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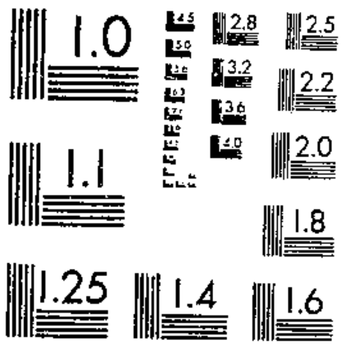

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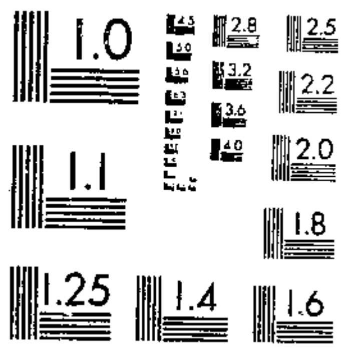

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ESTIMATES OF ELASTICITIES FOR FOOD DEMAND IN THE UNITED STATES

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Economics, Statistics, and Cooperatives Service
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ABSTRACT

Various estimates of quantity- and price-dependent demand equations for total food demand are made. The regression coefficients are used to derive estimates of price and income elasticities and flexibilities. The results indicate that response of food demand to price and income changes is low compared with estimates in previous studies.

KEYWORDS: Food demand, Elasticities, Flexibilities

On January 1, 1978, three USDA agencies--the Economic Research Service, the Statistical Reporting Service, and the Farmer Cooperative Service--were merged into a new organization, the Economics, Statistics, and Cooperatives Service.

Washington, D. C. March 1978

CONTENTS

SUMMARY

To help provide up-to-date estimates of demand for food, statistical demand functions are estimated. Both quantity-dependent and price-dependent equations are estimated. Formulations of demand equations include those using actual data, logs of data, first differences of data, and first differences of logs. Principal component regression is used to overcome multicollinearity in the independent variables.

Results show that the response of food demand to price and income changes is low compared with estimates in previous studies. The price elasticity of demand for food is about -.25, and flexibility of price with respect to food demand is about -2.0. A plausible explanation is that with rising income, the income elasticity of food has declined.

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INTRODUCTION

To conduct many policy analyses, the nature of the demand for total food must be known. Recent rises in food prices have enhanced the importance of up-to-date estimates on demand for food. It is generally agreed that the total demand for food is less elastic than demand for individual food items. The total demand for food is limited by human needs, which are relatively well satisfied in an affluent society. As the relative prices of various food items change, substitution among commodities takes place. But total food consumption varies very little. This report summarizes the results of ongoing research on demand for food.

THE DATA

Per capita food consumption is measured as a price-weighted (Laspeyres) index number of quantities of food. 1/ The Consumer Price Index (CPI) for all items can be divided into two major components: food and all other items. The CPI is published regularly by the U.S. Bureau of Labor Statistics. Per capita disposable income is personal income less personal tax and nontax payments. It represents the consumer's spendable income. The analysis in this report is based on annual data for 1957-76 (table 1).

1/ The meaure is described in (9). (Underscored numbers in parentheses refer to references listed at the end of this report.)

REGRESSION RESULTS

Quantity-dependent and price-dependent demand equations are provided in tables 2 and 3, respectively. The quantity-dependent equations are based on the classical demand theory--consumer maximizing utility subject to income constraint. This results in quantity as a function of prices and income as outlined by Phlips (7). The case for price-dependent equations is elaborated by Fox (3) and Waugh (10). A formal theoretical framework is given by Samuelson (8). In the traditional theory, utility is considered a function of quantities consumed (direct utility function), and the maximization process leads to quantity demand as a function of prices and income. If these optimum quantities are substituted into the direct utility

