AN ECONOMETRIC MODEL OF AGGREGATE FOOD MARKETING SERVICES

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I. The Problem

The purpose of the study is to describe quantitatively a market model of food marketing services for the post-W.W. II United States.

Although food expenditures have been taking a smaller portion of average U.S. family budget, the absolute amount has been rising. The growth in per capita food expenditure is mainly attributed to the fast growth of marketing services and service costs. Increasing marketing costs have long drawn attention to and concern about the growth of food marketing services, the competitive structure and the operating efficiency of the food marketing sector, and their relation to retail food prices.

Some authors [2, 3, 4, 18, 19] have estimated price and income elasticities of demand for food marketing services. All these previous empirical studies formulated demand for services as a final demand. Yet final demand cannot be observed since services and raw food materials are not only jointly demanded but jointly supplied. Consumers purchase both food and marketing services without being confronted with separate prices and quantities of each. Therefore, a more logical formulation of the problem would be to view the demand for services as a derived demand. That is the food marketing industry's demand for services as a factor of production. The marketing firm adds services to food materials in various combinations and markets them through commercial food distribution channels. It is the marketing firm who is faced with and has knowledge of the quantities of services which they will purchase at various prices. Though the initiator, marketing firms respond to the consumers' reactions. They are not only competing with other marketing firms, but with other consumer goods and service industries for the consumers' limited budget as well. That is why many food products, both new and old disappear from the grocery shelves each year [14].

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When this study was still in process, Gardner [5] published his analysis of farm-retail price spread in which marketing inputs and agricultural commodities were treated as two factors of production to produce food at retail. Likewise, this study originally viewed food marketing services as a factor of production. While Gardner's formulation was similar to our's no empirical results were made available.

Many previous studies used the market basket statistics to derive a price series, and used the bill for marketing both food-at-home and food-away-from-home data deflated by the price series to obtain a quantity series. Since the market basket statistics measures the "price" of food-at-home only, some bias obviously has been introduced.

This study intends to quantitatively describe the consumers' and "the producers'" (namely, the food marketing industry's) behavior which determines the market equilibrium of the marketing services for food-at-home. However, it should be noted that the results obtained are not exactly comparable to previous work, because of the difference in model specification, method of estimation, and the data used.

II. Theoretical Considerations

Since marketing services must be performed on raw food products the decision units obviously include both the food marketing industry and the consumers. A model which describes the market must include behavior relationships that simultaneously determine the market equilibrium of both food marketing service as a factor and retail food as a final product. Therefore, there are six simultaneous equations in this model -- (i) the derived demand for services equation, (ii) the supply of services equation, (iii) quantity of services demanded equal to quantity supplied at equilibrium, (iv) the demand for retail food equation, (v) the supply of retail food equation, and (vi) quantity of retail food demanded equal to quantity supplied at equilibrium. Four equations are stochastic, containing random disturbances. A stochastic relation explains the manner in which the regressand responds to changes in the regressors, and is used to describe human behavior and technical or institutional relationships. Although a relation is constructed to capture the crucial features of reality, it is still a simplification. A random variable must be introduced to represent the net effect of the omitted variables, inherent indeterminancy of human behavior, and errors of the observations. The only exceptions are definitional relations and identities. The two relations which specify the market equilibrium conditions in this model belong in this category.

Since a market is always in equilibrium, the model is simplified into a framework of four equations in four jointly dependent variables by substituting equilibrium quantity for the variables of quantity demanded and quantity supplied and equilibrium price for the price variables. The model also includes ten predetermined variables in addition to the four jointly dependent variables, viz. $\log_e$ (price of services),

$\log_e$ (quantity of services) $\log_e$ (price of retail food), and $\log_e$ (quantity of retail food).

(1) The derived demand for food marketing services equation

A producer's demand for an input is derived from the equilibrium condition which states that the marginal value product of the input is equal to its price, subject to the production function and the supply conditions of other inputs. The income variable, one of the major determinants in a consumer demand function, has no place in the producer's demand function.

