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EXTENSION

Consumer Demand for Fresh Fruits and Vegetables

in the United States (1960-1993)

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Price and expenditure elasticities at the retail level between 1960 and 1993 were estimated for 11 fresh fruits and 10 fresh vegetables by employing a composite demand system approach and using annual data. Most fresh fruits and vegetables were found to respond significantly to changes in their own prices but insignificantly to changes in expenditures. The study partially incorporated the interdependent demand relationships between fresh fruits (vegetables) and all other commodities, yet effectively avoided the problems of insufficient degrees of freedom.

Per capita annual consumption of fresh fruits and vegetables (excluding fresh potatoes) in the United States reached an average of 114.4 and 103.2 pounds during 1991–93, an increase of 21.3% and 30.42%, respectively, over the period of 1970–72 (Putnam and Allshouse, 1994). The rise, however, was not uniform among fresh fruits or vegetables, involving dozens of varieties. For example, the overall increase in fresh fruit consumption was due entirely to sharp increases in consumption of fresh non-citrus fruits and melons, while the overall gains in fresh vegetable consumption were due mainly to increased consumption of onions, bell peppers, tomatoes, cucumbers, carrots, broccoli and head lettuce (Putnam and Allshouse, 1994).

Among other factors, own price, prices of closely related products and per capita income have long been regarded as major determinants of demand for a commodity. Knowledge of price and income elasticities for fresh fruits and vegetables is thus useful both to producers and to researchers. For instance, price elasticity estimates are sometimes used to derive demand functions for given products. Gaps in the knowledge regarding price elasticities for fresh vegetables have caused researchers to make rather strong assumptions about such values (e.g., Epperson and Lei, 1989; Chien and Epperson, 1990).

In spite of the long recognition of the interdependence among food commodities of similar tastes and uses, most earlier U.S. fresh fruit and vegetable demand studies were partial demand analyses involving only one or a small number of products, as indicated in two reviews by Nuckton (1978 and 1980). Price and Mittelhammer (1979) estimated demand elasticities at the farm level for 14 fresh fruits by mixed two-stage least squares incorporating available prior information, but not within the framework of a complete demand system. Two early works, Brandow (1961) and George and King (1971), involved the estimation of matrices of demand elasticities for a large number of agricultural commodities by using a synthetic method. There were, however, only three fresh fruits and six fresh vegetables included in George and King's (1971) study, and Brandow's (1961) matrix had even less detail.

One practical problem for a complete demand system approach in the direct estimation of a large-scale demand system is the insufficiency of the degrees of freedom. In George and King's (1971) classic study, all commodities were classified into 16 separable groups, and the demand equation for a single commodity within a group was specified as a function of prices of all commodities within the group, price indices for other groups and income. This procedure may not be very effective in overcoming the problem of insufficient degrees of freedom if the number of commodity groups classified is large and individual groups consist of a great number of individual commodities. Further, in George and King's (1971) study some of the cross-price elasticities within each food group were not estimated directly. In addition, the cross-price elasticities showing the effect of individual commodity prices on the commodities outside the group were generated by applying the homogeneity and symmetry conditions. The outcomes of this procedure are thus affected by the ordering of the food categories in the demand matrix. By carrying out sequential estimations, however, Huang (1985; 1993) estimated the complete demand elasticity matrix directly and therefore provided a partial, but empirically feasible, solution to the above problem.

The purpose of this study is to estimate directly the U.S. demand for fresh fruits and vegetables at the retail level for the period 1960–93. Specifically, this study estimates demand elasticity matrixes for 11 fresh fruits and 10 fresh vegetables, represents a significant expansion in the availability of demand estimates for individual produce items at the retail level and provides updated demand estimates based on the most recently available data. The empirical estimation procedures, as proposed by Huang (1985; 1993), follow two sequential steps. First, a proposed aggregate demand system consisting of 11 food groups and a nonfood sector was estimated. The price effects of commodity groups other than fresh fruits (vegetables) were then excluded in the estimation of the demand coefficients for individual fresh fruits (vegetables) within respective demand subsystems. Therefore, the possible interdependent demand relationships between fresh fruits (vegetables) and other commodity groups were partially isolated in the estimation, yet without causing the problem of insufficient degrees of freedom.

