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THE DEMAND FOR UNITED STATES FARM OUTPUT†

Much attention has been given to estimating the price elasticity of demand for individual farm commodities. But remarkably little attention has been given to estimating the price elasticity of demand for farm output in aggregate. It is well known that reducing the quantity marketed will increase receipts if demand is inelastic, and will decrease receipts if demand is elastic. Producers of commodities with an inelastic demand have sometimes restricted production and marketing to raise income. Less production of one commodity often leads to increased production and hence to lower prices and incomes for other commodities.

Society is concerned with the income of the entire farming industry—not just with the income of one commodity group that can successfully raise income by marketing restrictions. Acting presumably in the interest of all farmers, the U.S. Department of Agriculture in the past has attempted to raise farm prices and incomes by reducing aggregate farm production and marketing by diverting land from crops to soil conserving uses and by other means. The ability of general production controls to raise total farm income clearly depends on the elasticity of demand for aggregate farm output. Public policies for commercial agriculture have been predicated in the past on the assumption that demand for farm output is highly inelastic. Yet to my knowledge, no formal estimate has been made of this very basic elasticity parameter. Because of the wide opportunities for substitution of one commodity for another in consumption, the price elasticity of demand for any one farm commodity is a very misleading measure of the impact on aggregate farm prices and incomes of a change in farm output and marketings. These effects can best be gauged from the price elasticity of demand for farm output in aggregate.

The objective of this paper is to estimate the price elasticity of demand for U.S. farm output. Some disaggregation is necessary because of the structure of demand and limitations in data and estimation procedures. The method used in this study is to aggregate those commodities for which interdependence is sizable, either because of strong complementarity or substitutability. Thus farm output

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is divided into food (and feed), cotton, and tobacco, and each of these components is further divided into domestic and foreign consumption categories.

Major emphasis is given to estimating the domestic demand for food and the long-run demand for food and feed exports. The price elasticity of domestic demand for U.S. food is estimated at the farm and retail level. The export demand is expected to have a strong influence on the total demand elasticity. Hence, various approaches are used to estimate the elusive elasticity of foreign demand for U.S. food and feed. These estimates are combined with previous estimates of demand for cotton and tobacco to compute the elasticity of demand for U.S. farm output in aggregate.

DEMAND FOR FOOD IN THE U.S.

The primacy of the domestic food use of farm output, and possible shortcomings of past measures of demand elasticities, prompt an effort to improve estimates of the domestic demand for food in the U.S. Before examining the new estimates, results of several past studies are reviewed below.

Past Estimates of Demand Elasticities

All of the estimates of elasticities of domestic food demand summarized in Table 1 were based on single-equation least squares with data in logarithms. Except for selected equations by Waugh (*37*), all the equations were estimated with per capita food quantity regressed on deflated food price and deflated per capita disposable income.

The price and income elasticities declined between the periods 1926–41 and 1948–62 according to Waugh's estimates for the most recent period of demand at the farm level with quantity the dependent variable. The price elasticity of demand at the farm level appeared to be approximately −.2 in the prewar period and −.1 in the postwar period. The income elasticity fell from .3 to .1 between the two periods according to Waugh's results.

Brandow, Foote, King, and Stevens (*4*, p. 19; *12a*, p. 22; *18*, pp. 1408–17; *24*, Table 2) have summarized estimates of elasticities of demand for food made before the studies shown in Table 1. A recent estimate of food demand was made by Houthakker and Taylor (*17*, p. 61). Their dependent "quantity" variable was a constant-dollar measure of annual personal consumption expenditure for food from 1929 to 1961 compiled by the U.S. Department of Commerce. In their dynamic equation, income was the only exogenous variable. In a static equation, price and income were included but the authors gave no estimate of the price and income elasticities.

In addition to the time series estimates above, numerous estimates have been made of the income elasticity of demand for food from cross-sectional data.[1] The latter estimates tend to be higher than results from time series because habit causes people to adjust consumption patterns slowly as they move up the income scale (*19*, pp. 128–36).

In the following analysis, several variations and refinements are made that potentially can improve on the previous time series demand estimates. These in-

[1] For summaries of these estimates see *18*, pp. 1408–17; *24*, Table 2.

TABLE 1.—SUMMARY OF INCOME AND PRICE ELASTICITIES OF AGGREGATE DEMAND FOR FOOD IN THE UNITED STATES, ESTIMATED BY LEAST SQUARES FROM TIME SERIES*

Study	Period	Dependent variable	Elasticity with respect to: Income	Price	R^2
Daly (1957)	1929–41 plus 1948–56[a]	Quantity of food at retail	.52	−.26	.88
	1929–41 plus 1948–56[b]	Quantity of food at farm	.18	−.12	.76
Burk (1961)	1924–41[c]	Quantity of all food at retail	.23	−.17	.85
	1948–57[c]	Quantity of all food at retail	.18	−.24	.88
	Combined[c]	Quantity of all food at retail	.25	−.14	.97
	1929–41[d]	Quantity of farm foods sold	.42	−.19	.91
	1948–57[d]	Quantity of farm foods sold	.35	−.10	.94
	Combined[d]	Quantity of farm foods sold	.45	−.12	.97
Brandow (1961)	1923–41[e]	Price of food at retail	.29	−.34	...[e]
	1948–56[e]	Price of food at retail	.24	−.29	...[e]
	Combined[e]	Price of food at retail	.26	−.34	...[e]
Waugh (1964)	1926–41	Price of food at retail[f]	.28	−.27	.92
		Quantity of food at retail[g]	.23	−.20	.87
	1948–62	Price of food at retail[f]	.29	−.51	.92
		Quantity of food at retail[g]	.19	−.24	.87
	1926–41	Price of food at farm[f]	.39	−.27	.95
		Quantity of food at farm[g]	.30	−.19	.84
	1948–62	Price of food at farm[f]	.03	−.19	.74
		Quantity of food at farm[g]	.06	−.10	.88
	1926–41	Price of marketing services[f]	.21	−.26	.86
		Quantity of marketing services[g]	.18	−.19	.86
	1948–62	Price of marketing services[f]	.94	−1.22	.98
		Quantity of marketing services[g]	.23	−.20	.79

* Sources of data are shown by citation number in notes *a–g*.
[a] From *9*, equation 10, p. 6.
[b] From *9*, equation 17, p. 10.
[c] From *8*, equation 3.6, Table 3.2.
[d] From *8*, equation 3.2, Table 3.2.
[e] From *4*, p. 18. R^2 not given.
[f] From *37*, Table 3.2.
[g] From *37*, Table 3.3.

clude adding (a) more recent observations to the variables, (b) more variables to the specification, (c) a procedure to remove bias in the coefficients caused by presence of autocorrelation in the residuals, (d) estimates of long-run and short-run demand elasticities with respect to price and income, (e) an alternate deflator and coding of the variables, and (f) an alternative approach for calculating the elasticity of demand at the farm level.

Specification of Demand Variables

The implicit demand function (1) for all food in the U.S. contains several conceptually relevant variables. According to the function,

$$(1) \qquad (P, Q, Y, P_N, D_1, D_2, D_3, D_4, T, U) = 0$$

there exists some relationship between food price P, food quantity Q, consumer disposable income Y, the price(s) of related commodities P_N, and the distribution of population by age D_1, income D_2, location D_3, and occupation D_4. T in the demand function relates to tastes and preferences and to factors such as fads, wars, technology changes, etc. The random error is designated as U. When it is recognized that each of the variables may be represented by current as well as by lagged values, the highly complex problem of specifying variables becomes apparent. When it is also conceded that 30 years of time series of the type available for statistical estimation of (1) are likely to contain no more than a half dozen independent relationships and that multicollinearity precludes use of numerous variables in the demand equation, the problem of specification comes into sharper focus. Exclusion of relevant variables correlated with included variables biases the coefficients.[2] And inclusion of too many correlated variables in a single regression causes estimates of coefficients to be unstable and unreliable.

Another problem that has plagued researchers is the selection of the dependent variable (*14,* Chapter 2). Use of simultaneous equation techniques that permitted more than one variable to be dependent gained wide acceptance in the early postwar period. The fact that none of the estimates in Table 1 were by procedures that allow for joint interdependency in the variables, testifies to the trend away from the simultaneous equation approach. The trend away from techniques allowing for joint interdependency has been prompted by several factors including the simplicity and low computing cost of single equations. Also, requirements generally call for prediction of only price or quantity, and single equation least squares estimates are likely to predict with efficiency if not low bias, when all variables except (say) price are known and can be used to predict price.

The case for making price dependent receives more support for study of aggregate than of disaggregate demand for food. For individual food items, the individual consumer finds the supply to be perfectly elastic, and he adjusts purchases at will to a desired level consistent with the given prices and other variables. This consideration suggests selection of food quantity as the dependent or effect variable in a micro analysis. Prices and other independent variables are known with some certainty, but errors arise in predicting purchases; hence the econometrician minimizes error around Q. At the macro level, the marketing system allocates food already produced to create the time, place, and form utility that increases profits. Prices adjust to bring this allocation. Thus a case can be made that price, not quantity, is the dependent or effect variable in the demand equation for all food.