Therefore, given a set of production possibility curves, the assumptions of competitive product and factor markets, and profit maximization, the demand for a factor of production becomes a function of (i) its own price, (ii) the price of the final product, (iii) the prices of complements and substitutes in production, and (iv) the state of the art, or technology. In addition, (v) the producers' past purchasing behavior, a previously significant explanatory variable, is also incorporated in the demand function. The derived demand for food marketing services equation becomes:

$$\ln Q^m_t = \alpha_0 + \alpha_1 \ln P^m_t + \alpha_2 \ln P^r_t + \alpha_3 \ln P^f_t + \alpha_4 \ln Q^m_{t-1} + \alpha_5 t + u^1_t \quad (1)$$

where

Q^m = per capita consumption of food marketing services by U.S. civilians,

P^m = deflated price index of food marketing services,

P^r = deflated price index of retail food,

P^f = deflated price index of farm food,

Q^m_{-1} = Q^m lagged by one year,

t = time with 1947 equal to one, and

u^1 = random shock.

The quantity of an input demanded is expected to have a negative relation with respect to its own price, and a positive relation with respect to the price of the final product and the technical factor. The lagged quantity variable, representing habit formation is also expected to carry a positive sign. There is no a priori knowledge available with respect to the proper sign for $\ln P^f$. Service and food which are complements in producing a certain grocery product may become substitutes using a different processing method. Service which is a necessity to some consumers may be a luxury to others. In other words, whether aggregate marketing service and physical quantities of food are substitutes or complements of each other in production and in consumption is not well defined. Economic theory can not provide information regarding the expected sign and magnitude of the coefficient under such circumstances.

Since the equation is constructed with all variables in logs, except time, the coefficients indicate elasticities with respect to the explanatory variables -- e.g., α_1, the direct price elasticity, α_2 and α_3, cross elasticities, and α_4, elasticity with respect to the previous purchasing behavior.

(2) The supply of food marketing services equation

Since food marketing service is an input, intermediate input to be precise, in the production of retail food products, the supply of services equation is that confronting the food marketing industry. This is the other blade of a pair of scissors that underlies the equilibrium conditions of the food marketing services as a factor of production. Given a production function, the assumptions of competitive product and factor markets, and profit maximization, the supply of food marketing services is assumed a function of (i) own price, (ii) price of farm food products, (iii) prices of various primary factors used to produce the intermediate input, and (iv) technical change. Lagged quantity variable (v) is introduced for the same reason as in Equation (1). The supply function becomes

$$\ln Q^m_t = \beta_0 + \beta_1 \ln P^m_t + \beta_2 \ln P^f_t + \beta_3 \ln Q^m_{t-1} + \beta_4 t + \beta_5 \ln w_t$$

$$+ \beta_6 \ln r_t + \beta_7 \ln i_t + \beta_8 \ln P^o_t + u^2{}_t \quad (2)$$ 1/

where Q^m, P^m, P^f, Q^m_{-1} and t have the same meaning as in Equation (1),

w = deflated average wage rate in the food marketing industry,

r = interest rate for long-term borrowings,

i = interest rate for short-term borrowings,

P^o = deflated price index of other inputs used in food marketing, and

u^2 = random disturbance.

A priori information suggests a positive sign with respect to $\ln P^m$, $\ln Q^m_{-1}$ and t, and a negative sign with respect to ln w, ln r, ln i, $\ln P^o$. The aggregation problem discussed in the previous subsection also applies in this equation -- i.e., there is no *a priori* knowledge available regarding the expected sign of the coefficient of $\ln P^f$.

1/ Certainly a possible variation would be to assume that the wage rate and some other factor prices are endogeneously determined as one reviewer suggested.