Methodology and Estimation Procedures

Let the demand system derived from a consumer's utility maximization be

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

where n is the number of commodities consumed, q_i the quantity demanded for commodity I, p an n-coordinate vector of the prices, and m the consumer expenditure. By taking the total differential of (1), one obtains

$$dq_i = \Sigma^n_{j-1} (\partial q_i/\partial p_j)\, dp_j \div (\partial q_i/\partial m)dm, \; i=1, 2, ..., n. \quad [2]$$

Dividing both sides of (2) by q_i and expressing the price slopes in terms of elasticities, one obtains the following differential-form demand system:

$$dq_i/q_i = \Sigma^n_{j-1}\eta_{ij}\, (dp_j/p_j) \; + \epsilon_i \; (dm/m), \; i=1, 2, ..., n. \quad [3]$$

where $\eta_{ij}=(\partial q_i/\partial p_j)(p_j /q_i)$ is a price elasticity of the ith commodity with respect to a price change of the jth commodity, and $\epsilon_i = (\partial q_i/\partial m)(m/q_i)$ is the expenditure elasticity of the ith commodity. Empirically, the derivatives in (3) are approximated by the relative changes in commodities' quantity and price and per capita expenditure, respectively, and equation [3] is thus expressed as

$$q'_i = \Sigma^n_{j=1}\eta_{ij}\, p'_j + \epsilon_i m', \quad i = 1, 2,\ldots,n. \qquad [4]$$

For time-series data, variables q'_i, p'_j, and m' are defined as the first-order differences $(q_{i,t}-q_{i,t-1}) /q_{i,t-1})$, $(p_{j,t} -p_{j,t-1})/p_{j,t-1}$, and $(m_t -m_{t-1})/m_{t-1}$, respectively.

To ensure theoretical consistency with the classical demand theory, the following parametric constraints are imposed on the demand system (4):

Engel aggregation: $\sum^{n}_{i=1} ,w_i \epsilon_i = 1,$ [5]
Homogeneity: $\sum^{n}_{i=1} \eta_{ij} + \epsilon_i = 0,$ [6]
Symmetry: $\eta_{ij} /w_j + \epsilon_i = \eta_{ji} /w_i + \epsilon_j,$ [7]

where *wi* (I=1,...,n) is a fixed expenditure weight of the *i*th commodity at the selected base period. Note that the Engel aggregation and symmetry restrictions are only enforced locally at the point the selected fixed expenditure weights refer to. While there are other demand models, such as the Rotterdam and the almost ideal demand system (AIDS), for which global enforcement of the neoclassical restrictions can be accomplished, an advantage of using the demand system (4) is that its dependent variables, defined as relative changes of quantities demanded, can be quantified easily by using available time series data usually expressed as index numbers. In addition, one can directly interpret demand parameters in model (4) as elasticities.

Incorporating restrictions (5)–(7) reduces the total demand parameters to be estimated in the demand system (4) from n(n+2) to [n(n+3)/2-1] (including n constants), which is still intractable if *n* is large. To overcome the problem of degrees of freedom, George and King (1971) modeled consumers' choices in a two-stage maximization process. Suppose that the *n* commodities consumed belong to *G* separable groups. In the first stage, the total expenditure m is allotted among the *G* commodity groups such that the utility is maximized. The obtained expenditure for a particular commodity group m_I (I=1,...,G) is expressed as a function of the group price indexes and the total expenditure. In the second stage, each group expenditure is split into individual commodity expenditures such that the utility generated from each commodity group is maximized. A demand equation for the $_j$th commodity belonging to group I is then expressed as

$$q_j^I = q_j^I[p_1^I, p_2^I, \ldots p_{nI}^I, m_I(P_1, P_2, \ldots, P_G, m)] \qquad [8]$$

or simply,

$$q_j^I = q_j^I(p_1^I, p_2^I, \ldots p_{nI}^I, P_1, P_2, \ldots, P_G, m), (_j = 1, \ldots, n_I; I = 1, \ldots, G) \qquad [9]$$

where p_{ji} and P_I (j=1,...,nI; I=1,...,G) represent the price of the *j*th commodity in the *I*th group and the price index of commodity group I, respectively, and $n_1+...+n_G = n$. The first difference form of (9) for each commodity, as similar to (4), is estimated by single-equation regression. Evidently, George and King's (1971) procedure has significantly overcome the problem of insufficient degrees of freedom and made the estimation feasible. This is not sufficient, however, if the number of commodity groups (G) and the number of single commodities in an individual group (n_I) are relatively large.