There is now considerable support for the assumption that many economic relationships in agriculture are recursive. Production and consumption are not jointly interdependent because of the long-run nature of the production process in agriculture. Farm managers make production decisions based on what prices are expected when the crop or livestock is ready for market at the end of the production period. Viewed at the *end* of the production period, the current output tends to be predetermined by past prices. Price, the dependent variable in the demand equation, is a function of the demand quantity which is predetermined from the supply function and from exogenously determined stock decisions made

[2] If the excluded variable continues to vary in relation to the included variable in the future as in the past, the bias in the coefficient need not lead to biased predictions. However, each coefficient gives a biased estimate of the impact on the variable being predicted of a change in the specific independent variable alone.

by the government. Quantity is dependent in the supply equation. This relationship between the supply and demand is interdependent, however, because current price and current quantity are included in the demand equation. Nevertheless, the equations can be estimated by single equation least squares. The correlation between the disturbance in the demand equation and the current quantity, which would give rise to least squares bias in the coefficients, is removed by using as observations in the demand equation the predicted quantity from the supply equation.

Predicted observations of quantity from the supply equation, although independent of disturbances in the demand equation, are likely to contain substantial error due to imperfect specification of the supply equation. This specification error plus recognition that the supply quantity is not directly relevant for the demand equation because of changes in stocks and other adjustments in market channels, leads to use of the current observed consumption rather than predicted consumption of food as "quantity" in the demand equation. This approach is similar to that used by pioneers such as Henry Schultz and Richard Stone. Thus ironically the genesis of thought on demand for farm products in aggregate appears to have completed a full cycle, and current thought is that the simple single equation least squares technique provides the "best" estimate of demand for U.S. food.

Price is used as the dependent variable in several empirical equations in this study. The resulting estimates of price flexibility are useful for judging the impact of a change in quantity on food price. Although it is argued above that price is the relevant dependent variable, quantity is the dependent variable in some equations. The resulting estimates of the price coefficient or elasticity of demand are useful for comparing results of alternate specifications and for judging the effect of a price change on quantity demanded.

Specification of Adjustment Lags

Empirical estimates have failed to distinguish between the short-run and long-run price elasticities of aggregate demand for food in the U.S. The widely held view, however, is that the elasticity (absolute value) is greater in the long run (cf. *21*, pp. 774–88). Thus it is useful to examine, within the framework of the models used in this study, the expected relative magnitude of the price elasticities of demand over various lengths of run.

Model I

$$P_t - P_{t-1} = \alpha[P_t^* - P_{t-1}] \tag{2}$$

$$P_t^* = a - bQ_t + cP_{Nt} + dY_t + e_t \tag{3}$$

$$P_t = a\alpha - b\alpha Q_t + c\alpha P_{Nt} + d\alpha Y_t + (1-\alpha)P_{t-1} + \alpha e_t \tag{4}$$

Model II

$$Q_t - Q_{t-1} = \gamma[Q_t^* - Q_{t-1}] \tag{5}$$

$$Q_t^* = r - sP_t + uP_{Nt} + vY_t + w_t \tag{6}$$

$$Q_t = r\gamma - s\gamma P_t + u\gamma P_{Nt} + v\gamma Y_t + (1-\gamma)Q_{t-1} + \gamma w_t \tag{7}$$

Two dynamic models depicting long-run and short-run adjustments are shown in equations (2) to (7). Model I (equations 2, 3, 4) assumes that prices adjust with a distributed lag to the quantity. The rate of adjustment is α (2) and the unexplained error is e (3). Equation (4) formed by substituting (3) into (2) contains only observed variables and can be estimated by least squares. The model postulates that for a sustained level of the quantity Q_t and other variables, there is an equilibrium price P_t^* (3). The actual adjustment in prices made during the current year, the left side of (2), is some proportion α of the equilibrium adjustment, the right side of (2). Because of inertia of past decisions, costs and time required to change prices in response to a new level of Q, the actual current adjustment in prices is less than the desired adjustment. Also decision-makers in the market may wait to see if the quantity change is permanent before they adjust prices. The result is that the long-run price flexibility is greater (absolute value) than the short-run price flexibility and $0 < \alpha < 1$. Since the price elasticity of demand is essentially the inverse of the price flexibility of demand, it follows from the above reasoning that the long-run price elasticity will be less than the short-run elasticity.

The adjustment rate of quantity to a change in price and other variables is γ (5) and the error is w (6) in Model II. At least three factors are at work in Model II to change the quantity consumed by individuals given a sustained higher price P_t. One is the substitution effect—people will reduce purchases Q in the long run because they increasingly will find substitutes for the commodity. Another is the learning effect—people will not initially be aware of a higher P, will follow their old buying habits, or for other reasons will not respond immediately with reduced purchases of Q. Finally, there is a stock effect—consumers and storage firms will respond to a higher price by depleting old stocks or by failing to expand inventory in the short run. But in the long run, working inventories will need to be replenished, and Q will rise. Of these three "consumer" effects described in the context of Model II, only the inventory effect explains a higher price elasticity of demand in the short than in the long run. Because most food items are perishable, the stock effect is likely to be small. Hence the consumer effect suggests a higher price elasticity in the long run and the market effect, discussed in the context of Model I, suggests a lower price elasticity in the longer run. The net effect can best be answered from the empirical results.

If there are no errors in the data or equations, least squares estimates of the static form of Models I and II with $\alpha = \gamma = 1$ will result in $s = 1/b$. In this unlikely case, equations (4) and (7) give the same estimate of the price elasticity of demand. In practice there will be errors. Cross price effects are unlikely to be adequately accounted for. The result is a tendency for the reciprocal of the price flexibility from equation (4) to be less (absolute value) than the true price elasticity; and for the reciprocal of the price elasticity from equation (7) to be less than the true price flexibility (*16*, pp. 789–92). The difference between the two estimates arising from substitution effects should be low for all food, however, because the cross price elasticity of demand for food is low—there are few substitutes for food.

Adjustments to the equilibrium or desired quantity may be slow for reasons discussed above *given subjective certainty of the magnitude of explanatory vari-*

ables. But another kind of lag may exist due to the degree of certainty with which explanatory variables are known. Purchases may be based on expected income, not on current actual income. Demand may not respond to an increase in income because the consumer is uncertain that his income will be permanent. Thus in addition to the adjustment models in equations (2) to (7), an expectation model for income is postulated in this study. Expected income $\overline{Y}_t$, is specified as (8), a declining average of income over a three-year period. It is not always

$$\overline{Y}_t = .50Y_t + .33Y_{t-1} + .17Y_{t-2} \tag{8}$$

feasible to separate expectation and adjustment effects. Hence an alternate approach to (8), using a separate distributed lag on income, is employed in this study to provide flexibility (cf. *19a*).

A First Order Autoregressive Scheme

Under favorable circumstances, presence of autocorrelation in the residuals does not bias the parameter estimates although autocorrelation does lead to biased estimates of standard errors and multiple correlation coefficients. But autocorrelation in the residuals does lead to bias and inconsistency in the parameter estimates if lagged observations of the dependent variable are included as in equations (4) and (7). To reduce this source of bias, several equations are estimated with a first order autoregressive scheme.

Failure to specify all relevant variables leads to an unexplained residual U_t that is likely to exhibit positive autocorrelation over time. Because the Durbin-Watson and other tests for autocorrelation are unreliable, equations are estimated with the autoregressive scheme postulated in equation (9). The current residual U_t in (9) is presumed to be composed of a systematic component βU_{t-1} and a

$$U_t = \beta U_{t-1} + u_t \tag{9}$$

random component u_t independent of the past residuals. Estimation of β removes the systematic component from U_t and theoretically leads to unbiased estimates of the coefficients in distributed lag equations such as (4) and (7).[3]

The Data

The domestic demand for food at the retail level is estimated with U.S. annual data from 1922 to 1965, excluding the years 1942–47. Price and income data are deflated by the implicit price deflator of the Gross National Product, 1957–59 = 100. Data are in original values, not logarithms since there appears to be little basis for choosing other than a linear model within the range of available data. Sources and other details of the data are discussed in the Appendix.

The food quantity variable Q is intended to measure the quantity of food sold at the retail level. Farm ingredients are weighted by base period retail prices and summed to form a price-weighted index of all food that moves through retail stores. The base price weights for the 11 major food categories are updated fre-

[3] For a discussion of methods and interpretations of autoregressive least squares, see Martin (*19a*).

quently; hence the index is a modified Laspeyres formula. The food index does not explicitly measure marketing costs, but rather is a weighted average of pounds of meat, gallons of milk, etc. However, some marketing margin effect is included because the retail prices used to weight quantities include marketing costs. The index excludes alcoholic beverages, but includes coffee, tea, and cocoa.