(3) The demand for retail food products equation

The consumers' final demand for food is a function of (i) its own price, (ii) consumers' income level, (iii) the price of competing non-food consumers' goods and services, (iv) past consumption behavior, and (v) time trend representing consumers' changing tastes and preferences. Tobin introduces both current and the previous year's income into the demand for food function and interprets the income elasticity as the sum of the two. He argues there is "evidence for a lag in adjustment of food expenditure to changes in income and by the high correlation of family incomes in two successive years." [16, p. 114] Moreover, he and Stone argue that the statistical demand equation should be consistent with both cross section and time series observations. Therefore, the income elasticity, .29884[2/] estimated from the BLS 1960-61 Survey of Consumer Expenditures data will be used to restrict the long-term income effect in the estimation of the demand for retail food products equation. The estimated income elasticity is smaller than the cross section estimate by Tobin [16], and the time series estimates by Waldorf [19], Stone, Tobin-Stone [10, p. 8] and Hassan-Johnson-Finley [9], as we expected. It is because we estimate the elasticity of food-at-home only. Away-from-home food consumption and beverages (esp. alcoholic beverages) consumption are believed on the average to be more income-elastic. Therefore, the demand for retail food equation becomes

$$\ln Q^r_t = \gamma_0 + \gamma_1 \ln P^r_t + \gamma_2 t + \gamma_3 \ln P^{nf}_t + \gamma_4 \ln Y_t + \gamma_5 \ln Y_{t-1} + \gamma_6 \ln Q^r_{t-1} + u^3_t \quad (3)$$

subject to $\gamma_4 + \gamma_5 = .29884$

$$\text{or} \quad (\ln Q^r_t - .29884 \ln Y_t) = \gamma_0 + \gamma_1 \ln P^r_t + \gamma_2 t + \gamma_3 \ln P^{nf}_t - \gamma_5 (\ln Y_t - \ln Y_{t-1}) + \gamma_6 \ln Q^r_{t-1} + u^3_t \quad (3')$$

where

Q^r = per capita consumption of retail food products by U.S. civilians,

P^r = deflated price index of retail food products,

P^{nf} = deflated price index of non-food consumers' goods and services,

Y = deflated per capita disposable personal income,

Y_{-1} = Y lagged by one year,

Q^r_{-1} = Q^r lagged by one year, and

u^3 = disturbance term.

All the regressors in Equation (3), except ln P^r, are expected to carry a positive sign.

2/ Data and estimation are available upon request from the authors.

(4) The supply of retail food products equation

The supply of a good is a function of (i) its own price and (ii) prices of various factors of production. Sale level of the previous period (iii) is also incorporated into the function. Specifically, the supply of retail food products equation is assumed to be

$$\ln Q^r_t = \partial_0 + \partial_1 \ln P^m_t + \partial_2 \ln P^r_t + \partial_3 \ln P^f_t + \partial_4 \ln w_t + \partial_5 \ln r_t + \partial_6 \ln i_t + \partial_7 \ln P^o_t + \partial_8 \ln Q^r_{t-1} + u^4_t \quad (4)$$

where all the variables carry the same meaning as in Equations (1) - (3). We expect a positive sign with respect to $\ln P^r$, $\ln Q^r_{-1}$, and a negative sign for the remainder of the variables.

The distribution of the stochastic disturbances are assumed to satisfy the assumptions of zero expectations, constant variances over time, zero lagged co-variances, and independence between random disturbances and the fixed predetermined variables.

Economic models are characterized by relations of a simultaneous, dynamic and stochastic nature. A model is identified when each and every equation of the model is identified. Since the model in this study is overidentified, estimation will be by Two-Stage Least Squares.

III. Description of Data

All the data series[3/] used to represent the variables specified in this study come from various government publications. The data are annual observations for the period 1948-1961 and 1964-1973. The years 1962 and 1963 are excluded since the marketing bill statistics for 1962 are published as preliminary values in Agricultural Statistics, 1963. They are part of an old series which is no longer published. Since our model includes current and lagged variables, both 1962 and 1963 are, therefore, removed from the sample.