Huang (1985; 1993) conducted a sequential estimation procedure alternatively to further overcome the problem of degrees of freedom in the direct estimation of a large-scale demand system. In the first step, all commodities consumed are partitioned into G–1 food groups and a composite nonfood sector. Thus, the demand system (4) is re-specified as

$$Q_I^I = \Sigma^{G}_{J=1} H_{ij} P_{Ij} + \epsilon_i m_I, \qquad I = 1, 2, \ldots, G \qquad [10]$$

where Q_I' and P_J' are, respectively, relative changes in aggregate quantity and price for commodity groups *I* and *J*, which are usually expressed as the Laspeyres quantity index and the consumer price index. Various parameters /and + represent corresponding direct- and cross-price and expenditure elasticities of the aggregate commodity groups. The aggregate demand system (10) is estimated directly while incorporating the parameter restrictions (5)–(7).

In the second step, the demand parameters within each food group are estimated group by group using the aggregate parameter estimates obtained from (10) as information to represent approximately the price effects outside the food group under estimation. The demand subsystem for a food group, say group I, is defined as

$$\tilde{q}_i^I = \Sigma\, \eta_{ij} p_j^I + \epsilon_i m_I, \qquad i \in I \qquad j \in I \qquad [11]$$

where $\tilde{q}_i^I = q_i^I - \Sigma^G_{J=1} H_{IJ} P_J^I$ for $J \neq I$. The dependent variable $\tilde{q}_i^I$ is the adjusted quantity (in difference-form) for the *i*th commodity belonging to group *I* and is obtained by subtracting the price effects of those food and nonfood prices outside the group from q_i^I. In estimating the within-group demand subsystem (11), the symmetry condition (7) is imposed.

Data Sources

The basic data required for this study are the time series data of quantities and retail prices of individual fresh fruits and vegetables, quantity and price indexes for food groups and the nonfood sector and per capita total expenditure. Overall, annual data covering 1960–93 for 11 food categories, one nonfood sector, 11 fresh fruits and 10 fresh vegetables were obtained.

George and King (1971) used the proportionality factors, developed by deJanvry (1966), to group food commodities. In order to calculate the proportionality factors, however, one needs information on income elasticities and budget shares for all individual food commodities. For simplicity, the breakdown of food groups in this study is based mainly on the availability of data. The 11 food categories generally correspond to the major food groups published in various issues of Food Consumption, Prices and Expenditures (Hiemstra, 1968; Prescott, 1982; and Putnam and Allshouse, 1993) and are very similar.

The food category and nonfood price indexes were obtained from the CPI Detailed Report by the U.S. Department of Labor. The quantity indexes for each food group were collected from various issues of Food Consumption, Prices and Expenditures (Hiemstra, 1968; Prescott, 1982; and Putnam and Allshouse, 1993). Per capita total expenditure is calculated by dividing the personal consumption expenditures (obtained from the U.S. Department of Commerce) by the midyear U.S. civilian population. The quantity index for the nonfood composite sector is derived from the current value of per capita expenditure on nonfood divided by the CPI of all items less food.

The fresh fruit subsystem to be estimated consists of apples, bananas, cherries, grapefruits, grapes, lemons, oranges, peaches, pears, strawberries and watermelon. The fresh vegetable subsystem includes asparagus, cabbage, carrots, celery, cucumbers, lettuce, onions, peppers, potatoes and tomatoes. The data on per capita consumption and retail prices (or price indexes) for individual fresh fruits and vegetables were collected from various issues of Food Consumption, Prices and Expenditures (Hiemstra, 1968; Prescott, 1982; and Putnam and Allshouse, 1994), U.S. Fresh Market Vegetable Statistics, 1949–80 (Pearrow and Davis, 1982), Fruits and Tree Nuts (USDA) and Vegetables and Specialties (USDA). There were no retail prices (or price indexes) reported for cabbage, carrots, celery and onions in 1979; for grapes, grapefruits, lemons and strawberries in 1978–79; or for cucumber and peppers in 1960–62 and 1979. For asparagus, cherries, watermelon, pears and peaches, the data on retail prices were only available in years 1963–78, 1980–91, 1953–77 and 1980–93, respectively. The missing data were estimated from a set of price linkage equations between retail price and grower price and the CPI of food, which generate quite reasonable predictions (see appendix). The quantity data used for estimating the demand systems are defined as the retail-weight equivalents of civilian food disappearance. As all food is not sold through retail food stores, it should be pointed out that the price and quantity data series may not correspond exactly. It is what one can achieve, however, given the limited availability of data sources.

