FOOD DEMAND ANALYSIS

Implications for Future Consumption

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PROJECTING AGGREGATE FOOD EXPENDITURES TO THE YEAR 2000

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ABSTRACT

This study develops and implements an econometric model for projecting food and related consumption expenditures. The model is a block recursive system in which the budget shares are projected from a set of equations comprising a complete inverse demand system, and the quantities are determined through lagged supply response relationships. The estimated model is subjected to various simulations over the sample period to evaluate its performance. Its reliability is characterized by the small forecasting error found in these simulations. The estimated model is then used for projecting aggregate food expenditures.

Keywords: Projections; Food expenditure; Expenditure share; Inverse demand system.

INTRODUCTION

A major purpose of the demand research conducted under the S-165 Regional Committee on U.S. Food Demand and Consumption is to facilitate and enhance making projections of U.S. food consumption and expenditure. In fact, this objective provided the major motivation for the theme of the current symposium.

Much of the demand work under S-165 has been based on surveys of food consumption and expenditure and, consequently, has focused on estimating Engel relations that show the effects of various socio-economic and demographic factors. Because of the cross-sectional nature of the surveys which are often characterized as being taken "at a point in time," relative prices are taken as constant and do not appear explicitly in the demand relations.[2] Given the long history, development, and use of these procedures, there is little reason to question their usefulness for deriving parameter estimates of Engel relations. Similarly, given competent application, there is little reason to question the rather substantial value and practical usefulness of the estimated parameters, per se.

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1 The authors are agricultural economists with the National Economics Division, Economic Research Service, U.S. Department of Agriculture.

2 We know there are exceptions in which researchers have tried to estimate price response parameters using such survey data.

However, for the specific purpose of making projections, there are sound reasons for questioning the appropriateness of these estimated Engel relations. There are two basic issues. One issue deals with the inherent partial and restrictive nature of the estimated relations as a representation of the complete demand structure. The other issue concerns the question of what constitutes a complete model for projections purposes.

Briefly, on the first issue, for a set of n commodities the theory of consumer demand leads to the specification of demand for a specific commodity as an n+1 dimensional surface in prices and income. Thus, there is potentially a different quantity-income relation--a trace on the surface, if you will--for each combination of relative prices. So, in essence, when we estimate an Engel relation at a point in time for a given set of relative prices, we have only one of the relations out of the potential set that exists at that given point in time, and that relationship is a partial demand relationship in the sense that it is conditional on a set of (unknown) prices. Consequently, some very stringent assumptions are required if we use such a relationship to project in the time dimension: (1) the relationship remains invariant through time, and (2) the set of relative prices remains unchanged over the projection period. The latter assumption raises further questions about the second issue, namely, the completeness of the model. Perhaps this problem can be most easily brought into focus by a question or two. If we have only the demand side in a supply-demand framework, how can we determine an equilibrium? Or, if relative prices don't change, how can the quantity consumed change? Of course, the answer is--by assumption: supply is perfectly elastic, or shifts in supply coincide exactly with changes in quantities consumed.

Thus, in addition to the rather restrictive condition that "projections" in the time dimension must be made from a time-invariant, partial demand relationship estimated at a single point in time, the projections must be generated on the additional assumption that relative prices remain unchanged over the projection period. Based on our experience and that of other demand studies,it seems quite clear that, in terms of magnitude, the overwhelming determinants of changes in per capita consumption are the set of relative prices and income. Consequently, both are essential factors that need to be incorporated in projecting consumption over time.

There have been a number of attempts, using time series data, to estimate aggregate demand functions for food. The studies by Waugh (1964), and Girshick and Haavelmo (1947) are noteworthy examples. Waugh estimated food consumption as a function of deflated food prices and per capita income. However, such a model cannot be used alone for projecting food expenditures because the endogeneity of food prices is ignored. Girshick and Haavelmo clearly recognized the importance of supply in analyzing the aggregate demand for food. But, perhaps because their primary focus was on the identification problem, their model contained only a partial demand specification which did not account for the economic interdependence inherent in the consumers' budget allocation between the various food and nonfood items.

In the following we outline and implement a prototype model for making projections of food expenditures, based on time-series data, that builds upon the earlier work cited. In the process we attempt to alleviate at least some of the aforementioned problems. Although our primary objective is on projections, major emphasis is on the demand component of the model, where we introduce a complete demand system. To make long-run projections feasible, we introduce a supply response specification, although it is a rather simplistic one. In order to keep things manageable at this stage of development, the model is intentionally very aggregative. Total personal consumption expenditures are grouped into three categories: (1) food consumed at home, (2) food consumed away from home, and (3) nonfood. The model is estimated using quarterly data on U.S. personal consumption expenditures. Subsequently, the estimated model is subjected to various simulations, both for evaluating model performance over the sample period and for projecting aggregate food expenditures to the year 2000.

