-.0153	.1361	-.0094	.0077	.0042	.0055	-.0121
	(.0150)	(.0059)	(.0176)	(.0111)	(.0119)	(.0111)	(.0074)	(.0060)	(.0283)	(.0102)	(.0096)	(.0035)	(.0073)	(.0076)
CHEESE	-.2409	.0402	-.1489	.0639	-.0157	-.0052	-.0403	-.0374	.0716	-.0287	-.0804	.0247	-.0510	-.0250
	(.0577)	(.0213)	(.0580)	(.0365)	(.0365)	(.0367)	(.0266)	(.0194)	(.0936)	(.0333)	(.0329)	(.0119)	(.0236)	(.0252)
F.MILK	.0020	.0169	.0020	-.0242	.0100	-.0319	-.0063	.0348	-.0316	.0240	.0530	.0104	-.0052	-.0240
	(.0205)	(.0114)	(.0259)	(.0203)	(.0190)	(.0169)	(.0115)	(.0109)	(.0497)	(.0133)	(.0132)	(.0048)	(.0088)	(.0118)
O.MILK	.0887	-.0510	.0543	.1599	.0483	-.1898	-.0241	-.0982	-.4096	.1290	.0450	-.0312	.0006	.0598
	(.1134)	(.0825)	(.1287)	(.0675)	(.0744)	(.0761)	(.0502)	(.0368)	(.2115)	(.0471)	(.0651)	(.0287)	(.0311)	(.0510)
FLOUR	.0081	.0083	-.0177	-.0137	.0070	.0003	.0110	-.0063	-.0707	.0300	-.0048	-.0110	.0037	-.0060
	(.0242)	(.0127)	(.0330)	(.0215)	(.0209)	(.0190)	(.0123)	(.0118)	(.0532)	(.0169)	(.0162)	(.0056)	(.0112)	(.0144)
RICE	-.0813	-.0350	.0061	.0713	-.0330	.0016	-.0223	-.0471	.0299	.0059	-.0091	.0233	.0587	.0630
	(.0641)	(.0335)	(.0805)	(.0612)	(.0614)	(.0493)	(.0325)	(.0328)	(.1416)	(.0482)	(.0434)	(.0146)	(.0322)	(.0393)
POTATO	-.0580	-.0007	-.0285	-.0741	-.0087	.0632	-.0252	.0131	.1968	-.0465	-.0126	.0133	-.0295	.0273
	(.0336)	(.0165)	(.0701)	(.0488)	(.0513)	(.0306)	(.0188)	(.0236)	(.0919)	(.0335)	(.0264)	(.0080)	(.0224)	(.0234)
BUTTER	-.1670	.0477	-.1226	-.0989	-.1073	.2149	-.0114	-.0390	.5255	-.1129	-.1267	.0194	-.0597	.0005
	(.1748)	(.0666)	(.1190)	(.0534)	(.0538)	(.0580)	(.0417)	(.0306)	(.1496)	(.0474)	(.0576)	(.0211)	(.0310)	(.0461)
MARGAR	.0665	-.2674	.1845	.1035	.1102	-.0464	-.0641	.0741	-.3696	-.0172	.1003	-.0030	-.0108	-.0469
	(.0934)	(.1379)	(.1714)	(.0439)	(.0503)	(.0509)	(.0339)	(.0232)	(.1421)	(.0295)	(.0447)	(.0216)	(.0199)	(.0341)
O.FATS	-.0313	.0327	-.2191	-.0645	-.0272	.0141	.0035	-.0171	.1168	.0021	-.0421	-.0069	-.0067	.0043
	(.0296)	(.0306)	(.0496)	(.0220)	(.0226)	(.0197)	(.0126)	(.0106)	(.0494)	(.0166)	(.0165)	(.0062)	(.0103)	(.0133)
APPLES	-.1166	.0883	-.3005	-.2015	.1400	.1510	-.0445	.1016	-.0446	-.0478	-.1596	.0578	.0276	.0775
	(.0633)	(.0372)	(.1042)	(.1469)	(.1119)	(.0940)	(.0637)	(.0533)	(.3175)	(.0499)	(.0509)	(.0146)	(.0341)	(.0383)
ORANGE	-.1256	.0911	-.1271	.1360	-.9996	-.0746	-.1132	-.0175	.3843	-.0180	-.0861	.0604	-.1434	.0485
	(.0625)	(.0418)	(.1051)	(.1097)	(.1465)	(.0899)	(.0660)	(.0538)	(.3496)	(.0499)	(.0461)	(.0161)	(.0333)	(.0369)
BANANA	.3261	-.0501	.0882	.1928	-.0965	-.4002	.0148	-.1024	.2630	-.0332	.0408	.0034	-.0990	-.0853
	(.0879)	(.0553)	(.1198)	(.1202)	(.1173)	(.1334)	(.0717)	(.0564)	(.3306)	(.0569)	(.0607)	(.0206)	(.0373)	(.0472)
GRAPES	-.0423	-.1679	.0513	-.1382	-.3556	.0350	-1.3780	-.2154	1.7077	.0647	.0133	-.0039	-.0020	-.0027
	(.1524)	(.0885)	(.1845)	(.1963)	(.2074)	(.1728)	(.1829)	(.1032)	(.5820)	(.1053)	(.1081)	(.0331)	(.0688)	(.0898)

See note at end of table.