The remaining data needed are the fixed expenditure weights for each of the above 12 commodity groups and for those individual fresh fruits and vegetables that are used in imposing parametric constraints. The expenditure weights between food and nonfood groups are calculated from the personal consumption expenditures reported by the U.S. Department of Commerce, and the averages over the period of 1960–1993 are used. As in Huang (1993), the expenditure weight for total food is then allocated proportionally to each food group in accordance with its value in 1967–69, as reported in table 3 of the 1979 issue of Food Consumption, Prices and Expenditures (Johnson, 1979).

Although shares of expenditures on some food groups have changed differently over time, the expenditure weights of 1967–69 are the only available complete data. Finally, the average expenditure share of each fresh fruit (vegetable) as a percentage of the considered fresh fruit (vegetable) group over the period of 1960–1993 was calculated by using the available quantity and price data as described above. The expenditure weight obtained for the fresh fruit (vegetable) group with respect to the total per capita expenditure in the second step is then further allocated proportionally to each single fresh fruit (vegetable) in accordance with the estimated average expenditure shares.

Empirical Results

The demand systems of (10) and (11) are estimated in two sequential steps, applying the iterative seemingly unrelated regressions (SUR) procedure. In the first step, the aggregate demand system (10) is estimated while incorporating the Engel aggregation, homogeneity and symmetry conditions, and the results are reported in table 1. All direct-price elasticities except those for the food group of flour and cereal products are negative as expected; and nine out of 12 coefficients are different from zero at a significance level of 5% or better. The positive estimate of the direct-price elasticity for the food group of flour and cereal products is not significant statistically. The magnitudes of the (negative) direct-price elasticities range from -0.0288 for fresh vegetables to -0.987 for nonfood commodities. The expenditure elasticities for all food groups are less than 1; and six out of 12 coefficients differ from zero at a significance level of 10% or better. The negative expenditure elasticities obtained for the food groups of eggs, flour, cereal products and fresh fruits do not necessarily imply that they are inferior goods, as the estimates are insignificant statistically.

The aggregate parameter estimates obtained in the first step are used as information in the estimation of the fresh fruit and vegetable demand subsystems. The quantity variable in the fresh fruit (vegetable) demand subsystem is adjusted by subtracting the price effects of all other food groups and the nonfood sector outside the fresh fruit (vegetable) group in estimation, which are represented approximately by the aggregate cross-price parameters of the aggregate demand equation for the fresh fruit (vegetable) group. The results from estimating (11) with imposing the symmetry condition are presented in tables 2 and 3. From table 2, nine out of 11 estimates of own-price elasticities for fresh fruits are negative (exceptions are cherries and pears), and among them eight coefficients are significant statistically at a level of 10% or better. Except grapes and oranges, all estimated own-price elasticities are less than unity. Most estimated expenditure elasticities for fresh fruits are positive, with the exceptions of apples, cherries, grapefruit and strawberries, but none of them are significant statistically.

As shown in table 3, all estimated own-price elasticities for fresh vegetables are negative, with the exception of cabbage. Except those for celery and lettuce, all estimates of own-price elasticities are significant at a level of 5% or better. The magnitudes for those (negative) own-price elasticities range from -0.0115 for lettuce to -0.650 for asparagus. The expenditure elasticities obtained from this study are all positive and less than one, but only those estimates for celery and tomatoes are significant statistically at a level of 10% or better.

The elasticity estimates and their statistics from this study are quite similar to those of Huang's study (1993), yet about twice the number of fresh produce items have been included in the current work. In general, fresh fruits and vegetables are found to respond significantly to changes in their own prices, but not to changes in income, implying that price is a more important factor than income in determining U.S. fresh fruit and vegetable demand.