The "index of per capita food consumption" measures food available at the retail level, hence does not measure food actually consumed. Bennett states that "foods providing two-thirds to three-fourths of the aggregate calories are estimated at a level of distribution antecedent to retail" (*2*, p. 1148). Examples are flour, sugar, vegetable oils, lard, and milk. Expenditures for food purchased at restaurants are not included but the "quantities" of basic food ingredients therein are included. Because food purchased as meals is excluded, multiplying the food quantity index by the BLS consumer price index for food (which includes price of food consumed away from home) would not give total outlays for all food. Despite the many inadequacies, according to the USDA "The index of per capita food consumption is regarded as the best available measure of changes in overall food consumption at the retail level" (*6*, p. 66).

The food price variable P is the consumer price index for food compiled by the Bureau of Labor Statistics. The CPI reflects changes in prices paid for food by urban wage earners and clerical workers. The group currently comprises over half of the U.S. urban population and about 40 per cent of the U.S. total population. The sample is scientifically oriented and is based on over 1,500 stores located in suburbs as well as in central stores of 56 cities (*33*, p. 179). The weights placed on components of the per capita food consumption index and the consumer price index for food are somewhat similar. But the consumer price index places greater weight on bakery products, fish, processed and prepared foods, and nonalcoholic beverages than does the food consumption index. Also, beginning with 1953 the CPI for food includes prices of food consumed away from home (primarily in restaurants)—a category not included in the food consumption index.

Empirical Results

Demand equations in Tables 2 to 5 contain the results of several variations of the basic model. Food price was dependent in half the equations, food quantity in the other half. Equations were estimated from 1922–41 data alone (Tables 2 and 4), 1948–65 data alone (Tables 3 and 5) and from the combined data for the two periods (not shown but available from author). Variations also include demand with and without the variables measuring age distribution (D) and nonfood prices (P_N). The equations were estimated with and without a first order autoregressive scheme, and with and without separate lags on the income variable Y.

There was no consistent difference in magnitude of the price flexibility coefficients $\partial P/\partial Q$ between the prewar and postwar periods in Tables 2 and 3. Values of F were calculated to test simultaneously the null hypothesis that the respective parameters were equal in the two periods, i.e., $\partial P/\partial Q$ (1922–41) = $\partial P/\partial Q$ (1948–65), $\partial P/\partial D$ (1922–41) = $\partial P/\partial D$ (1948–65), etc. With P dependent, the calculated F led to rejection of the null hypothesis at the .05 level in

TABLE 2.—DEMAND EQUATIONS FOR ALL FOOD AT RETAIL, ESTIMATED BY LEAST SQUARES, UNTRANSFORMED DATA, 1922–41, PRICE (P) DEPENDENT*

Equation number	R^2	Constant	Coefficients of variable Q_t	D_t	P_{Nt}	Y_t	P_{t-1}	$\hat{\mu}$	$\hat{\beta}$	T
10	.93	613.92	−1.15	−6.48	−.61	.031	.35	...	...	1.10
			(1.66)	(1.81)	(2.29)	(1.99)	(1.75)			(1.16)
11	.94	146.87	−1.03	−1.33	−.54	.027	.35	...	.51	−.21
			(1.80)	(.19)	(2.01)	(2.18)	(1.22)		(1.11)	(.21)
12	.94	286.36	−1.00	−3.98	−.54	.028	.45	.35	...	.29
			(1.65)	(.57)	(1.94)	(2.10)	(1.67)	(1.53)		(.20)
13	.94	158.59	−1.04	−2.01	−.48	.029	.38	.26	.35	−.094
			(1.90)	(.24)	(1.77)	(2.34)	(.94)	(.88)	(.50)	(.077)
14	.89	199.56	−1.80	...	...	.050	.19	...	...	−.52
			(2.74)			(3.85)	(1.13)			(3.25)
15	.91	83.51	−1.32	...	...	.041	.20	...	.51	−.34
			(1.97)			(3.36)	(.71)		(1.09)	(2.03)
16	.91	98.75	−1.21	...	...	.040	.48	.28	...	−.29
			(1.81)			(3.24)	(2.17)	(2.51)		(2.04)
17	.92	76.66	−1.16	...	...	.041	.39	.16	.38	−.29
			(1.97)			(3.51)	(.94)	(.59)	(.57)	(2.33)
18	.92	73.27	−1.20	...	...	.043	.32	.00	.54	−.29
			(2.05)			(3.80)	(1.09)		(1.90)	(2.32)
19	.88	207.34	−4.84	...	...	.058	.18	.00	...	−.53
			(2.65)			(5.32)	(.85)			(3.01)

* See Appendix for sources of data. Variables are defined as follows:
P Consumer price index for food.
Q Index of per capita food consumption.
D Proportion of population 14–64 years of age.
P_N Consumer price index for items other than food.
Y Personal disposable income per capita.
μ Coefficient of income lag. Rate of adjustment of dependent variable to income is $1-\mu$. When μ is not specified income has the same lag as the other independent variables. When μ is .00 the income variable is forced to have no lag.
β First order autoregression coefficient. When β is not given the equation is estimated by ordinary least squares.
T Time (the time trend has no lagged effect).
Figures in parentheses are t values (Student-t distribution).

"paired" equations (14) and (24), and in equations (19) and (29). Since the null hypothesis was rejected in only two of the ten equational forms, there was little basis for concluding that the economic structure of retail demand had changed between the two periods.[4] The coefficient of Q_{t-1} indicated that past value of explanatory variables had a greater impact in the 1948–65 period than in the 1922–41 period; and hence that the rate of adjustment of food price to a change in food quantity was more rapid in the earlier period.

The coefficients of population distribution D and price of nonfood items P_N were unstable and unreliable due to intercorrelation with other variables and were dropped in the bottom six equations of Tables 2 and 3. Based on the resulting change in the coefficient of T, the effect of these variables cannot be separated from the time trend. The effect of nonfarm prices on the demand for food appeared to be low. This suggests that food had no discernible net substitution or complementary relationship with other goods according to Tables 2 and 3.

Addition of an autoregressive scheme did little to improve the equations in

[4] Results of the F tests are not shown but are available from the author.

TABLE 3.—DEMAND EQUATIONS FOR ALL FOOD AT RETAIL, ESTIMATED BY LEAST SQUARES, UNTRANSFORMED DATA, 1948–65, PRICE (P) DEPENDENT*

Equation number	R^2	Constant	Coefficients of variable Q_t	D_t	P_{Nt}	Y_t	Q_{t-1}	$\hat{\mu}$	$\hat{\beta}$	T
20	.96	253.58	−1.84	−.56	−.10	.031	.58	...	...	−1.04
			(4.01)	(1.06)	(.18)	(2.88)	(2.28)			(2.27)
21	.96	230.29	−1.87	−.84	.26	.033	.55	...	.135	−.99
			(4.00)	(1.18)	(.37)	(2.86)	(1.88)		(.75)	(2.35)
22	.96	211.80	−1.79	−1.02	.52	.035	.38	.21	...	−.91
			(3.43)	(1.26)	(.83)	(2.47)	(1.52)	(1.33)		(2.15)
23	.96	221.38	−1.83	−1.06	.45	.036	.41	.25	−.053	−.93
			(2.94)	(1.13)	(.51)	(2.16)	(1.11)	(.78)	(.14)	(2.06)
24	.95	191.16	−1.58	...	...	.024	.62	...	...	−.68
			(4.34)			(2.92)	(3.67)			(2.24)
25	.96	179.41	−1.56	...	...	.024	.62	...	.052	−.64
			(4.04)			(2.72)	(3.38)		(.38)	(1.98)
26	.95	162.89	−1.39	...	...	.023	.50	.17	...	−.46
			(3.31)			(2.17)	(2.25)	(.96)		(1.33)
27	.95	167.15	−1.41	...	...	.025	.50	.20	−.058	−.49
			(3.21)			(2.21)	(2.25)	(.54)	(.17)	(1.32)
28	.94	179.92	−1.43	...	...	.022	.57	.00	.053	−.36
			(3.29)			(1.99)	(2.69)		(.37)	(1.01)
29	.94	191.58	−1.45	...	...	.024	.58	.00	...	−.39
			(3.54)			(2.21)	(2.97)			(1.13)

* See Table 2 and Appendix for definition of variables. Figures in parentheses are t values.

Tables 2 and 3. The first order autoregressive coefficient $\hat{\beta}$ was not significant at the .05 level in any of the equations where it was included in the two tables.

Because food price may respond differently to income than to the other variables, two approaches were used. One was to use an income expectation variable $\bar{Y}$ which was a weighted average of current and past income (cf. equation 8). The t-value on the coefficient of $\bar{Y}_t$ was lower than that on Y_t however. The variable appeared to add little to the explanation of food demand, and was dropped. A second approach was to allow a separate lag μ on income. The t-value and magnitude of the estimated coefficient $\hat{\mu}$ were low (Tables 2 and 3). The null hypothesis that $\mu = 0$ is not rejected; hence $\hat{\mu}$ was forced to zero in equations (18) and (19). The new form did not appreciably change the lag on the other variables.

The statistical basis for concluding that the adjustment rate was not unity (i.e., the coefficient of the lagged dependent variable differed from zero) was stronger for the late period (Table 3) than for the early period (Table 2). Approximately two-thirds of the price adjustment to equilibrium was made in one year according to equation (10). Nearly half the adjustment was made in one year according to equation (20).