MODEL SPECIFICATIONS

Before we can further specify an appropriate demand model, or introduce the supply component, it is necessary to make some assumption about the market mechanism. The basic assumptions we propose are that the quantity supplied is predetermined, and that demand determines the equilibrium price at which the predetermined quantity is purchased. To justify the endogeneity of prices in the demand-supply system, Waugh (1964) rationalized that, in competitive markets, changes in prices are generally determined by changes in quantities marketed and changes in income, not the other way around. Since it is commonly assumed that the aggregate quantity supplied becomes increasingly fixed as the time frame becomes shorter, the assumption appears more consistent with a quarterly, as opposed to annual, demand for food commodities. This general specification provides the broad prescriptive basis for the model, which includes (1) an inverse demand system in which prices are functions of predetermined quantities and income, and (2) a lagged supply response in which quantity supplied is a function of lagged price and equilibrium quantity consumed.

Demand

Let q denote an n-coordinate column vector of per capita quantities demanded, p an n-coordinate vector of their prices, $m = p'q$ the consumer's expenditure, and $U(q)$ the utility function, assumed to be nondecreasing and quasi-concave in q. The primal function for maximizing consumer utility is the following Lagrangian function:

$$\underset{q,k}{\text{Maximum}} \quad L = U(q) - k\,(\,p'q - m\,). \tag{1}$$

The necessary conditions for an optimum are obtained as

$$U_i'(q) = k\ p_i, \qquad i=1,2,..,n \tag{2a}$$

$$p'q = m. \tag{2b}$$

A solution of equations (2a) and (2b) gives the ordinary demands

$$q_i = f_i(\ p,\ m), \tag{3a}$$

or
$$q_i = g_i(\ \bar{p}\ ), \tag{3b}$$

where $\bar{p}$ is a normalized price vector defined as $\bar{p} = p/m$.

The inverse demand system can be obtained by eliminating the Lagrangian multiplier from the necessary conditions of equation (2a). Multiplying by q_i in equation (2a) and summing over n to satisfy the budget constraint of (2b), the Lagrangian multiplier is

$$k = \sum_{j=1}^{n} q_j\ U_j'(q)/m. \tag{4}$$

Substituting (4) into (2a) yields the Hotelling-Wold identity (Hotelling, 1935, and Wold, 1944), which defines the inverse demand system from a differentiable direct utility function as:

$$\bar{p}_i = U_i'(q)/\sum_{j=1}^{n} q_j\ U_j'(q). \qquad i=1,2,..,n \tag{5a}$$

Further, by using the fact that $\partial \ln U/ \partial \ln q_i = (k/U)\ p_i q_i$, is the necessary condition for an optimum in the logarithmic case, the Hotelling-Wold identity can be expressed as

$$\bar{p}_i = (\ \partial \ln U/ \partial \ln q_i\ )/[q_i \sum_{j=1}^{n} (\ \partial \ln U/ \partial \ln q_j\ )]. \tag{5b}$$

The identity can be used for deriving a wide variety of inverse demand systems (Huang, 1983). For this study, we follow Christensen et al. (1975) by specifying the utility function as a transcendental logarithmic form

$$\ln U = a_o + \sum_{i=1}^{n} a_i \ln q_i + (1/2) \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \ln q_i \ln q_j, \tag{6}$$

where $b_{ij} = b_{ji}$. Applying the Hotelling-Wold identity from (5b), the inverse demand system is obtained as follows:

$$\bar{p}_i = (a_i + \sum_{j=1}^{n} b_{ij} \ln q_j)/q_i [\sum_{j=1}^{n} (a_j + \sum_{k=1}^{n} b_{jk} \ln q_k)], \quad i=1,2,..,n. \tag{7}$$

Defining $a_m = \sum_{j=1}^{n} a_j$, $b_{mk} = \sum_{j=1}^{n} b_{jk}$, and $w_i = p_i q_i / m$, equation (7) can be simplified as

$$w_i = (a_i + \sum_{j=1}^{n} b_{ij} \ln q_j) \; / \; (a_m + \sum_{j=1}^{n} b_{mj} \ln q_j), \quad i=1,2,..,n. \tag{8}$$

In other words, the expenditure share of the i-th commodity is a non-linear function of the set of per capita quantities demanded.

Supply

Since the predetermined quantity variable in the demand component is $\ln q_t$, for convenience we use the same transformation for the supply variables. Because the supply component is based on quarterly data, we assume that a commodity is distinct from season to season (i.e., quarter to quarter), such that the desired quantity supplied in quarter t, say $\ln \overset{*}{q}_{i,t}$ is determined by the price in the same quarter of the previous year, $p_{i,t-4}$ (which is defined as the price deflated by the index of total expenditures):

$$\ln \overset{*}{q}_{i,t} = \alpha \ln p_{i,t-4} \text{ for } \alpha > 0 \qquad i=1,2,..,n. \tag{9}$$

Following the Nerlovian "rigid supply response" assumption (Nerlove 1958), the adjustment toward the desired quantity from the quantity supplied in the same season of the previous year is only gradual:

$$(\ln q_{i,t} - \ln q_{i,t-4}) = \beta (\ln \overset{*}{q}_{i,t} - \ln q_{i,t-4}), \; i=1,2,.,n, \tag{10}$$

where β is the coefficient of adjustment with value $0 < \beta < 1$.