Table 1. Demand Elasticities for Food Groups and Nonfood

Commodities	Price												Expenditure
	Meats	Eggs	Dairy	Fats	Sweeten	Flour	F. fruit	F. veg	P. fruit	P. veg	O. food	Nonfood	
Meats	-.38160 (5.83)	.00957 (1.14)	-.00099 (0.03)	.01605 (1.50)	-.00437 (0.35)	-.00358 (0.13)	-.00772 (0.36)	-.02940 (1.39)	.00885 (0.66)	-.00771 (0.57)	-.02059 (0.89)	-.08378 (0.69)	.50528 (3.68)
Eggs	.11538 (1.70)	-.11727 (4.12)	.00998 (0.12)	-.01122 (0.37)	-.05835 (2.00)	-.06123 (0.77)	-.02065 (0.48)	.05469 (1.20)	.01019 (0.36)	.09303 (0.36)	.00361 (0.12)	.09519 (0.72)	-.11336 (0.86)
Dairy	.00767 (0.10)	-.00115 (0.05)	-.24764 (2.09)	-.06014 (1.82)	.01633 (0.52)	.10936 (1.27)	-.03871 (0.90)	-.03218 (0.70)	-.04173 (1.43)	.03337 (0.74)	-.00183 (0.05)	-.09682 (0.60)	.35345 (2.32)
Fats	.14999 (1.55)	-.01633 (0.49)	-.25142 (1.82)	-.16968 (2.03)	.12280 (2.27)	-.21020 (1.20)	-.04214 (0.66)	-.17369 (2.59)	-.03307 (0.73)	.12679 (1.76)	-.03279 (0.69)	.16689 (0.80)	.36285 (1.85)
Sweeten	.01348 (0.27)	-.02927 (2.06)	.03919 (0.67)	.05554 (2.35)	-.15243 (4.90)	-.13236 (1.90)	.01568 (0.54)	.05470 (1.86)	.03388 (1.67)	.05238 (1.85)	.01518 (0.63)	-.00346 (0.03)	.03752 (0.33)
Flour	.03309 (0.33)	-.02562 (0.75)	.19356 (1.38)	-.07722 (1.13)	-.11434 (1.85)	.31209 (1.39)	.04216 (0.65)	.01923 (0.29)	.03901 (0.86)	-.11720 (1.50)	-.00030 (0.01)	-.10635 (0.49)	-19812 (1.02)
F. fruit	-.01602 (0.10)	-.01913 (0.48)	-.12101 (0.80)	-.03180 (0.60)	.03331 (0.61)	.09035 (0.64)	-.27297 (2.24)	.15362 (1.62)	.02335 (0.39)	.06303 (0.90)	.01046 (0.14)	.21846 (0.68)	-.13165 (0.41)
F. veg	-.15625 (1.18)	.03997 (1.15)	-.08705 (0.66)	-.11895 (2.59)	.08573 (1.86)	-.02784 (0.24)	.12430 (1.59)	-.02880 (0.26)	-.09827 (1.97)	.05417 (0.97)	-.06521 (1.03)	.07053 (0.26)	.15200 (0.55)
P. fruit	.10854 (0.73)	.01051 (0.27)	-.21056 (1.41)	-.03980 (0.73)	.09121 (1.62)	.11372 (0.81)	.03020 (0.35)	-.17424 (1.97)	-.29000 (3.70)	-.17149 (2.53)	.08049 (1.12)	.16139 (0.50)	.29004 (0.90)
P. veg	-.03983 (0.46)	.06999 (2.37)	.09917 (0.73)	.09067 (1.77)	.08095 (1.75)	-.22756 (1.58)	.04927 (0.83)	.05356 (0.92)	-.10111 (2.54)	-.10913 (1.25)	-.06436 (1.65)	-.27335 (1.52)	.37175 (2.28)
O. food	-.08806 (0.96)	-.00440 (0.30)	-.01222 (0.20)	-.01643 (0.79)	.00511 (0.22)	-.01628 (0.32)	-.00130 (0.03)	-.04639 (1.17)	.02680 (1.06)	-.04220 (1.80)	-.29594 (4.79)	-.15184 (0.70)	.64313 (2.72)
Nonfoods	-.04975 (8.13)	-.00951 (9.34)	-.02882 (6.26)	-.00442 (3.10)	-.01932 (11.98)	-.02851 (7.57)	-.00901 (3.73)	-.00987 (3.86)	-.00410 (2.55)	-.01171 (6.71)	-.01205 (4.18)	-.98734 (62.88)	1.1744 (74.71)
Weights	.064308	.008139	.030601	.007329	.016932	.018941	.008718	.010564	.006009	.010241	.016720	.8015	

Note: 1) Numbers in parentheses are t-ratios; 2) Some notations are meats (red meat, poultry, fish and eggs), fats (fats & oils), sweeteners (caloric sweeteners), flour (flour and cereal products), f. fruit (fresh fruits), f. veg (fresh vegetables), p. fruit (processed fruits), p. veg (processed vegetables), o. food (other foods), weights (expenditure weights).