Disaggregated Food Demand System for the United States—Continued

Quantity \ Price	CABAGE	O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	D.BEAN	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD	EXPEND
BEEF.V	-0.0016	0.0001	-0.0017	-0.0003	-0.0046	0.0020	0.0078	0.0466	0.0237	-0.0143	0.0019	-0.0151	-0.1022	0.4549
	(.0017)	(.0082)	(.0058)	(.0029)	(.0029)	(.0032)	(.0080)	(.0280)	(.0106)	(.0139)	(.0093)	(.0080)	(.0995)	(.0585)
PORK	.0003	.0074	-.0123	-.0008	-.0045	.0008	.0329	.0073	-.0394	.0184	-.0011	-.0238	-.0139	.4427
	(.0019)	(.0089)	(.0063)	(.0032)	(.0031)	(.0035)	(.0082)	(.0290)	(.0104)	(.0146)	(.0095)	(.0083)	(.1042)	(.0624)
O.MEAT	-.0091	-.0763	-.0326	.0211	.0502	.0034	.0285	.0363	-.0732	.0629	-.0065	-.0634	-.1458	.0607
	(.0119)	(.0494)	(.0214)	(.0293)	(.0347)	(.0384)	(.0187)	(.0947)	(.0218)	(.0425)	(.0206)	(.0760)	(.4532)	(.1123)
CHICKN	.0042	-.0132	.0298	.0078	.0324	.0025	-.0120	.1496	.0064	-.0215	.0117	.0714	-.9546	.3645
	(.0065)	(.0274)	(.0167)	(.0100)	(.0100)	(.0112)	(.0152)	(.0684)	(.0166)	(.0351)	(.0167)	(.0276)	(.2277)	(.0863)
TURKEY	.0070	.0106	-.0258	-.0444	-.0533	.0469	.0632	-.0939	-.0453	-.1057	.0101	-.0106	.4765	.3196
	(.0190)	(.0809)	(.0290)	(.0308)	(.0330)	(.0367)	(.0244)	(.1234)	(.0288)	(.0707)	(.0289)	(.0905)	(.5556)	(.1691)
FISH	.0001	-.0008	.0597	-.0286	.0420	.0469	-.0242	.3826	-.0226	.0247	-.0158	.1221	.1458	.1155
	(.0216)	(.0878)	(.0326)	(.0346)	(.0388)	(.0423)	(.0256)	(.1339)	(.0258)	(.0623)	(.0260)	(.0961)	(.6221)	(.1783)
C.FISH	-.0223	-.2254	.0343	.0088	-.0744	-.0535	-.0369	.0934	-.0155	-.1205	.0203	-.0449	-.1008	.0005
	(.0232)	(.0986)	(.0306)	(.0402)	(.0453)	(.0488)	(.0235)	(.1271)	(.0346)	(.0815)	(.0345)	(.1222)	(.6993)	(.2049)
EGGS	-.0112	.0169	-.0246	.0093	-.0025	.0092	-.0051	.0487	-.0078	.0167	.0082	.0369	.0870	-.0283
	(.0040)	(.0186)	(.0082)	(.0057)	(.0059)	(.0065)	(.0077)	(.0344)	(.0089)	(.0192)	(.0087)	(.0167)	(.1227)	(.0445)
CHEESE	.0244	-.0373	-.0270	.0644	.0176	-.0149	.0172	-.0820	.0364	-.0976	.0246	.0313	-.4064	.5927
	(.0137)	(.0599)	(.0262)	(.0199)	(.0212)	(.0232)	(.0207)	(.1023)	(.0229)	(.0545)	(.0229)	(.0607)	(.3957)	(.1197)
F.MILK	-.0053	.0195	-.0111	-.0032	.0073	-.0071	-.0136	.0448	.0101	-.0278	.0196	-.0904	.3933	-.2209
	(.0054)	(.0257)	(.0108)	(.0088)	(.0081)	(.0089)	(.0083)	(.0418)	(.0090)	(.0212)	(.0086)	(.0287)	(.2081)	(.0686)