Table 1--Data for aggregate food demand, United States

Year	Food	Per capita food consumption	Per capita disposable income	Items other than food
	CPI	Indices	Indices	CPI
1957	84.9	96.1	65.4	83.8
1958	88.5	94.8	66.4	85.7
1959	87.1	96.8	69.2	87.3
1960	88.0	96.4	70.5	88.8
1961	89.1	96.0	72.1	89.7
1962	89.9	96.3	75.1	90.8
1963	91.2	96.6	77.6	92.0
1964	92.4	97.6	83.1	93.2
1965	94.4	97.2	88.6	94.5
1966	99.1	98.3	94.7	96.7
1967	100.0	100.0	100.0	100.0
1968	103.6	101.2	106.9	104.4
1969	108.9	101.5	113.5	110.1
1970	114.9	102.8	122.1	116.7
1971	118.4	103.3	130.9	122.1
1972	123.5	103.8	140.0	125.8
1973	141.4	101.9	156.3	130.7
1974	161.7	102.8	169.3	143.7
1975	175.4	102.2	184.7	157.1
1976	180.8	105.1	200.4	167.5

CPI - Consumer Price Index

function, indirect utility is obtained as a function of prices and income. Maximization of the indirect utility function leads to price as a function of quantity. 2/

The regressions include those using actual data, logarithms of data, first differences of data, and first differences of logarithms. Results of an additional analysis based on principal components are included in tables 2 and 3.

Equations (1) and (7) in the tables are based on actual data (no transformation). All the coefficients have the expected signs and are statistically significant. The R^2 (corrected for degrees of freedom) shows that 96 percent of the variation in quantity (equation 1) and 99 percent of the variation in price (equation 7) are explained by the variables included in the regressions. The independent variables included in the analysis have high multicollinearity. But, surprisingly, the t-values are well behaved. If the regression equations are used for forecasting for a period during which the multicollinearity will persist, the problem of collinearity is not serious.

It is well known that economic data have high autocorrelation--i.e., the variables are correlated with values in the last time period. 3/ Estimated values of autocorrelations for the variables in this study are:

CPI food	.81
Per capita consumption	.82
Per capita income	.83
CPI nonfood	.80

To overcome autocorrelation, first differences of the data are used in regression equations (2) and (8). The constant term is included to account for trend. However, the estimates of the constant are not statistically significant. As usual, the adjusted R^2 is low for first difference equations. The Durbin-Watson (DW) test shows no negative serial correlation due to differencing. 4/

2/ In the theoretical formulation, price normalized by income is considered a function of quantity. The price-dependent equations included in this report are modified from the theoretical formulation.

3/ See (1) for an example.

4/ The test for negative serial correlation in disturbances is made by comparing 4-DW with the tabulated values of the Durbin-Watson statistic.

Table 2--Quantity-dependent demand equations for food, United States, 1957-76

Equation	Type of equation	Dependent 1/ variable	Independent variables 1/: Constant	PR	YD	OP	$\bar{R}^2$	DW	Elasticities 2/: Price	Income	Other price
(1)	No transformation	QT	93.621	-.262	.158	.164	.96	1.80	-.438	.170	.217
			3/	(7.527)	(4.805)	(2.259)					
(2)	First differences	QT	-.035	-.226	.089	.215	.39	2.92	-.377	.095	.325
				(3.632)	(1.032)	(2.151)					
(3)	Double log	QT	4.119	-.283	.111	.277	.96	1.65	-.283	.111	.277
				(6.117)	(4.278)	(3.604)					
(4)	Double log (homogeneity)	QT	4.611	-.168	.223		.91	1.08	-.168	.223	-.055
				(2.718)	(12.306)						
(5)	First differences of logs	QT	.006	-.326	.217	.288	.49	2.11	-.326	.217	.288
				(4.383)	(1.962)	(2.661)					
(6)	Principal components	QT	99.716	-.249	.187	.101			-.416	.334	.152

1/ Definitions of variables:
QT=Index of per capita food consumption
PR=Consumer price index for food
YD=Index of per capita disposable income
OP=Consumer price index for items other than food.

2/ Estimates of elasticities in equations (1), (2), and (6) are based on th 1974-76 averages of the variables.

3/ Numbers in parentheses are t-values.