Multiple coefficients of determination were lower when Q was dependent (Tables 4 and 5) than when P was dependent (Tables 2 and 3). Also adjustment rates were faster with Q dependent.

An F test was used to examine the null hypothesis that the respective parameters in the individual equations in Tables 4 and 5 were equal when Q was dependent. The F test suggested rejection of the null hypothesis that the parameters

TABLE 4.—DEMAND EQUATIONS FOR ALL FOOD AT RETAIL, ESTIMATED BY LEAST SQUARES, UNTRANSFORMED DATA, 1922–41, QUANTITY (Q) DEPENDENT*

Equation number	R^2	Constant	Coefficients of variable							
			P_t	D_t	P_{Nt}	Y_t	Q_{t-1}	$\hat{\mu}$	$\hat{\beta}$	T
30	.89	163.40	−.25	−1.18	−.047	.020	.090	...	...	.19
			(3.53)	(.58)	(.50)	(5.00)	(.39)			(.35)
31	.89	164.49	−.25	−1.74	−.041	.021	−.028	...	.20	.29
			(3.36)	(.77)	(.37)	(5.40)	(.12)		(.53)	(.54)
32	.91	110.56	−.18	−.74	.12	.024	.26	−.15	...	.20
			(2.10)	(.45)	(.96)	(6.24)	(1.30)	(.88)		(.41)
33	.92	26.54	−.13	.10	.20	.024	.45	−.097	−.45	.021
			(1.81)	(.078)	(1.84)	(6.14)	(2.35)	(.50)	(1.39)	(.045)
34	.89	79.97	−.23	...	...	.019	.15	...	...	−.10
			(4.02)			(6.62)	(1.04)			(1.58)
35	.89	78.19	−.23	...	...	.019	.13	...	.042	−.095
			(3.65)			(6.12)	(.71)		(.13)	(1.42)
36	.89	73.04	−.21	...	...	.020	.21	.033	...	−.091
			(3.39)			(7.01)	(1.32)	(.27)		(1.48)
37	.90	75.07	−.20	...	...	.019	.33	.13	−.31	−.11
			(3.64)			(6.52)	(1.58)	(.83)	(.84)	(1.65)
38	.89	76.51	−.20	...	...	.021	.22	.00	−.037	−.090
			(3.24)			(8.09)	(1.10)		(.11)	(1.44)
39	.89	75.04	−.20	...	...	.021	.21	.00	...	−.089
			(3.61)			(8.34)	(1.39)			(1.51)

* See Table 2 and Appendix for definition of variables. Figures in parentheses are t values.

TABLE 5.—DEMAND EQUATIONS FOR ALL FOOD AT RETAIL, ESTIMATED BY LEAST SQUARES, UNTRANSFORMED DATA, 1948–65, QUANTITY (Q) DEPENDENT*

Equation number	R^2	Constant	Coefficients of variable							
			P_t	D_t	P_{Nt}	Y_t	Q_{t-1}	$\hat{\mu}$	$\hat{\beta}$	T
40	.84	136.20	−.28	−.55	.32	.018	−.010	...	...	−.65
			(2.93)	(2.42)	(1.30)	(3.59)	(.056)			(3.02)
41	.87	130.81	−.28	−.89	.31	.021	−.23	...	.28	−.56
			(2.96)	(1.81)	(1.20)	(3.83)	(1.11)		(1.44)	(2.95)
42	.85	125.36	−.31	−.63	.36	.016	−.16	.19	...	−.65
			(3.14)	(2.05)	(1.37)	(3.70)	(.68)	(1.00)		(2.91)
43	.87	124.24	−.31	−.94	.32	.019	−.29	.031	.34	−.60
			(2.24)	(.94)	(1.15)	(2.34)	(1.07)	(.070)	(.52)	(2.07)
44	.72	136.02	−.27	...	...	.016	−.11	...	...	−.47
			(2.50)			(2.91)	(.59)			(2.28)
45	.73	118.35	−.30	...	...	.016	−.20	...	.20	−.38
			(2.66)			(2.81)	(.68)		(.67)	(1.49)
46	.74	124.93	−.34	...	...	.015	−.26	.20	...	−.53
			(2.93)			(2.89)	(.97)	(.96)		(2.36)
47	.75	117.25	−.37	...	...	.015	−.31	.15	.16	−.49
			(2.88)			(2.46)	(1.05)	(.29)	(.22)	(1.37)
48	.74	114.67	−.34	...	...	.016	−.30	.00	.29	−.43
			(2.90)			(3.08)	(1.02)		(.93)	(1.69)
49	.72	142.16	−.29	...	...	.016	−.16	.00	...	−.53
			(2.56)			(3.10)	(.78)			(2.27)

* See Table 2 and Appendix for definition of variables. Figures in parentheses are t values.

were equal in the two periods at the .05 level for "paired" equations (30) and (40), (36) and (46), and (39) and (49); and at the .01 probability level in equations (34) and (44). The fact that the null hypothesis was rejected in four of the ten equational forms was inconclusive evidence that the structure of demand had changed between the two periods depicted in Tables 4 and 5.

Again there is considerable instability in the coefficients of D and P_N, brought about by multicollinearity. Consequently these variables were eliminated in several equations.

A significant positive coefficient of Q_{t-1} would indicate that the short-run response to price was less than the long-run response, a zero coefficient would indicate that the two were equal, and a significant negative coefficient would indicate that the long-run response was lower. There were several negative coefficients in Tables 4 and 5, but they did not differ significantly from zero. The positive coefficients too were generally near zero on the lagged quantity; hence the adjustment rate was rapid according to Tables 4 and 5. However, there was an apparent tendency for the coefficients to become negative in the 1948–65 period, suggesting that over time the long-run price coefficient declined relative to the short-run price coefficient.

Introduction of an autoregressive coefficient $\hat{\beta}$ added little to the equations, and appeared to be an inadequate replacement for the "specification error" caused by dropping D and P_N. Judging by the small coefficient $\hat{\mu}$, income worked its full effect on the food demand quantity in one year. Providing income with a separate rate of adjustment, or using expected rather than actual income, did not improve the explanation of demand. The specification in Tables 4 and 5 gave no basis for concluding that the long-run and short-run income coefficients differed in magnitude.

Price and Income Elasticities of Demand at Retail

The price flexibility estimates were larger (absolute value) in the long run than in the short run, and were greater in the postwar than in the prewar period. The impact on prices of a given change in quantity appeared to be rising over time. Based on an average of results from equations (10), (14), and (18) for the prewar period and equations (20), (24), and (28) for the postwar period, the short-run price flexibility was −1.3 in the prewar period and −1.6 in the postwar period. The long-run price flexibility, based on an average from the same respective equations as above, was −1.7 in the prewar period and −4.2 in the postwar period.

As stated earlier, price flexibility estimates from equations with P dependent should be used to gauge the impact of a change in quantity upon price. For comparison purposes in Table 6, however, the reciprocal of the price flexibility from equations with P dependent were included with other price elasticity of demand estimates from selected equations with Q dependent.

Compared to results with P dependent, the equations with Q the dependent variable show smaller differences in price elasticities at the retail level between the short run and long run, between the prewar and postwar periods, and among the selected equations. The elasticity of demand based on an average of estimates from prewar equations (30), (34), and (38) was −.25 in the short run and −.30

TABLE 6.—PRICE ELASTICITIES OF DEMAND FOR ALL FOOD AT THE RETAIL LEVEL, COMPUTED FROM SELECTED EQUATIONS*

Equation number and period	Short run computed at mean of:				Long run computed at mean of:			
	1922	1922–41	1964	1948–65	1922	1922–41	1964	1948–65
			Price (*P*) Dependent[a]					
10:1922–41	−.99	−.96	...	...	−.65	−.63	...	...
20:1948–65	...	...	−.52	−.56	...	...	−.22	−.23
14:1922–41	−.63	−.61	...	...	−.51	−.49	...	...
24:1948–65	...	...	−.60	−.65	...	...	−.23	−.25
18:1922–41	−.95	−.92	...	...	−.64	−.62	...	...
28:1948–65	...	...	−.67	−.72	...	...	−.29	−.31
			Quantity (*Q*) Dependent					
30:1922–41	−.29	−.28	...	...	−.32	−.31	...	...
40:1948–65	...	...	−.26	−.28	...	...	−.26	−.28
34:1922–41	−.26	−.25	...	...	−.30	−.29	...	...
44:1948–65	...	...	−.26	−.28	...	...	−.24	−.25
38:1922–41	−.23	−.22	...	...	−.29	−.29	...	...
48:1948–65	...	...	−.32	−.34	...	...	−.25	−.26

* Computed from data in Tables 2–5.
[a] Reciprocals of price flexibility estimates.

in the long run. The average price elasticity from postwar equations (20), (24), and (28) was −.30 in the short run and −.25 in the long run. (The short run refers to one year, the long run to an infinite number of years.) Elasticities were computed at the point estimates for 1922 and 1964, and at mean values for 1922–41 and 1946–65. The latter in theory contain less error for the period represented, but are likely to contain more error than the point estimates as measure of elasticities for 1922 and 1964.