O.MILK	.0280	.0345	-.0089	.0125	-.0534	.0654	-.0138	.0699	.0008	-.0065	.0090	.2742	.3066	-.2664
	(.0233)	(.0972)	(.0266)	(.0470)	(.0529)	(.0573)	(.0223)	(.1237)	(.0271)	(.0594)	(.0251)	(.1380)	(.8070)	(.2230)
FLOUR	-.0051	.0211	.0148	.0074	-.0126	-.0010	-.0070	.0897	.0224	-.0473	.0091	.0193	.1948	-.1333
	(.0065)	(.0315)	(.0128)	(.0098)	(.0093)	(.0101)	(.0118)	(.0507)	(.0152)	(.0292)	(.0138)	(.0327)	(.2104)	(.0701)
RICE	.0421	.0536	-.0479	-.0235	.0348	.0110	.0479	-.3783	.0181	.2168	-.0398	-.0366	-.0102	-.3664
	(.0177)	(.0902)	(.0441)	(.0268)	(.0239)	(.0268)	(.0408)	(.1660)	(.0397)	(.0825)	(.0366)	(.0876)	(.6139)	(.2301)
POTATO	.0036	.0241	-.0093	.0197	-.0201	-.0170	-.0906	.2992	.0517	.0305	.0595	.0055	-.3086	.1586
	(.0106)	(.0666)	(.0350)	(.0141)	(.0114)	(.0131)	(.0333)	(.1406)	(.0446)	(.0754)	(.0416)	(.0434)	(.4531)	(.2225)
BUTTER	-.0168	.2184	-.0332	-.0158	.0767	.0267	-.0015	-.0298	.0508	-.0810	.0322	-.1435	.4401	.0227
	(.0196)	(.0885)	(.0277)	(.0378)	(.0356)	(.0441)	(.0209)	(.1170)	(.0285)	(.0719)	(.0277)	(.1367)	(.6073)	(.1915)
MARGAR	.0368	-.0682	-.0223	.0095	-.0348	.0884	-.0053	-.0090	.0255	.0177	-.0115	.1250	-.6436	.1112
	(.0156)	(.0607)	(.0168)	(.0310)	(.0394)	(.0447)	(.0135)	(.0804)	(.0153)	(.0344)	(.0140)	(.0824)	(.4801)	(.1073)
O.FATS	-.0146	.0002	-.0032	.0015	.0171	-.0139	-.0134	.1554	.0308	-.0621	-.0092	-.0214	-.1947	.3691
	(.0057)	(.0309)	(.0159)	(.0103)	(.0104)	(.0128)	(.0123)	(.0703)	(.0183)	(.0333)	(.0163)	(.0311)	(.1996)	(.0531)
APPLES	.0493	-.0082	.0266	-.0686	.0688	.0873	.0907	-.2487	-.0249	.1146	.0504	.1048	.1997	-.3514
	(.0186)	(.0874)	(.0481)	(.0354)	(.0311)	(.0309)	(.0384)	(.1818)	(.0459)	(.0892)	(.0440)	(.1051)	(.6831)	(.2126)
ORANGE	.0253	.1643	-.0976	.0015	.0369	.0770	.0328	-.2441	-.0681	.0473	-.0207	.0874	.3879	.4866
	(.0180)	(.0863)	(.0499)	(.0378)	(.0349)	(.0337)	(.0436)	(.1981)	(.0552)	(.0884)	(.0520)	(.1023)	(.7338)	(.2587)
BANANA	-.0229	.0719	.0149	-.0047	.0813	.1431	-.0362	-.0013	-.0348	-.0781	-.0404	.2453	.1276	-.0429
	(.0228)	(.0988)	(.0454)	(.0477)	(.0454)	(.0442)	(.0332)	(.1695)	(.0365)	(.0907)	(.0360)	(.1369)	(.7410)	(.1899)
GRAPES	-.0735	-.1178	.1477	.0440	-.1147	-.2295	.0556	.2340	-.0544	-.1529	-.0047	.2128	-.0071	.4407
	(.0426)	(.1858)	(.0641)	(.0837)	(.0728)	(.0718)	(.0482)	(.2470)	(.0447)	(.1086)	(.0428)	(.2207)	(1.2223)	(.3263)