Table 3--Price-dependent demand equations for food, United States, 1957-76

Equation	Type of equation	Dependent variable 1/	Independent variables 1/				$\bar{R}^2$	DW	Flexibilities 2/		
			Constant	QT	YD	OP			Price	Income	Other price
(7)	No transformation	PR	272.759	-2.974	.451	.785	.99	1.61	-1.788	.485	.710
			3/	(7.527)	(3.427)	(3.909)					
(8)	First differences	PR	-.765	-2.068	.521	.701	.79	1.97	-1.238	.560	.634
				(3.632)	(2.234)	(2.374)					
(9)	Double log	PR	9.597	-2.422	.199	1.137	.99	1.17	-2.422	.194	1.137
				(5.413)	(1.910)	(7.740)					
(10)	First differences of logs	PR	-.020	-1.724	.664	.789	.77	2.37	-1.724	.664	.789
				(4.383)	(2.905)	(3.514)					
(11)	Principal components	PR	113.068	2.891	.421	.833			-1.732	.451	.753

1/ Definitions of variables:
QT=Index of per capita food consumption
PR=Consumer price index for food
YD=Index of per capita disposable income
OP=Consumer price index for items other than food.

2/ Estimates of flexibilities in equations (7), (8), and (11) are based on the 1974-76 averages of the variables.

3/ Numbers in parentheses are t-values.

Regressions (3) and (9) use logarithmic transformation of the data to analyze the multiplicative effects of income and price on quantity, and of income and quantity on price. The regression coefficients of these equations give the estimates of relevant elasticities. The Durbin-Watson statistic for the price dependent equation (9) is inconclusive. Equation (4) further constrains equation (3) to be homogeneous of degree zero--that is, it assumes that if prices and income change in the same proportion, then the quantity demanded remains unchanged. 5/ Equations (5) and (10) are based on first differences of logs. The difference of a log is approximately equal to the rate of change. If the rate of change is r:

$$\log P_t - \log P_{t-1} = \log \frac{P_t}{P_{t-1}}$$
$$= \log \frac{P_{t-1}(1+r)}{P_{t-1}}$$
$$= \log (1+r)$$
$$\simeq r.$$

The DW statistic for testing negative serial correlation is inconclusive for the quantity-dependent equation (5). For the price-dependent equation (10), the DW statistic shows no serial correlation.

As noted above, if these equations are used for forecasting and if the multicollinearity persists in the forecast period, the high correlation among independent variables presents no serious problem. If, however, the equations (or elasticities) are to be used in policy analysis to assess the impact of individual variables, something needs to be done about collinearity. When the independent variables are highly correlated, the relative size of the regression coefficients is not reliable. In order to overcome this drawback, a principal component analysis is used. 6/ This analysis transforms the matrix of independent variables into vectors which are independent. It shows that the sample variation of the independent variables can be adequately represented in two dimensions. Regressions on two principal components are included as equations (6) and

5/ The homogeneity restraint is included in the regression by deflating food price and disposable income by the price of items other than food.

6/ See (6, Section 11-1) for a discussion of principal components.

(11). The coefficients were transformed, so they are expressed in terms of the original units.

ELASTICITIES AND FLEXIBILITIES

The last three columns of tables 2 and 3 contain estimates of price and income elasticities and flexibilities. The estimates for quantity-dependent equations are elasticities (table 2), and those for price-dependent equations are flexibilities (table 3). The estimates for elasticities and flexibilities are based on the recent 3-year averages for the variables (except for logarithmic equations which have constant elasticities). The estimates for price elasticity range from -.168 to -.438, and those for price flexibility from -1.238 to -2.422. The range for income elasticity is from .095 to .334, and for income flexibility from .194 to .664. The estimates of elasticities and flexibilities based on averages of variables for the period 1957-76 are given in table 4. The estimates in table 4 differ from those in tables 2 and 3 because the different rates of change for the variables are included. These tables give a menu of various estimates. Some suggestions about the use of different estimates are given in the final section.

Table 4--Elasticities and flexibilities calculated at the sample mean 1/

Equation	Elasticities			Flexibilities		
	Price	Income	Other price	Price	Income	Other price
(1)	-.294	.174	.176			
(2)	-.253	.098	.231			
(3)	-.283	.111	.277			
(4)	-.168	.223	-.055			
(5)	-.326	.217	.288			
(6)	-.279	.205	.108			
(7)				-2.652	.442	.768
(8)				-1.845	.511	.686
(9)				-2.422	.199	1.137
(10)				-1.724	.664	.789
(11)				-2.579	.412	.815

1/ The estimates for logarithmic equations (3), (4), (5), (9), and (10) remain unchanged from tables 2 and 3.