Price and Income Elasticities of Demand at the Farm Level

The foregoing estimates were used to derive indirect estimates of the price elasticity of demand for food at the farm level. The procedure was to estimate the elasticity at the farm level by adjusting the price elasticity at retail with the price-margin equations shown in Table 7. The elasticity of price transmission—the denominator on the right side of equation (50)—was divided into the elas-

$$\frac{\partial Q}{\partial P_F}\frac{P_F}{Q} = \frac{\dfrac{\partial Q}{\partial P}\dfrac{P}{Q}}{\dfrac{\partial P_F}{\partial P}\dfrac{P}{P_F}} \tag{50}$$

ticity of demand at retail to give the price elasticity of demand at the farm level

$$\frac{\partial Q}{\partial P_F}\frac{P_F}{Q}.$$[5]

[5] The formula in (50) abstracts from some of the changes in the market, and considers marketing margin adjustments to be reflected in price rather than quantity. For a more complete formula, see *12*, p. 104. P_F is the price of food at the farm level (see Appendix).

TABLE 7.—PRICE-TRANSMISSION EQUATIONS ESTIMATED BY LEAST SQUARES WITH UNTRANSFORMED ANNUAL DATA, WITH PRICES RECEIVED BY FARMERS (P_F) DEPENDENT*

Equation number and period	R^2	Constant	P_t	T	$P_{F_{t-1}}$
51:1922–41	.69	−260.18	4.35 (2.42)	1.12 (.82)	.16 (.59)
52:1948–64	.94	−265.73	5.52 (2.74)	−1.62 (.83)	.21 (.92)
53:1922–64	.79	−148.43	2.85 (2.70)	−.12 (.46)	.47 (3.26)
54:1922–41	.68	−149.27	3.42 (2.46)	...	.23 (.90)
55:1948–64	.93	−439.75	6.06 (3.22)	...	.31 (1.62)
56:1922–64	.79	−160.48	2.95 (.46)	...	.46 (3.28)

* P_F is the index of prices received by farmers for crops and livestock (1910–14 = 100), deflated by the implicit price deflator of the Gross National Product. Other variables are defined in Table 2 and the Appendix. Figures in parentheses are t values.

An F test supported rejection of the null hypothesis that the respective coefficients in the price-transmission equations for 1922–41 and for 1948–64 were equal. Based on the first specification in equations (51), (52), and (53), the calculated F was 9.62, and $F_{.01}$ ($d.f.$ 29, 4) = 4.04. In the second specification in equations (54), (55), and (56), the calculated F was 12.84, and $F_{.01}$ ($d.f.$ 31, 3) = 4.48. Thus the structure of the margin equations had changed significantly.

Division of the retail price elasticities by the price-transmission elasticities resulted in quite low values of the price elasticity at the farm level (Table 8). Based on the equations with P dependent, the short-run elasticity was approximately −.25 and the long-run elasticity was −.10 in the postwar period. Long-run elasticity estimates were similar among equations for the 1948–65 period, but short-run elasticity estimates were somewhat smaller if based on equations with Q dependent than if based on equations with P dependent.

According to results from equations (10) and (18), the price elasticity of food demand at the farm level was −.5 in the short run and −.3 in the long run for the 1922–41 period. In this prewar period, equations with price dependent gave higher estimates of elasticities and greater differences between elasticities for the two lengths-of-run than did equations with quantity dependent. The equations with P dependent are considered to give conceptually superior results for reasons discussed earlier.

With price dependent and income lagged the same as other independent variables, the structure of the demand equation with P dependent permitted no difference in income elasticity in the short and long run (Table 9).[6] In equations

[6] The income elasticity in the short run was computed from equations as:

$$\frac{\partial Q}{\partial Y}\frac{Y}{Q} = \frac{\dfrac{\partial P}{\partial Y}}{\dfrac{\partial P}{\partial Q}}\frac{Y}{Q}.$$

Since the long-run values of $\partial P/\partial Y$ and $\partial P/\partial Q$ are the short-run values divided by $1-\hat{\beta}$, the latter adjustment coefficient cancels and the two lengths-of-run have the same elasticity estimate.

A simplified approach, which does not separate long- and short-run effects, is to consider the

TABLE 8.—PRICE ELASTICITIES OF DEMAND FOR FOOD AT THE FARM LEVEL*

Equation number and period	Short run, computed at mean of: 1922	1922–41	1964	1948–65	Long run, computed at mean of: 1922	1922–41	1964	1948–65
				Price (P) Dependent				
10:1922–41	–.59	–.55	...	...	–.33	–.30	...	...
20:1948–65	...	...	–.21	–.26	...	...	–.069	–.087
14:1922–41	–.39	–.35	...	...	–.26	–.24	...	...
24:1948–65	...	...	–.24	–.31	...	...	–.073	–.092
18:1922–41	–.57	–.53	...	...	–.32	–.30	...	...
28:1948–65	...	...	–.27	–.34	...	...	–.091	–.115
				Quantity (Q) Dependent				
30:1922–41	–.17	–.16	...	...	–.16	–.15	...	...
40:1948–65	...	...	–.11	–.13	...	...	–.083	–.105
44:1922–41	–.15	–.14	...	...	–.15	–.14	...	...
54:1948–65	...	...	–.10	–.13	...	...	–.075	–.095
38:1922–41	–.14	–.13	...	...	–.15	–.14	...	...
48:1948–65	...	...	–.13	–.16	...	...	–.078	–.099

* Computed from the price elasticities of demand at the retail level from Table 6 divided by the respective long- and short-run price transmission elasticities computed from equations (51) and (52) in Table 7.

(18) and (28), where income is given a separate lag, the long-run income elasticities were lower than the short-run elasticities. The equations with Q dependent indicated that length-of-run has little effect on the magnitude of income elasticities. The average long-run income elasticity of demand from equations (30), (34), and (38) is .29 in the prewar period and from equations (40), (44), and (48) is .30 in the postwar period.

The way in which the index of food consumption is constructed with "farm" quantities weighted by retail prices suggests that $(\partial Q/\partial Y)\ Y/Q$ might be taken as the lower limit of the income elasticity at the retail level and the upper limit of the income elasticity at the farm level.[7] The following approach is used to establish the lower limit of the income elasticity at the farm level: designating the farm share of the consumer food dollar as S, the formula relating the income elasticity of demand at the farm E_F, wholesale E_M and retail E_R level is (57). The average farm share of the consumer food dollar was 39.15 per cent in

$$E_F = \frac{E_R}{S} - \frac{1-S}{S} E_M \tag{57}$$

the 1922–41 period and 41.94 per cent in the 1948–65 period. The recent trend has been downward, however, and an estimate $S = .4$ was used for both periods.

price to reflect constant marketing margins. Since farmers receive 40 cents of the consumer food dollar $P_F = .4$ P. Substituting this relationship for P in the denominator of the formula $\partial P/\partial Q\ Q/P$, it is apparent that the farm level elasticity would be approximately 40 per cent of the retail level elasticity.

[7] With farm commodities weighted by retail prices, which are periodically changed to embody adjustments in marketing margins, it is apparent that Q is not a fully sensitive measure of food (including services) purchased at retail. And precisely for the same reason, it follows that Q is an "overly sensitive" measure of food quantity at the farm level.

Data on per capita use of all foods at the farm level (excluding marketing services) were not readily available for recent years. This index of food use (1957–59 = 100) at the farm level correlated .97 with the index of per capita food consumption (retail level) for the 1924–63 period.

TABLE 9.—INCOME ELASTICITIES OF DEMAND FOR FOOD AT THE RETAIL LEVEL COMPUTED FROM SELECTED EQUATIONS*

Equation number and period	Short run, computed at mean of:				Long run, computed at mean of:			
	1922	1922–41	1964	1948–65	1922	1922–41	1964	1948–65
			Price (P) Dependent					
10:1922–41	.33	.35	...	...	.33	.35	...	...
20:1948–65	...	...	.35	.31	...	...	.35	.31
14:1922–41	.34	.37	...	...	.34	.37	...	...
24:1948–65	...	...	.31	.28	...	...	.31	.28
18:1922–41	.44	.48	...	...	.29	.32	...	...
28:1948–65	...	...	.31	.28	...	...	.13	.12
			Quantity (Q) Dependent					
30:1922–41	.24	.26	...	...	.27	.29	...	...
40:1948–65	...	...	.36	.33	...	...	.36	.32
34:1922–41	.23	.25	...	...	.27	.30	...	...
44:1948–65	...	...	.33	.29	...	...	.29	.27
38:1922–41	.25	.27	...	...	.25	.27	...	...
48:1948–65	...	...	.29	.32	...	...	.29	.32

* Computed from data in Tables 2–5.

Estimates of the income elasticity of demand for marketing services vary widely. Daly has estimated it to be .77, Waugh .23 (*9*, p. 8; *37*, p. 23). If .5, the average of the two estimates, is arbitrarily used as the measure of E_M, then substituting into equation (57) with the retail elasticity .3 from Table 7, the result is zero (58):

$$\frac{.3}{.4} - \frac{.6}{.4}(.5) = 0 \tag{58}$$

The conclusion is that the income elasticity of demand for food at the farm level is very small.