See note at end of table.

Disaggregated Food Demand System for the United States—Continued

Quantity \ Price	BEEF.V	PORK	O.MEAT	CHICKN	TURKEY	FISH	C.FISH	EGGS	CHEESE	F.MILK	O.MILK	FLOUR	RICE	POTATO
GRAFRU	−0.2245	−0.0050	0.3819	0.5516	−0.2633	0.2321	0.0256	−0.2248	−0.2377	0.9963	−0.2977	−0.1945	−0.2033	0.0455
	(.1900)	(.1120)	(.1607)	(.1231)	(.0896)	(.1051)	(.1103)	(.0871)	(.1235)	(.3158)	(.1109)	(.3480)	(.1401)	(.0830)
O.FRUT	.0285	−.1439	−.1119	−.1356	−.1599	−.1887	.3587	.3615	.0867	−.1652	−.2262	−.3790	.0234	.1277
	(.1392)	(.0885)	(.1568)	(.1075)	(.0819)	(.0965)	(.1053)	(.0747)	(.1092)	(.2631)	(.1169)	(.2877)	(.1109)	(.0592)
LETTUC	−.0632	−.1657	.1530	.0954	−.0040	−.0416	.0567	−.0409	−.0513	.1924	.1111	.2484	.0059	−.0471
	(.0710)	(.0446)	(.0538)	(.0514)	(.0399)	(.0454)	(.0456)	(.0422)	(.0610)	(.1103)	(.0409)	(.1434)	(.0592)	(.0338)
TOMATO	−.1684	−.0683	.2535	.0768	.0394	−.1280	.1856	.0315	−.1632	.4793	.0422	−.0544	−.0143	−.0148
	(.0669)	(.0433)	(.0795)	(.0547)	(.0485)	(.0567)	(.0640)	(.0444)	(.0670)	(.1223)	(.0628)	(.1526)	(.0593)	(.0296)
CELERY	.1449	−.0261	−.3239	.1687	−.1459	−.1536	.2188	.0703	.1900	.3550	−.1137	−.3944	.1181	.0563
	(.0961)	(.0628)	(.1437)	(.0752)	(.0685)	(.0829)	(.0978)	(.0602)	(.0907)	(.1674)	(.1041)	(.1985)	(.0750)	(.0336)
ONIONS	−.4968	.0168	.3085	−.0318	.0795	−.1119	.1117	.0638	−.2641	−.1289	.0008	.0844	.2043	−.0849
	(.1567)	(.0967)	(.1041)	(.0979)	(.0791)	(.0881)	(.0911)	(.0855)	(.1231)	(.2084)	(.0768)	(.2704)	(.1126)	(.0645)
CARROT	.1907	−.1422	.0249	.4950	−.1294	−.3808	−.0306	−.2042	−.1844	−.8148	.2116	−.2094	.3159	.1133
	(.2199)	(.1386)	(.2247)	(.1534)	(.1379)	(.1513)	(.1686)	(.1293)	(.1887)	(.3990)	(.1807)	(.5011)	(.1973)	(.0968)
CABAGE	−.0912	.0261	−.0878	.0648	.0301	.0009	−.0924	−.2101	.2083	−.1977	.1116	−.1940	.2374	.0177
	(.1263)	(.0796)	(.1176)	(.0935)	(.0784)	(.0910)	(.0970)	(.0764)	(.1151)	(.2057)	(.0925)	(.2541)	(.0996)	(.0489)
O.VEGE	.0064	.0488	−.1130	−.0278	.0066	−.0008	−.1406	.0455	−.0456	.1028	.0196	.1155	.0435	.0164
	(.0897)	(.0553)	(.0726)	(.0589)	(.0497)	(.0553)	(.0613)	(.0527)	(.0749)	(.1462)	(.0576)	(.1830)	(.0757)	(.0460)
JUICE	−.0628	−.1846	−.1132	.1409	−.0374	.0836	.0466	−.1670	−.0787	−.1641	−.0143	.1747	−.0949	−.0164
	(.1445)	(.0884)	(.0716)	(.0816)	(.0405)	(.0465)	(.0432)	(.0528)	(.0744)	(.1391)	(.0358)	(.1691)	(.0842)	(.0549)
C.TOMA	−.0202	−.0233	.1125	.0599	−.1023	−.0680	.0191	.0911	.2988	−.0825	.0258	.1443	−.0760	.0494
	(.1191)	(.0745)	(.1598)	(.0798)	(.0703)	(.0808)	(.0929)	(.0596)	(.0923)	(.1852)	(.1036)	(.2115)	(.0838)	(.0361)
C.PEAS	−.3458	−.1962	.5188	.4912	−.2309	.1861	−.3266	−.0532	.1558	.2823	−.2241	−.5234	.2047	−.0982
	(.2221)	(.1374)	(.3591)	(.1520)	(.1431)	(.1719)	(.1985)	(.1182)	(.1868)	(.3251)	(.2210)	(.3812)	(.1417)	(.0557)
COCKTL	.1876	.0417	.0431	.0469	.2635	.2696	−.3062	.2321	−.1713	−.3832	.3537	−.0680	.0823	−.1085
	(.3191)	(.1979)	(.5165)	(.2203)	(.2068)	(.2437)	(.2784)	(.1696)	(.2664)	(.4649)	(.3114)	(.5353)	(.2061)	(.0830)
D.BEAN	.0700	.1745	.0342	−.0237	.0332	−.0140	−.0209	−.0173	.0187	−.0796	−.0085	−.0469	.0327	−.0551
	(.0756)	(.0439)	(.0238)	(.0283)	(.0130)	(.0140)	(.0127)	(.0188)	(.0224)	(.0408)	(.0114)	(.0594)	(.0298)	(.0199)
O.PRFV	.1005	.0062	.0088	.0655	−.0126	.0493	.0110	.0236	−.0215	.0398	.0072	.0965	−.0686	.0422
	(.0636)	(.0376)	(.0290)	(.0307)	(.0158)	(.0176)	(.0165)	(.0203)	(.0267)	(.0496)	(.0153)	(.0614)	(.0291)	(.0203)
SUGAR	.0689	−.0366	−.0198	.0059	−.0045	−.0022	−.0016	−.0031	.0115	.0104	.0001	.0259	.0025	.0075
	(.0223)	(.0125)	(.0062)	(.0069)	(.0034)	(.0031)	(.0042)	(.0049)	(.0055)	(.0098)	(.0031)	(.0171)	(.0064)	(.0059)
SWEET	−.0645	.0686	.0487	−.0214	−.0331	.0084	−.0389	.0252	−.0612	−.0842	−.0023	−.1437	.0942	.0115
	(.0790)	(.0473)	(.0325)	(.0393)	(.0226)	(.0204)	(.0264)	(.0283)	(.0355)	(.0628)	(.0183)	(.0882)	(.0361)	(.0271)
COFFEE	.0226	.0021	−.0057	.0163	.0040	−.0057	.0072	.0126	.0197	.0598	.0025	.0272	−.0206	.0241
	(.0589)	(.0345)	(.0177)	(.0210)	(.0103)	(.0095)	(.0125)	(.0144)	(.0167)	(.0285)	(.0087)	(.0466)	(.0179)	(.0167)
FRZN.D	−.0664	−.0645	−.0451	.0767	−.0026	.0375	−.0136	.0504	.0210	−.2530	.0785	.0522	−.0158	.0021
	(.0424)	(.0249)	(.0543)	(.0288)	(.0270)	(.0294)	(.0369)	(.0229)	(.0369)	(.0792)	(.0397)	(.0923)	(.0357)	(.0146)
N.FOOD	−.0257	−.0130	−.0053	−.0118	−.0005	−.0015	−.0022	−.0086	−.0038	−.0144	−.0018	−.0173	−.0036	−.0027
	(.0041)	(.0024)	(.0023)	(.0017)	(.0012)	(.0014)	(.0015)	(.0012)	(.0017)	(.0041)	(.0017)	(.0043)	(.0018)	(.0011)
WEIGHT	.0299	.0171	.0040	.0059	.0017	.0017	.0017	.0078	.0034	.0156	.0016	.0160	.0023	.0019