Table 2. Demand Elasticities for Selected Fresh Fruits

	Price											
Fruits	**Apples**	**Bananas**	**Cherries**	**Grapefruit**	**Grapes**	**Lemons**	**Oranges**	**Peaches**	**Pears**	**Strawberries**	**Watermelon**	**Expenditure**
Apples	-.19622 (1.31)	.07346 (0.96)	-.02644 (1.30)	-.03570 (0.67)	.16818 (2.30)	-.01565 (0.50)	.05671 (0.73)	.11869 (2.19)	-.05161 (1.15)	.08633 (2.53)	.03539 (0.70)	-.14824 (0.21)
Bananas	.10499 (0.95)	-.33408 (1.90)	.02430 (1.16)	.04458 (0.56)	-.06433 (0.65)	-.11809 (1.95)	-.00178 (0.02)	.11201 (1.36)	.00184 (0.02)	-.12700 (2.06)	-.17353 (2.07)	.62506 (1.27)
Cherries	-.56612 (1.29)	.36453 (1.17)	.09107 (0.80)	-.08651 (0.40)	-.04298 (0.14)	-.16786 (1.35)	-.15401 (0.50)	.17508 (0.75)	.08171 (0.43)	-.22664 (1.64)	.37336 (1.78)	-1.9307 (0.74)
Grapefruit	-.13169 (0.67)	.11456 (0.57)	-.01497 (0.40)	-.88563 (4.92)	.25951 (1.56)	.00516 (0.06)	.27007 (1.89)	.05126 (0.40)	.02730 (0.22)	.03809 (0.40)	-.12493 (0.94)	-.15862 (0.16)
Grapes	.42389 (2.29)	-.11255 (0.65)	-.00527 (0.15)	.17753 (1.56)	-1.0343 (4.90)	-.07814 (1.03)	-.29029 (2.17)	.20225 (1.75)	-.07350 (0.68)	-.01092 (0.14)	.16122 (1.37)	.73973 (0.83)
Lemons	-.09502 (0.51)	-.48888 (1.95)	-.04694 (1.35)	.00805 (0.06)	-.18503 (1.03)	-.36952 (1.68)	.08343 (0.57)	.38119 (2.50)	-.09399 (0.53)	-.25698 (2.04)	.33925 (2.13)	.54783 (0.72)
Oranges	.10772 (0.72)	.00256 (0.02)	-.01392 (0.51)	.14015 (1.88)	-.21996 (2.17)	.02673 (0.57)	-1.0362 (7.55)	.15918 (2.17)	.00090 (0.01)	.09419 (2.02)	.034176 (0.49)	.46359 (0.49)
Peaches	.41970 (2.18)	.27450 (1.36)	.02864 (0.74)	.04891 (0.39)	.28373 (1.75)	.22561 (2.49)	.29422 (2.17)	-.81803 (4.60)	-.03341 (0.25)	.09689 (1.04)	-.35994 (2.79)	.68225 (0.73)
Pears	-.31739 (1.16)	.00772 (0.02)	.02302 (0.42)	.04490 (0.21)	-.17782 (0.68)	-.09603 (0.53)	-.00308 (0.02)	-.05763 (0.25)	.30378 (0.94)	-.44186 (2.61)	.36762 (1.62)	.67887 (0.57)
Strawberries	.45443 (2.53)	-.46017 (2.06)	-.05549 (1.64)	.05440 (0.40)	-.02194 (0.13)	-.22520 (2.04)	.25896 (2.03)	.14412 (1.05)	-.37931 (2.61)	-.26400 (1.80)	.14705 (1.03)	-.36972 (0.49)
Watermelon	.09384 (0.69)	-.32335 (2.06)	.04654 (1.77)	-.09174 (0.94)	.17181 (1.37)	.15253 (2.13)	.04777 (0.49)	-.27352 (2.79)	.16189 (1.62)	.07502 (1.02)	-.61432 (4.35)	.75237 (1.27)
Weights	.001750	.001209	.000081	.000474	.000692	.000292	.000912	.000493	.000286	.000333	.000649	

Note: 1) Numbers in parentheses are t-ratios; 2) Weights: expenditure weights.