THE DEMAND ELASTICITY FOR FARM OUTPUT

Some farm items such as cotton and tobacco are not very good substitutes for each other or for food. Because these items are likely to have unique price elasticities, they are kept separate in the following analysis of farm output elasticity. Farm output O, excluding interfarm sales, is divided into several categories in equation (59), where the subscript d refers to output for domestic use and e for

$$O = O_{df} + O_{dc} + O_{dt} + O_{ef} + O_{ec} + O_{et} + C + W \tag{59}$$

export; the subscripts f, c, and t refer respectively to food (and feed), cotton, and tobacco. C is stock and W is waste and miscellaneous uses not included in other categories.

A change in price has considerable impact on stock C in the short run, but has little impact over a longer period. The length-of-run used in the following computations is assumed to be of sufficient duration to make dC/dP near zero. Also the derivative of waste with respect to price dW/dP is considered to be near zero. Hence the elasticity E of farm output with respect to farm commodity price is (60) where E_i refers to the elasticities of output in market i with respect to an

(60)

$$E = E_{df}\frac{O_{df}}{O} + E_{dc}\frac{O_{dc}}{O} + E_{dt}\frac{O_{dt}}{O} + E_{ef}\frac{O_{ef}}{O} + E_{ec}\frac{O_{ec}}{O} + E_{et}\frac{O_{et}}{O} = \sum_i E_i\frac{O_i}{O}$$

aggregate index of prices received by farmers. The estimated dollar volume of average farm output and relative shares O_i/O going to the respective markets in equation (60) are shown in Table 10 for the 1963–65 period. The domestic food and feed portion, $24.8 billion, excludes interfarm sales.

Elasticity of Domestic Demand for Farm Output

The price elasticity of demand for food from Table 8 is used as the measure of E_{df}. The items included in the domestic consumption of food Q defined earlier and the domestic food and feed consumption O_{df} in Table 10 differ somewhat. The index of food consumption includes certain items not coming from U.S. farm output, such as coffee, tea, cocoa, and a considerable quantity of sugar. Based on 1965 weights in the per capita food consumption index, these imported foods comprised approximately 10 per cent of the aggregate index (*34*, p. 4).

The elasticity of demand for food and feed used in industry and consumed directly in farm homes is not known. Also the elasticity of demand for wool is not included separately in equation (60). These commodities comprise only a small portion of all farm commodities, and E_{df} is used as an estimate of the average elasticity of demand for these items.

The estimated elasticities of demand for farm output and its components are shown in Table 11. The intermediate-run elasticity is intended to show the adjustment in approximately three years of the demand quantity in response to a sustained change in prices received by farmers. The long-run price elasticity indicates the predicted change in demand quantity after an indefinitely long period in response to a sustained change in the index of prices received by farmers. The

TABLE 10.—CONSUMPTION OF U.S. FARM OUTPUT, 1963–65 AVERAGE*

Unit	Domestic use: Food and feed	Domestic use: Cotton	Domestic use: Tobacco	Exports: Food and feed	Exports: Cotton	Exports: Tobacco	Total output all commodities
Billion dollars	24.83	1.55	.83	4.28	.78	.32	32.59
Per cent	76.2	4.8	2.5	13.1	2.4	1.0	100.0

* The value of farm "output" is estimated as cash receipts from marketings less approximate interfarm transfers (*30*, pp. 48–52). Cash receipts from cotton and tobacco (*30*, p. 51) are allocated to domestic use and exports at the percentages of their production so used (*28*; *32*). The remaining farm output, here called "food and feed," is allocated to domestic use and exports using supply-utilization percentages for all farm commodities (*33*; *34*, Table 89), adjusted to exclude cotton and tobacco.

TABLE 11.—INTERMEDIATE-RUN AND LONG-RUN PRICE ELASTICITIES OF DEMAND FOR COMPONENTS OF FARM OUTPUT AND FOR TOTAL FARM OUTPUT

Period	Domestic			Exports			Total
	Food and feed	Cotton	Tobacco	Food and feed	Cotton	Tobacco	
			Elasticities, Ei				
Intermediate run	−.18[a]	− .65[b]	−.10[c]	−1.91[e]	−1.8[g]	...[h]	...
Long run	−.10[a]	−1.84[b]	−.50[d]	−6.42[f]	−3.7[g]	...[h]	...
		Contribution, $Ei \frac{Oi}{O}$, of Market i to Total Elasticity					
Intermediate run	−.137	− .031	−.002	− .250	− .043	...[h]	− .46
Long run	−.076	− .088	−.012	− .841	− .089	...[h]	−1.106

[a] Data from Table 8 with P the dependent variable. See equation (60) for definitions. The short-run elasticity is −.25; the long-run elasticity is −.10. With 20 per cent of the adjustment completed each year, then approximately 50 per cent of the adjustment is completed in an intermediate run of three years.

[b] Waugh (*37*, p. 62) estimated the price elasticity of demand for cotton to be −.29 in the short run, −.65 in the intermediate run and −1.84 in the long run. Blakely (*3*, p. 48) estimated the price elasticity for cotton to be −.86.

[c] Several estimates summarized by Buchholz, Judge, and West (*5*, pp. 122–24) indicate the short-run price elasticity of demand for tobacco at retail as nearly unitary. The farmers' share of the retail tobacco dollar is 10 per cent (*29*, p. 16). If the marketing margin is a constant, then the price elasticity is .1 (−1) = −.1.

[d] The long-run price elasticity is inferred from estimates by Daly (*9*, p. 11) of the income elasticity of demand for tobacco at the farm level, assuming tobacco has few substitutes.

[e] Weighted average of price elasticities of −2.8 for wheat exports from Tweeten (*26*, p. 13); of −1.3 for feed grains and of −1.5 for soybean exports from Brandow (*4*, p. 55). The elasticities were weighted by the proportions of export value represented by the commodity with wheat priced at $1.00 per bushel, soybeans $2.00 per bushel, and feed grains $35.00 per ton to reflect market clearing prices.

[f] Computed as defined in the text.

[g] The intermediate-run foreign demand elasticity for cotton is the midpoint of Fowler's (*13*, p. 313) estimate for the mid-1950's, allowing for a five-year adjustment period. The long-run elasticity is from Brandow (*4*, p. 56), an estimate which Fowler says "applies to a longer adjustment period. . . ." (*13*, pp. 311–12).

[h] No estimate available. The weight, 1 per cent, is so small for this category that its omission has little impact on the total elasticity.

short-run estimates are omitted because the immediate impact of prices on exports and storage is unknown.

Two elasticity estimates are critical in Table 11: the domestic food elasticity because it has a large weight (see Table 10) and the foreign food elasticity because it has a large magnitude. The domestic demand for food was found to be more inelastic in the long run than in the short run. This result is probably incorrect for the "very long run." The estimate reflects only the structure of historical data. The "long run" in observed data was sufficiently extended to permit lags in the markets discussed previously to be reflected in the estimated equations and hence to show a declining price elasticity as the length-of-run is extended. But history has not recorded an extended period of low quantity and high prices of U.S. agricultural commodities. It seems reasonable that such a period now would lead to considerable scientific effort to develop petroleum, fish, and synthetic substitutes for farm produced foods. The effect would be to *raise* the long-term elasticity relative to the short-term elasticity. The demand elasticity plotted against time would have a ∪ shape. Thus the "long-run" elasticity for domestic food in Table 8 is believed to be below (absolute value) the true long-run elasticity. However, the true estimate also is believed to be highly inelastic.

Elasticity of Foreign Demand for Farm Output

The commercial foreign demand for U.S. farm commodities cannot be known with much precision because of imperfections in the market. Numerous institutional measures impede the free flow of commodities among nations in response to changing prices. Nevertheless, given the existing institutional framework, a change in price will change the volume of U.S. farm exports. The crucial question is "how much?"

The estimated intermediate-run elasticity of demand for food and feed exports presented in Table 11 is a weighted average of estimated elasticities for wheat, soybeans, and feed grains from previous studies. Unfortunately, data from econometric studies are not adequate for separating the lengths-of-run in the food and feed export market. Therefore the export demand elasticity is estimated by an alternative approach shown in Table 12. The assumption is that over time many of the institutional barriers such as quotas, tariffs, and variable levies succumb to price incentives.