See note at end of table.

Disaggregated Food Demand System for the United States—Continued

Quantity \ Price	BUTTER	MARGAR	O.FATS	APPLES	ORANGE	BANANA	GRAPES	GRAFRU	O.FRUT	LETTUC	TOMATO	CELERY	ONIONS	CARROT
GRAFRU	–0.1302	0.1752	–0.2274	0.2828	–0.0498	–0.2244	–0.1955	–0.2191	–0.6022	–0.0367	–0.0965	–0.0239	–0.1835	0.0291
	(.1013)	(.0550)	(.1409)	(.1491)	(.1535)	(.1233)	(.0937)	(.1067)	(.4243)	(.0712)	(.0713)	(.0213)	(.0470)	(.0552)
O.FRUT	.3195	–.1598	.2886	–.0229	.2019	.1055	.2840	–.1098	–.2357	.1467	.2032	–.0979	.1434	–.0322
	(.0908)	(.0617)	(.1198)	(.1624)	(.1823)	(.1322)	(.0966)	(.0776)	(.5471)	(.0661)	(.0662)	(.0238)	(.0434)	(.0535)
LETTUC	–.1079	–.0119	.0091	–.0393	–.0144	–.0212	.0170	–.0104	.2285	–.1371	.0148	.0409	–.0230	.0881
	(.0451)	(.0201)	(.0633)	(.0400)	(.0409)	(.0357)	(.0274)	(.0205)	(.1036)	(.0656)	(.0383)	(.0180)	(.0290)	(.0366)
TOMATO	–.1350	.0755	–.1791	–.1438	–.0784	.0279	.0038	–.0308	.3523	.0161	–.5584	–.0026	–.0163	.0220
	(.0610)	(.0339)	(.0700)	(.0455)	(.0420)	(.0424)	(.0313)	(.0228)	(.1156)	(.0426)	(.0624)	(.0235)	(.0250)	(.0399)
CELERY	.0769	–.0085	–.1086	.1932	.2072	.0088	–.0041	–.0285	–.6431	.1708	–.0094	–.2516	.0021	–.0179
	(.0839)	(.0615)	(.0988)	(.0490)	(.0551)	(.0539)	(.0360)	(.0255)	(.1557)	(.0751)	(.0884)	(.0636)	(.0437)	(.0728)
ONIONS	–.1622	–.0210	–.0707	.0624	–.3341	–.1773	–.0013	–.1500	.6395	–.0655	–.0411	.0015	–.1964	–.0327
	(.0841)	(.0385)	(.1116)	(.0780)	(.0776)	(.0666)	(.0511)	(.0385)	(.1938)	(.0826)	(.0642)	(.0298)	(.0693)	(.0639)
CARROT	.0024	–.1302	.0701	.2542	.1632	–.2186	–.0026	.0345	–.2067	.3610	.0818	–.0173	–.0467	–.0388
	(.1792)	(.0950)	(.2071)	(.1258)	(.1237)	(.1210)	(.0956)	(.0648)	(.3433)	(.1497)	(.1466)	(.0712)	(.0916)	(.1816)
CABAGE	–.0726	.1157	–.2494	.1815	.0964	–.0656	–.0875	.0312	–.1898	.2594	.3931	.0967	.0235	–.0537
	(.0856)	(.0488)	(.0987)	(.0685)	(.0676)	(.0655)	(.0510)	(.0356)	(.1876)	(.0734)	(.0724)	(.0365)	(.0451)	(.0679)
O.VEGE	.1417	–.0320	.0012	–.0055	.0923	.0305	–.0209	.0318	–.2789	.0409	.0182	–.0145	.0774	.0070
	(.0576)	(.0283)	(.0805)	(.0480)	(.0483)	(.0424)	(.0331)	(.0246)	(.1274)	(.0578)	(.0495)	(.0213)	(.0370)	(.0443)
JUICE	–.0511	–.0249	–.0243	.0309	–.1251	.0131	.0595	–.0729	.0277	.0063	–.0110	–.0011	.0856	–.0004
	(.0410)	(.0178)	(.0938)	(.0600)	(.0635)	(.0443)	(.0259)	(.0333)	(.1249)	(.0451)	(.0377)	(.0100)	(.0302)	(.0303)