By inserting this adjustment process into equation (9), we obtain the supply response relationship

$$\ln q_{i,t} = \alpha \; \beta \ln p_{i,t-4} + (1 - \beta) \ln q_{i,t-4}, \quad i=1,2,..,n. \tag{11}$$

Equations (8) and (11) establish a block recursive demand-supply relationship for modeling aggregate food consumption. Current quantity supplied is a function of lagged prices as well as the previous quantity supplied. The quantity previously marketed is a principal factor determining the expenditure share and price through the demand model. The model is obviously dynamic and, thus, can be used for projecting in the time dimension.

EMPIRICAL ESTIMATION RESULTS

The demand model specified in equation (8) is used for estimating the consumers' budget allocations for food consumed at home and away from home. The budget share for nonfood is deleted from direct estimation because its share is derivable from the estimated shares for food.

Each budget share equation is homogeneous of degree zero in the parameters; thus, a proportional change in a given set of the unknown parameters leaves the individual budget shares unchanged. Therefore, a normalization of the parameters is required so that the parameters can be identified. A convenient normalization choice proposed by Christensen et. al.(1975), which we also use, is to set the sum of constant terms, a_m, equal to -1.0. Hence, the empirical demand model becomes:

$$w_i = \left(a_i + \sum_{j=1}^{3} b_{ij} \ln q_j\right)/\left(-1.0 + \sum_{j=1}^{3} b_{mj} \ln q_j\right), \quad i=1,2, \qquad (12)$$

where $b_{mj} = \sum_{i=1}^{3} b_{ij}$, $b_{ij} = b_{ji}$, and the variables are defined as in equation (8).

The model is obviously nonlinear in parameters, and the parameters are constrained across equations. Consequently, constrained nonlinear estimation procedures should be employed. The idea is to minimize $e'(S^{-1} \times I_n)\, e$, in which e is a vector of residuals for the equations when stacked together, and S is a covariance matrix of the errors across the equations. The demand model estimation proceeds in two steps. First, the ordinary least squares (OLS) estimates are obtained initially by imposing S as an identity matrix. Subsequently, at each iteration it is imposed as a diagonal matrix containing estimates of the variances from the previous estimation. Second, given the OLS results as initial estimates, seemingly unrelated regression with a non-diagonal S is then performed.

For fitting the empirical model, we use the quarterly time series data on U.S. personal consumption expenditures.[3] The data set contains 107 sample observations, covering the period from the first quarter of 1959 through the third quarter of 1985. The quantity variables defined in the model are approximated by expenditures measured in 1972 constant dollars. The expenditure share variables in equation (8) are calculated on the basis of expenditures measured in current dollars. In the empirical estimation, the quantity data series are rescaled by setting the average value for the quarters in 1972 equal to one.[4]

Table 1 presents the estimation results for ordinary least squares and seemingly unrelated regression. The former took 8 iterations to reach convergence, whereas the latter took 5 iterations.[5] There are 8 independent parameters in table 1 with subscripts 1, 2, and 3, respec-

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3 Individual observations are annual per capita expenditure expressed on a quarterly basis.

4 The rescaling, which does not affect estimation of the response coefficients b_{ij}, is important because the magnitudes of the q_i vary substantially across equations, causing the moment matrix of q_i's to approach singularity.

5 The convergence criterion is set at 0.0001 for the maximum change in the estimated parameters.

Table 1 -- Estimation results for the demand model

Parameter	Ordinary least squares	Seemingly unrelated regression
a_1	-0.1398	-0.1397
	(.0005)	(.0005)
a_2	-.0410	-.0410
	(.0001)	(.0001)
b_{11}	.0274	.0268
	(.0130)	(.0131)
b_{12}	.0152	.0147
	(.0022)	(.0024)
b_{13}	.0345	.0282
	(.0149)	(.0118)
b_{22}	-.0412	-.0423
	(.0023)	(.0021)
b_{23}	.0092	.0081
	(.0040)	(.0029)
b_{33}	-.1609	-.1950
	(.0774)	(.0588)
R^2 for w_1	.94	.94
R^2 for w_2	.92	.92

Note: Figures in parentheses are the estimated standard errors. R^2's (the unadjusted coefficients of determination) are for the shares of food consumed at home (w_1), and food consumed away from home (w_2).

tively, for food consumed at home, food consumed away from home, and nonfood. We select the results obtained from the seemingly unrelated regression as the final demand model, because of the gain in statistical efficiency. Among these estimates, the standard errors of the constant terms and the coefficients for food consumed away from home are small relative to the coefficients. Larger standard errors, however, are found for the coefficients related to food consumed at home. The explanatory power for the observed budget shares appears quite good. The R^2's are more than 0.9 for both budget share equations.

It is possible to derive conventional flexibility measures on the basis of these estimated results as follows:

$$\text{Direct flexibility: } f_{ii} = -1.0 + (b_{ii}/w_i - b_{mi})/B, \qquad (13)$$

Cross flexibility: $f_{ij} = (b_{ij}/w_i - b_{mj})/B,$ (14)

where $B = a_m + \sum_{j=1}^{3} b_{mj} \ln q_j$. Accordingly, the derived flexibility is a function of the entire set of estimated coefficients, observed budget shares, and quantities. Since it is difficult to derive the statistical inference for these flexibilities and ascertain their accuracy, we do not derive these flexibilities here.