Table 3. Demand Elasticities for Selected Fresh Vegetables

Vegetables	Price										Expenditure
	Asparagus	Cabbage	Carrots	Celery	Cucumbers	Lettuce	Onions	Peppers	Potatoes	Tomatoes	
Asparagus	-.65028 (2.36)	-.19410 (1.63)	.20616 (0.63)	.57143 (2.32)	.00220 (0.01)	-.05813 (0.26)	.11116 (0.69)	-.51625 (2.07)	.41170 (2.24)	-.15534 (0.38)	.76106 (0.62)
Cabbage	-.04222 (1.62)	.01967 (0.58)	-.02111 (0.35)	.02555 (0.63)	-.06216 (1.62)	.10805 (2.09)	.04364 (1.22)	-.05460 (1.26)	-.02730 (0.62)	.12654 (1.58)	.21293 (0.72)
Carrots	.04222 (0.63)	-.01981 (0.35)	-.46853 (2.30)	-.19468 (1.99)	.08399 (0.88)	-.04936 (0.40)	.06513 (0.78)	-.04101 (0.39)	.07000 (0.65)	.14988 (0.75)	.15504 (0.22)
Celery	.10360 (2.32)	.02102 (0.63)	-.17285 (1.99)	-.03249 (0.37)	.12901 (2.06)	-.04394 (0.68)	-.06181 (1.34)	-.13066 (2.07)	.06820 (1.25)	.07951 (0.71)	.86049 (2.38)
Cucumbers	.00062 (0.01)	-.07616 (1.62)	.10934 (0.88)	.18988 (2.06)	-.30218 (2.61)	.07354 (0.74)	-.11986 (1.83)	.07494 (0.78)	-.01022 (0.12)	.02895 (0.18)	.40026 (0.72)
Lettuce	-.00230 (0.26)	.01984 (2.08)	-.00976 (0.40)	-.00948 (0.67)	.01108 (0.74)	-.01150 (0.13)	-.00370 (0.18)	-.01024 (0.56)	-.04812 (0.90)	.05124 (1.56)	.36278 (0.70)
Onions	.01488 (0.69)	.02665 (1.22)	.04240 (0.78)	-.04547 (1.33)	-.06021 (1.83)	-.01287 (0.19)	-.15880 (3.02)	-.03273 (0.81)	-.06250 (1.07)	-.01781 (0.24)	.60167 (1.51)
Peppers	-.10244 (2.07)	-.04990 (1.26)	-.03996 (0.39)	-.14288 (2.07)	.05574 (0.78)	-.05110 (0.56)	-.04855 (0.81)	-.25346 (2.47)	-.00807 (0.10)	.01094 (0.08)	.56609 (1.08)
Potatoes	.01856 (2.24)	-.00572 (0.62)	.01530 (0.65)	.01715 (1.27)	-.00173 (0.13)	-.05410 (0.90)	-.02091 (1.07)	-.00176 (0.10)	-.15522 (2.22)	.01338 (0.41)	.40476 (0.82)
Tomatoes	-.00845 (0.38)	.03146 (1.57)	.03967 (0.75)	.02396 (0.71)	.00583 (0.18)	.06892 (1.55)	-.00728 (0.24)	.00296 (0.08)	.01570 (0.40)	-.37899 (4.03)	.65813 (2.49)
Weights	.000085	.000392	.000417	.000471	.000320	.002129	.000638	.000430	.001897	.001569	

Note: 1) Numbers in parentheses are ratios; 2) Weights: expenditure weights.

To see if the employed sequential estimation procedure performs better than some of the other alternative estimation approaches, model (9) as expressed in first-difference form is applied to estimate the fresh fruit (vegetable) demand system. Since the price indexes of 12 commodity groups are included as independent variables in (9), the degrees of freedom drop considerably, and the multicollinearity problem is more likely to occur. As a result, parameter estimates obtained while imposing the symmetry restriction on the cross-price coefficients for individual fresh fruits (vegetables) are much less significant than those obtained from the above sequential estimation procedure. Indeed, George and King (1971) omitted a number of price indexes in their estimation by single-equation regression. Such does not apply, however, to a joint estimation of a demand system. Instead of classifying commodities, other than fresh fruits (vegetables), into a number of separable groups, one can also assume that all the other commodities have the same impacts on fresh fruit (vegetable) consumption and therefore treat them as one single, non-fresh-fruit (vegetable) group. The fresh fruit (vegetable) demand system established in this manner is also estimated with the restrictions of (5)–(7) being imposed. Many of the parameter estimates are rather close to those obtained by the sequential estimation procedure. This is not surprising as estimates of most aggregate cross-price parameters for the fresh fruit (vegetable) group are not significant statistically, as shown in table 1. In other words, the advantage (or necessity) of applying a two-step sequential estimation procedure partly depends on how the commodity group under estimation is interrelated with the remaining commodities with respect to demand.