C.TOMA	–.0397	.0156	.0117	–.1417	.0026	–.0085	.0289	–.0770	.1583	–.0167	.0417	.0240	–.0004	.0284
	(.0915)	(.0536)	(.1001)	(.0721)	(.0788)	(.0760)	(.0554)	(.0404)	(.2166)	(.0525)	(.0725)	(.0244)	(.0351)	(.0529)
C.PEAS	.3516	–.1145	.3146	.2653	.1458	.2455	–.1440	.0160	–.6776	.0359	–.2436	.0849	.0197	.1144
	(.1634)	(.1293)	(.1910)	(.1206)	(.1378)	(.1375)	(.0915)	(.0640)	(.3922)	(.0720)	(.1160)	(.0489)	(.0496)	(.0849)
COCKTL	.1578	.3766	–.3346	.4377	.3951	.5619	–.3750	.0673	–1.1184	–.0973	–.1011	.1094	.0729	.0196
	(.2634)	(.1907)	(.3051)	(.1557)	(.1732)	(.1738)	(.1173)	(.0818)	(.4802)	(.1121)	(.1640)	(.0627)	(.0750)	(.1191)
D.BEAN	–.0019	–.0027	–.0318	.0418	.0158	–.0142	.0085	.0029	–.0447	–.0093	–.0057	–.0006	.0177	.0065
	(.0118)	(.0054)	(.0278)	(.0183)	(.0212)	(.0124)	(.0075)	(.0099)	(.0375)	(.0134)	(.0112)	(.0030)	(.0091)	(.0091)
O.PRFV	–.0051	–.0015	.0825	–.0300	–.0287	–.0009	.0086	.0002	.0240	–.0094	.0044	.0031	–.0227	–.0006
	(.0159)	(.0078)	(.0382)	(.0208)	(.0231)	(.0152)	(.0092)	(.0116)	(.0440)	(.0156)	(.0137)	(.0039)	(.0105)	(.0107)
SUGAR	.0067	.0027	.0194	–.0029	–.0063	–.0027	–.0016	–.0036	.0010	.0014	–.0079	–.0017	.0006	.0013
	(.0036)	(.0014)	(.0092)	(.0049)	(.0060)	(.0030)	(.0015)	(.0022)	(.0091)	(.0034)	(.0029)	(.0007)	(.0022)	(.0020)
SWEET	–.0272	.0045	–.0809	.0324	.0147	–.0174	–.0139	–.0029	.0378	–.0408	.0318	.0050	–.0218	–.0252
	(.0244)	(.0083)	(.0451)	(.0255)	(.0258)	(.0203)	(.0101)	(.0130)	(.0526)	(.0221)	(.0186)	(.0047)	(.0140)	(.0127)
COFFEE	.0121	–.0031	–.0120	.0155	–.0062	–.0103	–.0003	–.0050	.0255	.0254	–.0170	–.0028	–.0055	–.0073
	(.0105)	(.0038)	(.0248)	(.0141)	(.0170)	(.0090)	(.0044)	(.0065)	(.0254)	(.0104)	(.0087)	(.0021)	(.0067)	(.0058)
FRZN.D	–.0453	.0284	–.0245	.0274	.0245	.0511	.0186	.0318	–.1216	.0042	.0233	.0159	.0020	.0003
	(.0432)	(.0186)	(.0394)	(.0280)	(.0278)	(.0285)	(.0191)	(.0162)	(.0791)	(.0221)	(.0302)	(.0087)	(.0151)	(.0203)
N.FOOD	–.0011	–.0024	–.0076	–.0020	–.0003	–.0013	–.0004	–.0002	–.0034	–.0034	–.0022	–.0005	–.0002	–.0002
	(.0014)	(.0008)	(.0018)	(.0013)	(.0014)	(.0011)	(.0008)	(.0007)	(.0035)	(.0009)	(.0008)	(.0003)	(.0006)	(.0007)
WEIGHT	.0018	.0013	.0072	.0015	.0015	.0012	.0005	.0005	.0030	.0019	.0017	.0004	.0007	.0005

See note at end of table.