For the supply model we use the same set of quarterly data to fit equation (11). The quantity used is consistent with the demand model; that is, the index of per capita consumption, in which the average quarterly value for 1972 is equal to 1.0. The price variable is defined as the ratio of the implicit price deflator and the index of total consumption expenditure, with the average quarterly value for 1972 being equal to 1.0. On the grounds that other within-year prices could be relevant information in the supply response, they were also considered in the empirical fitting. The results indicate that the prices lagged for one and four quarters are significant in all cases. Hence the empirical model used for a commodity becomes:

$$\ln q_t = a_o + a_1 \ln p_{t-1} + a_2 \ln p_{t-4} + a_3 \ln q_{t-4} + u_t \qquad (15)$$

where u_t is a disturbance term, and variables are defined as in equation (11).

The ordinary least squares estimates are presented in the first column of table 2 for each category. The low D.W. values indicate likely serial correlation in the error terms. To improve the statistical efficiency of estimates, an autoregressive regression procedure was applied. The estimated residual of each equation in the first step is used for fitting the autoregressive process

$$u_t = b\, u_{t-1} + e_t. \qquad (16)$$

Then, the structural parameters in the supply relation are reestimated by applying an Aitken estimation procedure to incorporate the estimates of the autoregressive process. The end-results of this procedure are regarded as the final model estimates, and are presented in the second column of table 2 for each category.

According to the estimated results, as expected, the response coefficients are positive for prices, lagged four quarters. The elasticities are relatively small for food items but large for nonfood. The implied coefficients for β appearing in equation (10) are 0.70, 0.76 and 0.53 for food consumed at home, away from home, and nonfood, respectively. The response coefficients for prices, lagged one quarter, are negative in all cases. In part, the coefficients may reflect a seasonal pattern of price movements, in which a higher price in the previous quarter is accompanied by an expectation of a lower price in the current quarter, causing a decrease in quantity supplied. The explanatory power for the

Table 2 -- Estimation results for the supply model

Parameter	Food consumed at home		Food consumed away from home		Nonfood	
	OLS	AUTOREG	OLS	AUTOREG	OLS	AUTOREG
a_0	-0.0115	-0.0101	0.0126	0.0307	-0.0101	-0.0091
	(.0025)	(.0040)	(.0039)	(.0063)	(.0022)	(.0022)
a_1	-.6149	-.4638	-.8530	-.6288	-1.1354	-1.0950
	(.0580)	(.0738)	(.1258)	(.1195)	(.0572)	(.0624)
a_2	.4970	.2824	.6198	.0967	.7355	.6914
	(.0634)	(.0844)	(.1307)	(.1314)	(.1128)	(.1253)
a_3	.5638	.3004	.6765	.2431	.4730	.4677
	(.0761)	(.1086)	(.0773)	(.1043)	(.1189)	(.1320)
b		.5858		.7188		.1123
		(.0802)		(.0688)		(.0984)
R^2	.93	.80	.97	.88	.99	.99
D.W.	.83		.55		1.76	

Note: Figures in parentheses are the estimated standard errors. Estimation results are OLS for ordinary least squares, and AUTOREG for Autoregressive regression.

nonfood equation is the largest, with R^2 equal to 0.99, while the R^2 is 0.80 for food consumed at home and 0.88 for food consumed away from home.

APPLICATIONS OF THE ESTIMATED MODEL

The set of actual data provides the basis for evaluating the forecasting performance of the model. Therefore, it may be desirable to review certain characteristics of the data series prior to conducting model simulations. Two variables are especially important for our purpose. The first is per capita expenditure measured in constant dollars. This data series, reflecting the quantity consumed over the period, can be projected from the supply model directly. The second variable of particular interest is the expenditure share, which represents the consumers' budget allocation through the demand model.

The historical movements of these two data series are summarized in table 3. The per capita consumption expenditures are characterized by a rather large increase in nonfood consumption, a moderate increase in food consumed away from home, and a relatively small change in food consumed at home. It is interesting to note that food consumed at home actually decreased for the period 1974-78. The rapid increase in the relative price of food consumed at home in that period is probably responsible for such a change. In the last two decades, the share of food consumed at home decreased from about 17 to 12 percent while the expenditure shares for both food consumed away from home and nonfood have increased. To better illustrate the variation in expenditures and shares over this period, the quarterly observations for the sample period are shown in figures 1 to 6.

Simulation over the sample period

To evaluate performance of the estimated model, several simulations over the sample period have been conducted. Recall that the model is a block recursive system, in which the quantities supplied are functions of predetermined prices and quantities, and the expenditure shares are functions of current quantities supplied. This block-recursive structure of the model provides a convenient and useful means for classifying the different simulations. For the purpose of this study, the simulation is termed "structure independent" if actual quantities

Table 3 -- Average annual per capita expenditure and share

Period	Per capita expenditure at 1972 dollars				Expenditure share			
	Food at home	Food away from home	Total food	Non-food	Food at home	Food away from home	Total food	Non-food
	- Dollars per person -				- - - Percent - - -			
1959-63	419	119	538	2,007	16.52	4.08	20.60	79.40
1964-68	446	129	575	2,385	15.13	4.01	19.14	80.86
1969-73	471	139	610	2,794	14.06	4.06	18.12	81.88
1974-78	464	155	619	3,168	13.66	4.39	18.05	81.95
1979-83	494	164	658	3,502	12.84	4.40	17.24	82.76
1984-85	516	178	694	3,857	11.74	4.45	16.19	83.81

Notes: (1) The figures for 1983 are for the first three quarters. (2) The shares are calculated as the average share over the period based on the expenditure measured in current dollars.