With appropriate adjustments for transportation cost, the price elasticity of demand for U.S. food and feed exports can be expressed as (61), where E_{di} and

$$E_{ef} = \sum_{i=1}^{n} \left[E_{di} E_{pi} \frac{Q_{di}}{O_{ef}} - E_{si} E_{pi} \frac{Q_{si}}{O_{ef}} \right] \tag{61}$$

TABLE 12.—ESTIMATED PRICE ELASTICITY OF DEMAND FOR U.S. FARM EXPORTS

Country or area	Home country or area: Demand elasticity[b]	Supply elasticity[c]	U.S. export demand elasticity imputed to:[a] Foreign demand	Foreign supply	All sources
Canada	–.1	.2	– .12	– .22	– .34
Europe					
EFTA	–.2	.2	– .97	– .95	– 1.92
EEC	–.2	.2	–2.21	–2.17	– 4.38
Spain, Greece, Finland, Ireland	–.3	.2	– .46	– .30	– .76
Asia					
Japan	–.3	.2	– .90	– .57	– 1.47
India & Pakistan	–.5	.2	–2.29	– .90	– 3.19
Misc. Asia[d]	–.5	.2	– .65	– .25	– .90
Australia	–.2	.2	– .12	– .12	– .24
LAFTA & Venezuela	–.4	.2	–1.51	– .74	– 2.25
Africa					
South Africa	–.3	.2	– .10	– .07	– .17
Egypt, Tunisia	–.5	.2	– .17	– .06	– .23
Total elasticity			–9.50	–6.35	–15.85

[a] See text and Appendix Table I for base of computations. No correction is made for transportation costs although some implicit correction is inherent from the past behavior of exports. A correction for transport costs would have had only a small impact on the estimated elasticities.

[b] Elasticities based on *11*, pp. 25, 67; *24*, Table 2.

[c] Elasticities based on *15*, Chapter 16.

[d] Taiwan, South Korea, Malaysia, Philippines, Thailand, Israel.

E_{si} refer respectively to the price elasticities of domestic demand and supply of food in country i, E_{pi} is the elasticity of prices in country i with respect to the market price of U.S. farm commodities, and Q_{di} and Q_{si} are respectively the domestic demand and supply quantities in country i. In this study Q_{si} is defined as Q_{di} less imports from the U.S. O_{ef} was defined in equation (59).

Few estimates of E_{di} and E_{si} for individual countries have been made.[8] Numerous more reliable estimates of the income elasticities of food demand are available for nations of the world, however, and can form the basis for estimating price elasticities. Based on static theory of a rational consumer, the demand function is homogeneous of degree zero in prices and income. This also means that the sum of all price and income elasticities is zero. Because the cross-price elasticity of demand for food with respect to prices of nonfood items has been found to be near zero and because static theory of consumer behavior provides a reasonable theory of aggregate food demand, it follows that the own-price elasticity of food should be nearly equal to the income elasticity. Signs will be opposite of course. Static demand theory shows that food must be a net substitute for all other commodities, hence the income elasticity is expected to be the lower limit of the own-price elasticity.

Price elasticities of demand, estimated from income elasticities, for selected regions of the world are shown in Table 12. These estimates are believed to be on the low side. The areas shown account for 85 per cent of U.S. farm exports.

Supply elasticities, showing the response of farm output to changes in prices received by farmers, are almost totally lacking for foreign countries. Heady and Tweeten have estimated the elasticity of aggregate farm output (supply) in the U.S. to be .1 in one year, .2 in four years, and .6 in twenty years (*15*, Chapter 16). The supply elasticity E_{si} for the areas in Table 12 are assumed to be .2.

The U.S. export demand elasticity imputed to foreign demand in area i is computed as $E_{di}\, Q_{di}/O$ and to foreign supply is $E_{si}\, Q_{si}/O$ in Table 12. The responsiveness of foreign domestic prices to a change in U.S. market prices is measured by E_{pi}. This elasticity is less than one in the short run, but is assumed to approach one in the long run. The results in Table 12 are interpreted in a long-run context; hence E_{pi} is considered to be unity and does not enter directly into the computations. Summing over the areas in the table, it is apparent that if the assumptions underlying the computations were correct, the demand quantity of U.S. food and feed exports would be increased 9.5 per cent due to increased consumption and 6.35 per cent due to reduced production as the export price is lowered 1 per cent.

This maximum price elasticity of -16 must be scaled down substantially, however. If foreign supply is perfectly inelastic, the price elasticity E_{ef} is reduced to -9.5. Several countries receive a substantial quantity of our exports under U.S. government programs. (See Appendix Table I.) If only Canada, Europe, Japan, Australia, LAFTA and Venezuela, and South Africa are considered commercial markets and all other countries are assumed to have no response to changing U.S. export prices, the elasticity is -11.53. The weighted sum of elasticities for the demand component alone from these same countries is -6.39. If half of all EEC imports of U.S. farm commodities are assumed to be part of a perfectly

[8] Several approximate estimates are summarized in *22*, pp. 161–71.

inelastic market because of variable levies, and the supply and demand components are included only for the "commercial" market composed of Canada, EFTA, and Venezuela, EEC (nonvariable levy), Japan, Australia, and South Africa, then the U.S. export demand elasticity is −6.42. This estimate is more realistic than the higher estimates of export demand elasticity in Table 12, and is the estimate used to compute the total demand elasticity for farm output in Table 11. Several years of adjustment to prices would be required to realize the elasticity of −6.42 computed from Table 12; therefore the estimate is considered to be the long-run elasticity of demand for U.S. exports.

Domestic sources of demand contribute to the price elasticity of demand for farm output only −.17 both in the intermediate run and long run according to the estimates summarized in Table 11.[9] Foreign demand contributes −.11 in the intermediate run and −.93 in the long run. The total elasticity of demand for U.S. farm output is computed to be −.5 in three years and −1.1 in the long run. Thus a 1 per cent increase in prices received by farmers would result in a .5 per cent decrease in aggregate quantity demanded in approximately three years and a 1 per cent decrease in many years.

Interrelation and Qualification of Export Elasticity Estimates

To add perspective to the export demand elasticity estimates, several comments on the uses and limitations of the elasticities are made below.

1. The estimates are intended to reflect a one-price export market. Competing exporters are assumed to follow our price adjustments, and the export price for a given commodity is the same for all countries—except for differences due to transport costs. If the U.S. would change its export prices and other competing exporters did not follow suit, the export demand elasticity would be even higher than indicated in this study. Competing exporters committed to hold or raise their market share might be expected to follow the U.S. in an export price reduction, but would not follow the U.S. in an export price increase. Such behavior would lead to a kinked demand curve for U.S. farm exports, with a high elasticity above current prices.

2. The export elasticity of demand for food and feed in the intermediate run, and the elasticities for cotton are taken from demand equations for individual commodities. Since the opportunities for substitution are greater for individual commodities than for commodities in aggregate (the latter being the theoretically desired concept in this study), it follows that the methodology imparts an upward bias to the intermediate-run export elasticity for farm commodities in aggregate. Also while there are few opportunities to substitute cotton for food crops in demand, there are opportunities to substitute these in production. And since the export demand for U.S. commodities depends on foreign supply (production) as well as on foreign demand, again there is a source of upward bias in the intermediate-run export demand elasticity for U.S. commodities in aggregate. These biases are partially offset by the fact that the export elasticity estimates taken from studies cited were originally intended for a shorter time period

[9] If the domestic demand is homogeneous of degree zero in prices and income, and if the elasticity of domestic demand farm output with respect to the prices of domestic nonfarm commodities is .02, then the income elasticity of domestic demand for farm output is .15.

than the intermediate run of 3 to 4 years used in this study. In the export market, the intermediate-run elasticity is expected to exceed the short-run elasticity.

3. Exports to noncommercial markets and to the EEC under variable levy were excluded from the long-run food and feed export elasticity to correct for institutional impediments to free trade. But it was impossible to adjust for all trade barriers in commercial markets, and the result is a tendency for upward bias in the elasticity estimate. On the other hand, the excluded noncommercial market could be expected to display some response to U.S. food and feed export prices. For example, the export demand elasticity for countries which allocate a fixed dollar volume of foreign exchange for imports of U.S. farm products would display a unitary elasticity of demand. The contribution to the U.S. export elasticity from noncommercial markets could more than offset the bias introduced by failure to incorporate into the elasticity estimate all institutional barriers found in the developed commercial markets.

A world trend in the future toward protectionist trade barriers could lower the export demand elasticity shown above and could reduce the U.S. commercial export demand. One means to discourage erection of trade barriers in foreign countries is for the U.S. to reduce its own reliance on import quotas and other impediments to foreign trade.

4. To compute the elasticity of demand for total U.S. farm output in Table 11, similar weights on the component market elasticities were used in the intermediate and long run. In the long run, however, a price decrease would lead to greater weight on exports, hence to a higher output elasticity of demand than indicated in this study. However, this bias could be offset by an eventual decline in the elasticity of export demand as exports expand from lower prices.

5. Other things equal, a higher domestic demand elasticity in a foreign country means a higher elasticity of demand for U.S. exports to that country. Since the price elasticities tend to be high in the less developed countries, the tentative conclusion that seems incongruent is that these countries would contribute significantly to the U.S. export demand elasticity. However, home-country demand elasticities are weighted by the value of food consumption, which is low in less developed countries. Consequently the per capita contribution to U.S. export demand elasticity is substantially less in low-income countries than in high-income countries. The procedure in equation (61) for weighting elasticities of demand and supply in foreign countries, and the exclusion of low-income countries from the analysis, go far to correct the long-run elasticities for food and feed in Table 11 for the lack of buying power in many countries.