Conclusions

Demand responses for 11 fresh fruits and 10 fresh vegetables to changes in prices and income (expenditures) are modeled using a composite demand system approach. The estimation follows two sequential steps. First, an aggregate demand system consisting of 11 food groups and a nonfood sector was estimated. The parameter estimates obtained in this fashion then were used as information to exclude the price effects of other food groups and the nonfood sector in the estimation of fresh fruit and vegetable demand subsystems, respectively. Thus, the analysis of fresh fruit and vegetable demand partially incorporates the interdependent demand relationships among all commodities. Since the price and expenditure elasticities were obtained directly from estimating the demand systems specified, their statistical inferences are straightforward.

Most fresh fruits and vegetables, as well as aggregate commodity groups, are found to respond significantly to changes in their own prices and in the directions as expected. All own-price elasticities obtained (except for grapes and oranges) are less than unity. The demand for all fresh vegetables and most fresh fruits increases when per capita total expenditures rise. Few estimates, however, of expenditure elasticities are significant statistically. The estimates are quite close to those of Huang's study (1993), yet more fresh produce items have been included in the estimation. This study, therefore, provides more detailed information about the U.S. retail demand for fresh fruits and vegetables.

The composite demand system approach, as conducted in two sequential steps, overcomes the problem of insufficient degrees of freedom and appears to be a promising approach in estimating a large-scale demand system. The cross-price parameters of commodity groups, however, represent only approximate effects of other prices outside a particular commodity group under estimation. Therefore, sufficient care should be given in grouping commodities in order to achieve a high degree of isolation of the price effects of all other commodity groups in the estimation of a demand subsystem. Finally, note that the matrixes of demand elasticities are estimated when the neoclassical restrictions are enforced locally at the point of reference for the selected fixed expenditure weights. When data become available, a functional form that allows global enforcement of the restrictions may apply.

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Appendix

Price Linkage Equations Used for Generating Missing Data

Model: $P_i^r = \alpha_0 + \alpha_1 P_i^g + \alpha_2 + CPI_{food}$,

P_i^r , P_i^g --- retail and grower prices for commodity i: $/lb;

CPI_{food} --- CPI for food: 82-84=100.

Commodity	Coefficient Estimates			R^2	Sample (years)
	α_0	α_1	α_2		
Asparagus	-.0692 (1.93)	1.263 (4.15)	.00660 (2.71)	0.9833	63–78
Cabbage	.03495 (5.73)	2.144 (9.50)	.00034 (1.08)	0.9803	60-78
Carrots	.04122 (7.74)	1.603 (11.8)	.00126 (9.99)	0.9918	60–78 & 80–93
Celery	.00515 (0.93)	1.988 (13.0)	.00210 (15.1)	0.9941	60–78 & 80–93
Cucumber	.03875 (1.56)	1.208 (1.27)	.00367 (2.56)	0.9247	63–78
Onions	.02480 (2.10)	.8664 (3.22)	.00219 (8.06)	0.9444	60–78 & 80–93
Peppers	.00065 (0.01)	2.550 (2.61)	.00282 (1.09)	0.9159	63–78
Cherries	-.4527 (0.86)	2.106 (1.74)	.01118 (2.19)	0.6089	80–91
Grapes	.23606 (2.22)	1.243 (3.73)	.00551 (6.02)	0.8783	80–93
Grapefruits	-.0808 (1.04)	.8539 (1.71)	.00426 (5.11)	0.8461	80–93
Lemons	.07466 (0.62)	.8945 (2.06)	.00599 (4.07)	0.8985	80–93
Peaches	-.1118 (0.65)	2.645 (1.56)	.00364 (4.30)	0.9024	80–91
Pears	.13012 (1.26)	.0269 (0.03)	.00499 (3.64)	0.7425	80–91
Strawberries	-.3728 (1.80)	.5150 (1.12)	.01161 (11.3)	0.9510	80–93
Watermelon	-.0056 (2.24)	1.361 (5.82)	.00126 (7.43)	0.9868	53–77

Note: For peaches, the CPI for fresh fruits is used in place of the CPI for food for the purpose of goodness of fit.

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