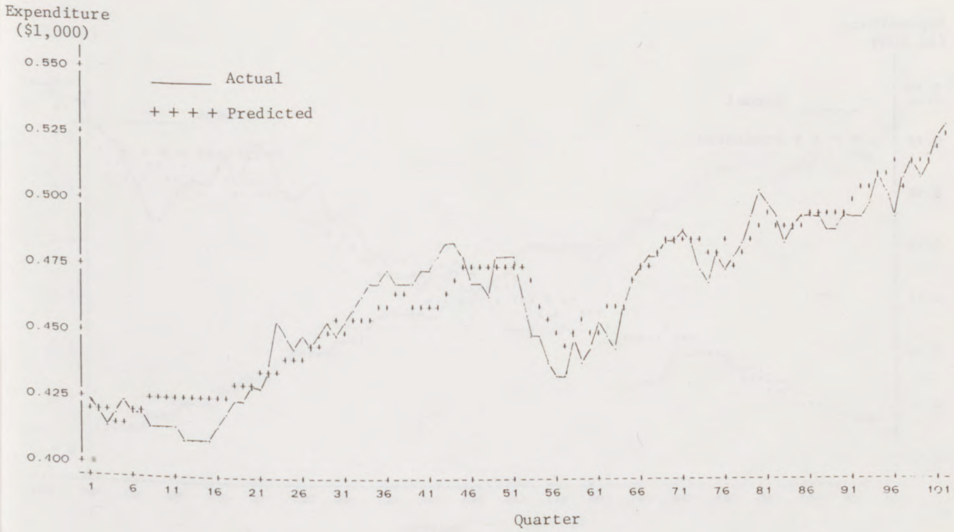

Figure 1--Food consumed at home: per capita expenditure by quarter, 1960-1985

supplied are used in the demand system to obtain projections, and "structure dependent" if projected quantities supplied are used. Similarly, the simulation is called "serial dependent" if projected prices and quantities are carried over from one quarter to the next, and "serial independent" otherwise. The following brief description and table 4 summarize five simulations covering various combinations of this dependence-independence. In each case the performance criterion used is the root-mean-square error.

Case 1 is a static simulation containing both structural and serial independence. That is, actual observations for independent variables that appear in the respective supply or demand equations are used. The forecasting performance as measured by the root-mean-square error shows that the errors are less than 3 percent for the projected per capita consumption, and the projected expenditure shares. Another static simulation is performed in case 2, in which the simulation is structure dependent but serial independent. In this simulation, the projected per capita expenditures from the supply component are used in the demand model for projecting the budget shares. The forecasting performance shows that the root-mean-square errors for the projection of budget shares are slightly larger than for case 1, because some projected errors from the supply model are incorporated in the projection of budget shares.

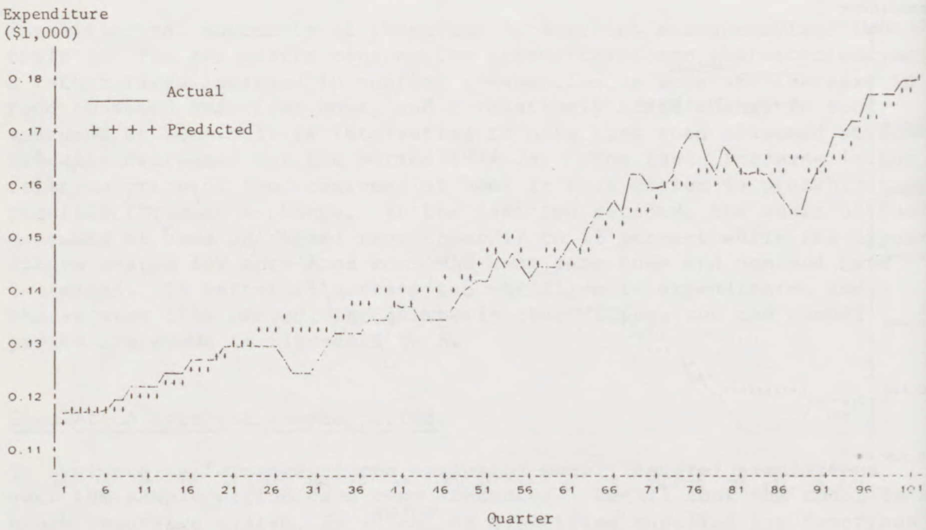

Figure 2--Food consumed away from home: per capita expenditure by quarter, 1960-1985