6. It would be useful though difficult to bracket the range of U.S. export prices and quantities within which the export demand estimates of this study apply. A small reduction in U.S. prices to expand exports would be met by similar price reduction by competing exporters, who could probably act to preserve their market share. The result would be a low short-run elasticity of U.S. export demand. For a larger decrease in U.S. export prices and a longer period, time and the high cost of subsidizing farmers would probably induce the governments in competing countries to pass lower export prices back to their farmers. Their farmers then would tend to contract production. Lower prices would also lead to greater consumption. If the U.S. were to drastically reduce prices on farm com-

modities for exports, and were to realize a sharply rising market share, strong measures likely would be used by foreign countries to halt the trend. Lack of buying power in importing countries would also become a more prominent restriction. From these considerations, I conclude that the U.S. export elasticity tends to be relatively low for small changes in U.S. export prices in the short run (competing exporters simply meet the competition), tends to be high (about the magnitude recorded in this study) for a larger reduction in price, and tends to be lower again for a major reduction in price. For example, I speculate that the export elasticities reported in this study would apply to feed grains (in corn equivalents) in an export price range of 90 cents to $1.15 per bushel. The price elasticity would be lower above and below this price range.

7. The elasticity estimates were constructed to minimize net bias and to represent the best estimates possible under current circumstances, data, and techniques. But the results are by no means exact, and it is well to consider the policy implications of a net bias. A sizable upward bias in the export elasticities could be present and still leave the true export demand elastic. Thus, sizable error in the data would still leave policies of lower export prices desirable (as long as prices are above marginal costs of farm production) to increase U.S. farm income and to improve U.S. balance of payments. However, a small error in the estimates of export or domestic demand parameters could mean an inelastic demand for farm output in the long run.

8. Finally, there is some confusion about the difference between the world demand elasticity and the U.S. export demand elasticity for a commodity. Ignoring for the moment the supply effect and institutional impediments that keep world prices from being reflected in domestic prices, the U.S. export demand elasticity tends to be the same ratio to the world demand elasticity as U.S. exports are to world production. Hence if the world demand elasticity for all grains is $-.3$, and world production is 29 times U.S. exports (as it was in 1964–65), then the U.S. export demand elasticity theoretically is $29(-.3) = -6.9$. Inclusion of the foreign supply response would make this figure much larger. Provisions for institutional impediments to trade would reduce the estimate.

SUMMARY AND CONCLUSIONS

The general objective of this paper was to estimate the demand elasticity for U.S. farm output. Particular emphasis was given to two components: domestic and foreign demand for food.

Efforts to improve on previous estimates of domestic demand for food at the farm level met with mixed success. Addition of variables measuring the dependent population and prices of items that compete with food for the consumers' income added little to the explanation of food demand. Inclusion of a time variable and a lagged dependent variable to permit gradual adjustment to an equilibrium improved the specification. Results suggest that the short-run (one year) price elasticity is $-.25$; the long-run elasticity is $-.10$ at the farm level. The true long-run price elasticity of domestic demand for food is believed to be underestimated from time series data, however, because these data do not reflect the measures that would be taken to find substitutes for farm produced food if prices were raised for an extended period. The income elasticity of demand at the farm level appears to be similar in magnitude (but opposite in sign) to the price elasticity. The specification was improved little by a first order autoregressive scheme.

Estimates of the price elasticity of demand for U.S. food and feed exports ranged up to −16. Adjustment downward of this estimate for institutional impediments and market imperfections led to an estimate of −6.4. A weighted average of the foreign and domestic components of U.S. farm output gave an estimate of the price elasticity of farm output of −.5 in the intermediate run and −1.1 in the long run. This estimate is highly sensitive to the choice of export demand elasticities—parameters that are not known with much reliability. This means that the results and implications of this study, while highly suggestive, must be interpreted within the limitations of the analysis.

The results of this study suggest important implications for pricing and output in agriculture. Policies to restrict output can increase farm income in the short and intermediate run because aggregate demand is inelastic. But if there is a one-price system that does not discriminate between foreign and domestic markets, gross farm revenue will not be influenced much in the long run by policies to restrict production. The elasticity of gross farm receipts with respect to output is $E_G = 1 + 1/E$. If $E = -1$ as found in this study, then $E_G = 0$, and gross income is unchanged by variation in output.

Because total farm production costs are relatively fixed in the short run, net farm income, NR, is more sensitive than farm prices or total receipts, TR, to changes in farm output. The short-run elasticity of net farm income with respect to output, E_N, is given by the formula $E_N = (TR/NR)\ (1 + 1/E)$ with a fixed level of production costs. If TR/NR is 3.0 and the short-run elasticity of demand for farm output is −.25, then a 1 per cent decrease in farm output would increase net farm income 9 per cent. In the long run, farm production costs adjust to changes in farm prices and output, and the elasticity E_N is difficult to estimate. It seems reasonable to speculate nonetheless that net farm income will not be affected much in the long run by government policies to reduce output because gross income tends not to be affected.

The above inferences apply only to aggregate farm production. Producers of a specific commodity for which long-run demand is inelastic may be successful in raising income by controls applied to the commodity even though demand for total farm output is elastic.

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APPENDIX

Variables Used in Analysis of Domestic Food Demand

P_t: Consumer price index for food, U.S., 1957–59 = 100. Data from *U.S. Food Consumption, Sources of Data and Trends, 1909–63* (*33,* p. 18), and Supplement (*34,* p. 39). Deflated by the implicit price deflator of the U.S. Gross National Product, 1957–59 = 100. 1929–65 data from *Economic Report of the President* (*38,* p. 214); 1922–29 from *Historical Statistics of the United States* (*35,* p. 139).

Q_t: Index of U.S. food consumption per capita, 1957–59 = 100. Data from *U.S. Food Consumption, Sources of Data and Trends, 1909–63* (*33,* p. 7), and Supplement (*34,* p. 4).

Y_t: Disposable personal income in the U.S. per capita, in dollars. Data from *U.S. Food Consumption, Sources of Data and Trends, 1909–63* (*33,* p. 184), and Supplement (*34,* p. 31). Deflated by implicit price deflator of the U.S. Gross National Product.

D_t: Nondependent percentage of the U.S. population, measured as the ratio of persons 14 to 64 years of age to total population times 100. Data from *Economic Report of the President* (*38,* p. 231); and *Population Estimates* (36).

P_N: Consumer price index for all items less food, U.S., 1957–59 = 100, based on data for city wage earners and clerical workers. 1935–65 data from *Economic Report of the President* (*38,* p. 262); 1922–35 data from *Historical Statistics of the United States* (*35,* pp. 125, 126), with basic data of the BLS-CPI index for all items adjusted for the index of food prices; and deflated by the implicit price deflator of the U.S. Gross National Product.

P_F: Index of prices received by farmers for crops and livestock, U.S., 1910–14 = 100 from *Economic Report of the President* (*38,* p. 294), and *Historical Statistics of the United States* (*35,* p. 283); deflated by the implicit price deflator of the U.S. Gross National Product.

APPENDIX TABLE I.—AVERAGE ESTIMATED IMPORTS OF U.S. FARM COMMODITIES (1963–65) AND FOOD CONSUMPTION (1963–64) IN SPECIFIED AREAS*
(Million dollars)

Country or area	Imports from U.S.[a] Food and feed	Cotton	Tobacco	Total estimated food consumption
Canada	386	51	4	5,715
Europe				
European Free Trade Association (EFTA)	467	51	155	23,619
European Economic Community (EEC)				
All commodities	1,120	130	105	53,865
Non-variable levy commodities	577	130	105	
Spain, Greece, Finland, Ireland	175 (156)	5	17	7,463
Eastern Europe including U.S.S.R.[b]	229	28	2	...[c]
Other[d]	46	21	15	...[c]
Asia				
Japan	586	132	31	14,536
India and Pakistan	546 (14)	42 (2)	3 (1)	22,342[e]
Miscellaneous Asia[f]	250 (145)	81 (46)	15 (6)	6,283
Other	213 (93)	30 (11)	12 (8)	...[c]
Oceania				
Australia	14	9	15	2,918
Other	4	2	4	...[c]
Latin America				
LAFTA[g] and Venezuela	354 (207)	6 (4)	8 (4)	18,369
Other	163 (130)	3 (2)	4	...[c]
Africa				
South Africa	24 (21)	5	0	1,693
Egypt, Tunisia	151 (27)	1 (0)	10 (2)	1,687
Other	141 (48)	7 (0)	11 (4)	...[c]

* Data for imports from the United States (actually U.S. exports by destinations) are from, or approximated from, *Foreign Agricultural Trade of the United States* (*31*). Food consumption data are consumer expenditures for food from, or approximated from, *Yearbook of National Accounts Statistics* (*27*).

[a] Data in parentheses for selected areas are approximate "dollar" sales differing from the totals by shipments under various U.S. government programs.

[b] Czechoslovakia, Poland, Yugoslavia, and U.S.S.R.

[c] Consumption data unavailable.

[d] Turkey, other Eastern Europe, and adjacent islands.

[e] Approximated at 50 per cent of the national income.

[f] Taiwan, South Korea, Malaysia, Philippines, Thailand, and Israel.

[g] Latin American Free Trade Association.