Disaggregated Food Demand System for the United States—Continued

Quantity \ Price	CABAGE	O.VEGE	JUICE	C.TOMA	C.PEAS	COCKTL	D.BEAN	O.PRFV	SUGAR	SWEET	COFFEE	FRZN.D	N.FOOD	EXPEND
GRAFRU	0.0234	0.1617	−0.1626	−0.1053	0.0115	0.0375	0.0177	0.0069	−0.1040	−0.0316	−0.0453	0.3307	0.3206	0.4588
	(.0270)	(.1254)	(.0747)	(.0553)	(.0462)	(.0454)	(.0582)	(.2827)	(.0580)	(.1270)	(.0565)	(.1702)	(.9733)	(.2636)
O.FRUT	−.0264	−.2583	.0131	.0405	−.0893	−.1134	−.0451	.1199	.0071	.0689	.0428	−.2313	.3008	−.3401
	(.0261)	(.1188)	(.0512)	(.0543)	(.0519)	(.0488)	(.0403)	(.1966)	(.0438)	(.0942)	(.0407)	(.1518)	(.9373)	(.2360)
LETTUC	.0563	.0599	.0051	−.0062	.0075	−.0154	−.0146	−.0609	.0048	−.1162	.0630	.0115	−.7115	.2344
	(.0160)	(.0846)	(.0290)	(.0207)	(.0149)	(.0179)	(.0226)	(.1091)	(.0261)	(.0621)	(.0260)	(.0664)	(.3723)	(.1154)
TOMATO	.0950	.0291	−.0071	.0185	−.0563	−.0179	−.0104	.0362	−.0755	.0964	−.0492	.0756	−.4466	.4619
	(.0175)	(.0805)	(.0270)	(.0318)	(.0268)	(.0291)	(.0210)	(.1065)	(.0247)	(.0582)	(.0242)	(.1011)	(.4024)	(.0904)
CELERY	.0879	−.0882	−.0019	.0399	−.0735	−.0728	−.0027	.0982	−.0581	.0575	−.0298	.1994	−.0710	.1632
	(.0332)	(.1303)	(.0268)	(.0402)	(.0424)	(.0418)	(.0212)	(.1141)	(.0229)	(.0551)	(.0223)	(.1097)	(.5597)	(.1501)
ONIONS	.0144	.3230	.1581	.0001	.0117	.0333	.0866	−.4461	.0074	−.1760	−.0395	.0167	.6478	.1603
	(.0280)	(.1545)	(.0554)	(.0393)	(.0293)	(.0341)	(.0439)	(.2097)	(.0476)	(.1119)	(.0481)	(.1295)	(.7008)	(.2045)
CARROT	−.0479	.0432	.0004	.0464	.0972	.0131	.0471	−.0058	.0399	−.2887	−.0735	.0052	.7146	−.1529
	(.0605)	(.2654)	(.0796)	(.0851)	(.0719)	(.0777)	(.0624)	(.3057)	(.0606)	(.1452)	(.0599)	(.2494)	(1.2275)	(.3365)
CABAGE	−.0385	−.2547	−.0186	.0237	−.0168	.0278	−.0127	.1463	.0333	−.2403	.0711	.2135	.1400	−.3767
	(.0405)	(.1334)	(.0414)	(.0433)	(.0368)	(.0410)	(.0323)	(.1597)	(.0368)	(.0886)	(.0359)	(.1367)	(.6426)	(.1577)
O.VEGE	−.0382	−.2102	−.0667	−.0157	.0226	.0260	−.0785	.1037	−.0581	.1600	−.0685	.0116	−.2383	.2837
	(.0199)	(.1436)	(.0333)	(.0278)	(.0214)	(.0246)	(.0258)	(.1232)	(.0282)	(.0673)	(.0280)	(.0885)	(.4745)	(.1526)
JUICE	−.0069	−.1540	−.5612	.0066	.0127	.0139	−.0441	.2572	.0630	.0801	−.0200	−.1298	−.0676	1.1254
	(.0140)	(.0758)	(.1006)	(.0306)	(.0207)	(.0278)	(.0615)	(.2281)	(.0589)	(.1010)	(.0548)	(.0642)	(.5608)	(.2505)
C.TOMA	.0127	−.0597	.0112	−.3811	.2490	−.0067	−.0588	.1562	.0088	.0274	−.0164	−.1150	−1.0712	.7878
	(.0240)	(.1035)	(.0500)	(.1072)	(.0638)	(.0818)	(.0418)	(.2087)	(.0348)	(.0715)	(.0325)	(.1425)	(.6441)	(.1454)
C.PEAS	−.0179	.1593	.0404	.4728	−.6926	.0745	−.0261	−.2508	.0497	−.1229	.0862	−.1451	−.0418	.3295
	(.0386)	(.1512)	(.0643)	(.1211)	(.1746)	(.1747)	(.0544)	(.3250)	(.0455)	(.0895)	(.0386)	(.2303)	(1.1465)	(.1616)