Case 3 is a typical dynamic simulation containing both structure and serial dependence. Under this simulation, given the initial values of endogenous variables and the time path of exogenous variables, the projected values of endogenous variables are generated sequentially. Obviously, the forecasting errors are cumulative over time, and the forecasting performance depends on the initial values chosen as a starting point. As expected, the root-mean-square errors for this case are larger than the previous static simulations. However, it is noteworthy that the errors are no more than 4 percent for any projected item. To illustrate the effects of choosing different initial values as a starting point, the dynamic simulation in case 3 is compared to cases 4 and 5 where the starting point for the simulations are the 5th, 25th, and 55th sample points, respectively. Since the observation of a dependent variable is stochastic, if a particular initial point chosen is far away from the mean value, the forecasting errors would be larger than those for an initial sample point closer to the mean value. As expected, the forecasting errors are different for each case.

Since graphic presentation of the actual and forecasted results often provides a better intuitive feel of forecasting performance, we would like to present figures for all cases, but to save space only the simulation results for case 1 are presented, in figures 1 to 6. This set of simulation results provides a basis for judging the performance of the demand and supply models in the absence of cumulative errors due to structural and serial dependence.

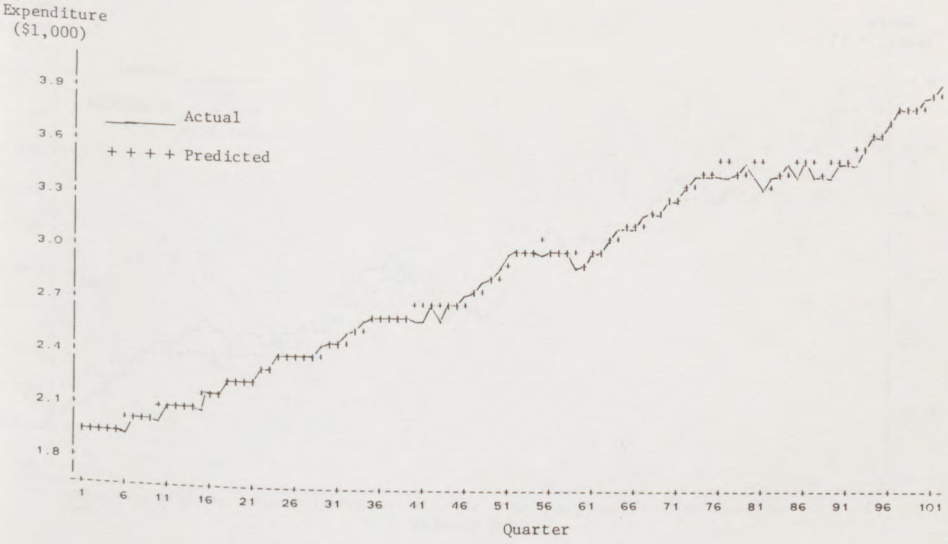

Figure 3--Nonfood: per capita expenditure by quarter, 1960-1985

In general, the forecasting performance of the model can be considered reasonably good, given that even in the worst case the root-mean-square error is less than 4 percent, and the error is even less for the food items which are of primary interest. We have confidence that the model can be used for fairly reliable projections of food consumption expenditures.

Projection to the year 2000

In accordance with our primary objective, the model is used to project food consumption expenditures to the year 2000. A dynamic simulation starting with the fourth quarter of 1985 is performed. Two exogenous variables, population and total consumption expenditures, are implicitly defined in the model. However, it is not necessary to project total consumption expenditures, largely because the price flexibility with respect to expenditure is well known to be unity. Thus, a change in expenditure will cause a proportional change in prices and no change in the projected expenditure shares and quantities supplied. For the dynamic simulation here, we need only the projected population.

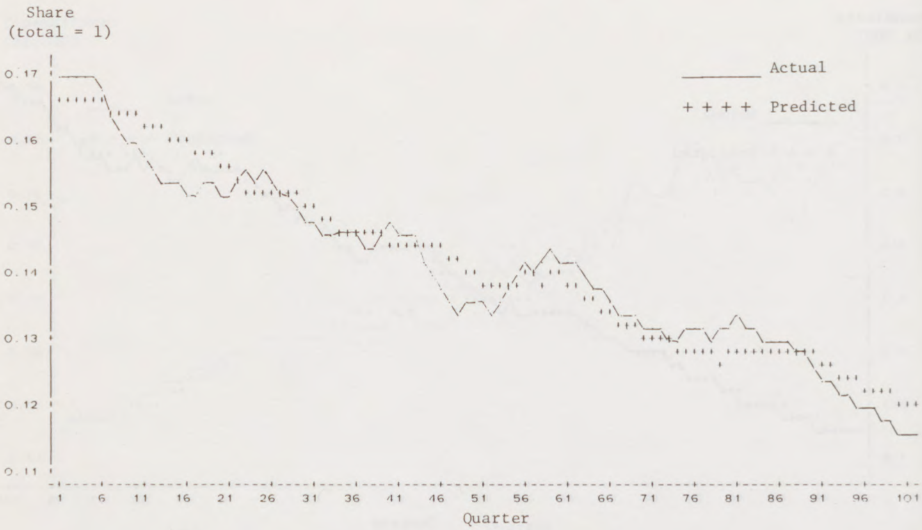

Figure 4--Food consumed at home: expenditure share by quarter, 1960-1985

Quarterly population is projected on the basis of population growth in the sample period according to the following semi-logarithmic equation:

$$\ln N_t = \underset{(0.005343)}{12.090782} + \underset{(0.000087)}{0.002783}\, t, \qquad (17)$$

where N_t is population measured in 1,000 persons; and t is the time trend, coded 1 for the first quarter of 1959. The estimation results imply the growth rate for population is 0.2786 percent per quarter, which is calculated by (Antilog 0.002783 - 1.0) x 100.