EARLIER STUDIES

A comparison of the present work with earlier studies will be useful. Brandow, in (2), fitted the following equation to data for 1923-56 (omitting 1942-47): 7/

$$\log PR = 4.131 - \underset{(.466)}{2.898} \log QT + \underset{(.149)}{.545} \log OP + \underset{(.092)}{.766} \log YD$$

Transposing the above equation, he obtains:

$$\log QT = 1.771 - .345 \log PR + .188 \log OP + .264 \log YD$$

Brandow uses the coefficient of log PR (-.345) as an estimate of elasticity. The fallacy of this approach is pointed out by Houck in (5).

Waugh, in (10), fits separate equations to the data for 1926-41 and 1948-62. He deflates the retail price index of food and the per capita disposable income by the CPI.

His equations are: 8/

$$\log PR = 7.3467 - \underset{(0.5588)}{3.6871} \log QT + \underset{(0.5588)}{1.0183} \log YD \quad R^2 = 0.923 \ (1926\text{-}41)$$

$$\log PR = 4.8094 - \underset{(0.6076)}{1.9700} \log QT + \underset{(0.0671)}{0.5658} \log YD \quad R^2 = 0.920 \ (1948\text{-}62)$$

$$\log QT = 1.9459 - \underset{(0.0325)}{0.2037} \log PR + \underset{(0.0257)}{0.2320} \log YD \quad R^2 = 0.869 \ (1926\text{-}41)$$

$$\log QT = 2.1043 - \underset{(0.0731)}{0.2370} \log PR + \underset{(0.0299)}{0.1852} \log YD \quad R^2 = 0.868 \ (1948\text{-}62)$$

7/ The variables are as defined in tables 2 and 3 except that YD is per capita disposable income. The values in parentheses are standard errors of the coefficients. The estimates of R^2 and DW are not given.

8/ The values in parentheses are standard errors of the coefficients. The estimates for DW are not given.

In (4), Hiemstra fits two equations for the retail food price index for the period 1948-66: 9/

$$\log PR = 3.998 - \underset{(1.499)}{1.427} \log QT$$
$$+\underset{(0.052)}{0.056} \log YD - 0.077 \log S$$
$$R^2 = .952 \quad DW = 1.14$$

$$\log PR = 1.940 - \underset{(0.285)}{0.928} \log S$$
$$+\underset{(0.068)}{1.155} \log OP - \underset{(0.030)}{0.195} \log YD$$
$$R^2 = .982 \quad DW = 2.33$$

The estimates of elasticities and flexibilities from various studies are included in table 5. The estimates of income elasticity and flexibility in this study are smaller than earlier estimates. A plausible explanation is that with rising income, the income elasticity of food has declined.

Table 5--Estimates of elasticities and flexibilities from various studies

Authors	Elasticities		Flexibilities	
	Price	Income	Price	Income
Mann, St.George (1957-76) 1/	-.283	.111	-2.422	.199
Brandow (1923-56, excluding 1942-47)	-.345	.264	-2.898	.766
Waugh (1926-41)	-.204	.232	-3.687	1.018
(1948-62)	-.237	.185	-1.970	.566
Hiemstra (1948-56)	---	---	-1.427	.506

1/ Estimates from table 4, equations (3) and (9).

9/ The variables are as defined in tables 2 and 3 except S = end-of-year stocks of food commodities.

CONCLUDING REMARKS

The estimates of elasticities and flexibilities presented above are based on different specifications of demand functions. The estimates to be used depend on the user's specific needs. If the objective is to make forecasts one may as well forget about elasticities and flexibilities and use equations (1) and (7). Policy analysts are generally interested in the impact of proposed programs on price and demand in the future. Some prefer using estimates based on logarithms because these elasticities do not depend on the level of variables. However, estimates based on the most recent 3-year average of the variables in equations (1) and (7) may prove more useful in policy analysis. The principal component analysis removes the collinearity among independent variables. Therefore, the estimate from principal component regressions gives better estimates of the relative effects of the independent variables.

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