COCKTL	.0375	.2375	.0565	−.0166	.0967	−.7323	.0801	−.2446	.0333	−.1130	.0397	.3094	−.9559	.7354
	(.0560)	(.2255)	(.1121)	(.2017)	(.2271)	(.3677)	(.0914)	(.5729)	(.0731)	(.1361)	(.0597)	(.3202)	(1.6794)	(.2788)
D.BEAN	−.0020	−.0689	−.0162	−.0136	−.0033	.0076	−.1248	.1010	.0117	.0309	−.0047	−.0400	−.5424	.5852
	(.0042)	(.0223)	(.0235)	(.0098)	(.0067)	(.0087)	(.0313)	(.0795)	(.0255)	(.0342)	(.0233)	(.0195)	(.2142)	(.1167)
O.PRFV	.0041	.0207	.0242	.0089	−.0075	−.0055	.0242	−.2089	.0247	−.0861	.0083	.0459	−.8558	.6311
	(.0050)	(.0257)	(.0208)	(.0117)	(.0096)	(.0130)	(.0190)	(.0921)	(.0264)	(.0353)	(.0216)	(.0236)	(.2015)	(.0675)
SUGAR	.0009	−.0100	.0069	.0012	.0016	.0010	.0050	.0336	−.0521	−.0075	.0104	.0038	.1130	−.1789
	(.0011)	(.0055)	(.0050)	(.0018)	(.0012)	(.0015)	(.0057)	(.0244)	(.0172)	(.0135)	(.0084)	(.0068)	(.0825)	(.0627)
SWEET	−.0188	.0844	.0198	.0045	−.0089	−.0062	.0207	−.2054	−.0214	−.0045	−.0932	.0217	.5967	−.0928
	(.0069)	(.0351)	(.0232)	(.0100)	(.0066)	(.0077)	(.0206)	(.0881)	(.0359)	(.0895)	(.0318)	(.0411)	(.2741)	(.1241)
COFFEE	.0060	−.0394	−.0039	−.0021	.0072	.0027	−.0016	.0302	.0274	−.1052	−.1868	−.0220	.0185	.0937
	(.0031)	(.0163)	(.0141)	(.0051)	(.0032)	(.0038)	(.0157)	(.0602)	(.0255)	(.0357)	(.0294)	(.0174)	(.1739)	(.1027)
FRZN.D	.0153	.0064	−.0264	−.0145	−.0099	.0166	−.0206	.1150	.0069	.0197	−.0179	−.1212	.1257	.0111
	(.0099)	(.0430)	(.0137)	(.0186)	(.0159)	(.0170)	(.0109)	(.0550)	(.0168)	(.0383)	(.0145)	(.0848)	(.2504)	(.0580)
N.FOOD	−.0006	−.0033	−.0002	−.0013	−.0004	−.0005	−.0040	−.0212	−.0175	.0029	−.0051	−.0058	−.9875	1.1873
	(.0003)	(.0017)	(.0009)	(.0006)	(.0006)	(.0006)	(.0009)	(.0034)	(.0017)	(.0019)	(.0011)	(.0018)	(.0125)	(.0043)
WEIGHT	.0004	.0027	.0012	.0007	.0004	.0003	.0032	.0132	.0142	.0053	.0047	.0057	.8137	1.0000

Note: For each pair of estimates, the upper part is the constrained estimated elasticity, and the lower part (in parentheses) is the standard error. The abbreviated notations are BEEF.V (beef and veal), O.MEAT (other meats), CHICKN (chicken), C.FISH (canned and cured fish), F.MILK (fluid milk), O.MILK (evaporated and dry milk), MARGAR (margarine), O.FATS (other fats and oils), GRAFRU (grapefruits), O.FRUT (other fresh fruits), LETTUC (lettuce), CABAGE (cabbage), O.VEGE (other fresh vegetables), JUICE (fruit juice), C.TOMA (canned tomatoes), C.PEAS (canned peas), COCKTL (canned fruit cocktail), D.BEAN (dried beans, peas, and nuts), O.PRFV (other processed fruits and vegetables), SWEET (sweeteners), COFFEE (coffee and tea), FRZN.D (ice cream and other frozen dairy products), N.FOOD (nonfood), and EXPEND (expenditures).

total food P. elast. −.2397

Exp. elast. = .2566

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