By making use of the projected population from this equation, we can generate the dynamic simulation results for quarterly per capita consumption and expenditure shares, sequentially. For convenience in presentation, these projected results are summarized in the rows (a) of table 5 for the average of those quarters starting with 1990 and at 5-year intervals thereafter.

The projected annual per capita consumption expenditures to the year 2000, measured in 1972 dollars, are \$591 for food consumed at home, \$230 for food consumed away from home, and \$6,181 for nonfood. Using 1985 actual value as a base, the corresponding percentage increases over the 15-year period are respectively, 12.79, 28.49 and 58.08 percent. These rates are consistent with the sample-period experience

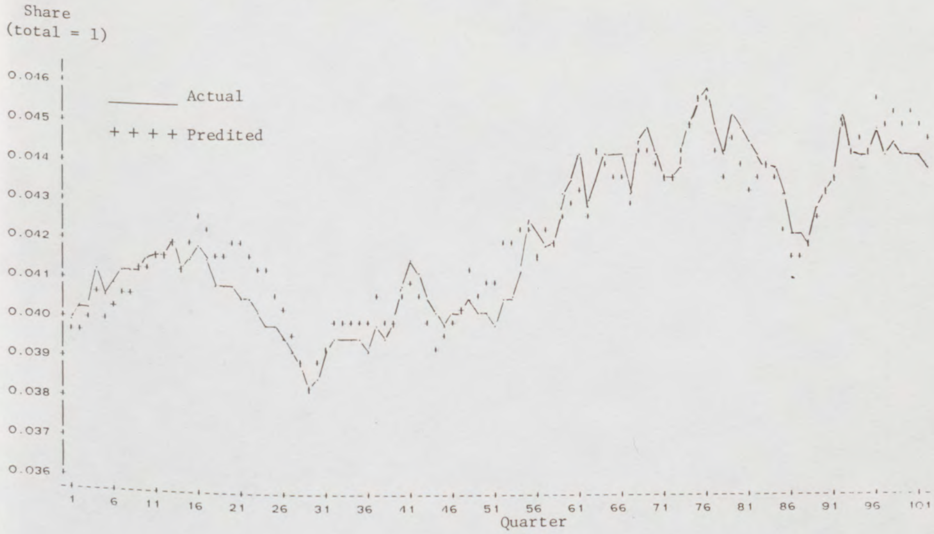

Figure 5--Food consumed away from home: expenditure share by quarter, 1960-1985

for a similar time span. Finally, the projected expenditure shares indicate that food consumed at home would decrease to 9.45 percent in the year 2000, whereas the shares for food consumed away from home and nonfood would increase to 4.67 and 85.88 percent, respectively. Again, these projected results are consistent with the sample experience.

As an alternative, we also used the middle series of projected population published by the U.S. Bureau of the Census. Because this is a semiannual series, we calculated the quarterly population as the average of the relevant semiannual figures. The simulated results are shown as row (b) of each category in table 5. The projected per capita expenditures in 1972 dollars are slightly lower than the projections in row (a). The projected expenditure shares in row (b) are slightly higher for food consumed at home, and lower for nonfood and food consumed away from home than the projections in row (a). The projected expenditure shares in row (b) are slightly higher for food consumed at home, and lower for nonfood and food consumed away from home than the projections in row (a).

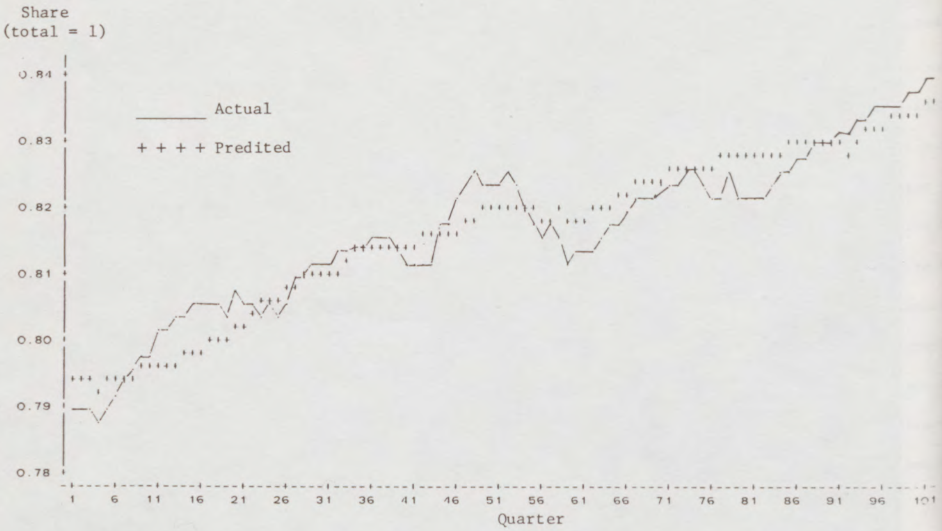

Figure 6--Nonfood: expenditure share by quarter, 1960-1985

SUMMARY

We have developed, estimated, and implemented a prototype model for making long term projections of food expenditure. A major emphasis in model specification is on the demand component, where a primary objective is to incorporate the theoretical demand properties and economic interdependence implied by the consumers' budget allocation behavior in the theory of consumer demand. Therefore, we specified and estimated a complete inverse demand system for two major food categories and one nonfood category. A rather simple, lagged-supply response specification is estimated and introduced to complete the model and determine the equilibrium values.

The model was estimated using quarterly data on personal consumption expenditures for the period 1959-85. Various simulations over the sample period are performed to assess the model's performance, and

Table 4 -- Model performance over the sample period: Root-mean-square errors

Simulation	Per capita expenditure: Food at home	Food away from home	Nonfood	Expenditure share: Food at home	Food away from home	Nonfood
	-------	-------	percent	-------	-------	-------
Static						
Case 1	1.85	2.64	0.92	2.32	1.37	0.44
Case 2	1.85	2.64	0.92	2.37	3.28	0.47
Dynamic						
Case 3	3.09	3.00	2.69	2.26	3.19	0.46
Case 4	3.21	3.21	2.67	2.34	3.35	0.48
Case 5	2.78	3.36	2.80	2.54	2.77	0.46

Notes: Root-mean-square errors are calculated by

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

in which y_t, $\overset{*}{y}_t$, and $\bar{y}$ are respectively actual values, predicted values, and sample mean.

Case 1: Actual values of independent variables are used in both the supply and the demand models.

Case 2: Actual values of independent variables are used in the supply model, while predicted values are used in the demand model.

Cases 3 to 5: Dynamic simulations start from the 5th, 25th and 55th quarters, respectively.

our assessment is that performance is fairly good. The model was subsequently used to make projections to the year 2000. The projections for all three items-food at home, food away from home, and nonfood--were quite consistent and compatible with sample period experience and appear quite reasonable, in our judgment. In general, we conclude that the prototype model, because of the several desirable characteristics incorporated and because of its empirical performance, is a prime candidate with potential for further development as a disaggregate, online, projections framework. Of course, to be of greater practical usefulness, disaggregation of the commodity categories in the model will have to be explored. And, obviously, the rather simplistic specification of the supply component will require more thorough consideration.

Table 5 -- Projected annual consumption expenditure and share for selected years

Year	Per capita expenditure at 1972 dollars				Expenditure share			
	Food at home	Food away from home	Total food	Non-food	Food at home	Food away from home	Total food	Non-food
	- - Dollars per person - -				- - - - Percent - - - -			
1985 (actual)	524	179	703	3,910	11.61	4.43	16.04	83.96
1990 (a):	538	192	730	4,604	11.10	4.51	15.61	84.39
(b):	530	188	718	4,405	11.35	4.49	15.84	84.16
1995 (a):	563	210	773	5,332	10.26	4.59	14.85	85.15
(b):	547	200	747	4,873	10.77	4.55	15.32	84.68
2000 (a):	591	230	821	6,181	9.45	4.67	14.12	85.88
(b):	561	210	771	5,291	10.30	4.60	14.90	85.10

Notes: (1) The projected values are the average of four projected quarters in each selected year. The figures in row (a) are based on the population growth in the sample period, and in those row(b) on the projections from the U. S. Bureau of the Census (1984, p.30). (2) The shares are calculated on the basis of projected expenditure measured in current dollars.

REFERENCES

Christensen, L.R., D.W. Jorgenson and L.J. Lau, "Transcendental Logarithmic Utility Functions", American Economic Review, 65 (1975): 367-383.

Girshick, M.A. and T. Haavelmo, "Statistical Analysis of Demand for Food: Examples of Simultaneous Estimation of Structural Equations", Econometrica, 15 (1947): 79-110.

Hotelling, H., "Demand Functions with Limited Budgets", Econometrica, 3 (1935): 66-78.

Huang, K.S., "The Family of Inverse Demand Systems", European Economic Review, 23 (1983): 329-337.

Nerlove, M., The Dynamics of Supply: Estimation of Farmers' Response to Price, Baltimore: John Hopkins Press, 1958.

Bureau of the Census, Projections of the Population of the United States, by Age, Sex and Race: 1983 to 2080. Current Population Reports, Series p-25, No. 952. U.S. Department of Commerce, Washington, D.C. 1984.

Waugh, F.V., Demand and Price Analysis, Technical Bulletin No. 1316, Economic Research Service, U.S. Department of Agriculture, 1964.

Wold, H., "A Synthesis of Pure Demand Analysis, III", Skandinavisk Aktuarietidskrift, 27 (1944): 60-120.