The data used to represent each variable are defined as follows:

Item	Data Series
P^r	Index of retail cost of market basket statistics (1957-59 = 100%) deflated by Consumer Price Index for all items (1957-59 = 100%)
Q^r	Consumer expenditures at constant 1957-59 prices (= consumer expenditures of the bill for marketing food-at-home statistics[4/] deflated by index of retail cost of the market basket statistics with 1957-59 = 100%) divided by civilian population

3/ Data sources are available upon request from the authors.

4/ 1947-62 data of the bill for marketing food-at-home statistics have been adjusted, by removing meals away from home. (Calculation procedure is available upon request.)

P^m Implicit price of food marketing service series (= marketing bill of current prices divided by marketing bill at constant 1957-59 prices) deflated by CPI for all items

Q^m Marketing bill at constant 1957-59 prices (= consumer expenditures at constant 1957-59 prices minus farm values at constant 1957-59 prices) divided by civilian population

P^f Index of farm value of market basket statistics (1957-59 = 100%) deflated by CPI for all items (1957-59 = 100%)

P^o Index of the prices of other inputs (intermediate goods and services) bought by food marketing firms (1957-59 = 100%) deflated by CPI for all items

w Weighted composite hourly earnings (in dollars) of production employees in food manufacturing and non-supervisory employees in wholesale and retail food trades deflated by CPI for all items

r Yields on corporate bonds (in percentage), per annum

i Average interest rate of short term bank loans in 35 cities (in percentage), per annum

P^{nf} CPI for all items less food (1957-59 = 100%) deflated by CPI for all items

Y Per capita disposable personal income (in dollars) deflated by CPI for all items

t Time with 1947 = 1.

IV. Empirical Results and Implications

In the first stage of the estimation procedure, some jointly dependent variables are regressed upon all the predetermined variables in the system in order to obtain their "calculated values." At the second stage, the left-hand side variable is regressed on the calculated values of the jointly dependent variables and the actual observations of the predetermined variables of the equation. The set of all the predetermined variables of the system used as the regressors in the first stage estimation includes:

$$\ln P^f, \ln Q^m_{-1}, t, \ln w, \ln r, \ln i,$$

$$\ln P^o, \ln P^{nf}, (\ln Y - \ln Y_{-1}), \text{ and } \ln Q^r_{-1}$$

The estimated structural model is reported in Table 1. Figures in the parentheses are ratios of the estimated regression coefficient to its standard error. Coefficient of determination (r^2), Durbin-Watson d statistic, and F-statistic are also provided.

Table 1
2SLS Estimates of the Structural Model

Const.	$\ln P^m$	$\ln P^r$	$\ln P^f$	$\ln Q^m_{-1}$	t	lnw	lnr	lni	$\ln P^o$	$\ln P^{nf}$	$\ln Y - \ln Y_{-1}$	$\ln Q^r_{-1}$
(1) Derived demand for food marketing services equation [$\ln Q^m$ as LHS]												
1.6865	-1.1382	2.3969	-1.1130	.6762	.0004	--	--	--	--	--	--	--
(2.33)	(1.30)	(1.49)	(1.69)	(4.73)	(.20)							
r^2 = .947, d = 1.831, F(5, 18) = 64.856												
(2) Supply of food marketing services equation [$\ln Q^m$ as LHS]												
1.4785	.3515	--	-.1248	.7332	.0042	-.1098	-.0028	-.0411	--	--	--	--
(1.89)	(.60)		(1.57)	(4.50)	(.31)	(.20)	(.05)	(.84)				
r^2 = .943, d = 1.975, F(7, 16) = 37.894												
(3) Demand for retail food products equation [($\ln Q^r$ - .29884 lnY) as LHS]												
-1.8522	--	-.4557	--	--	-.0108	--	--	--	--	.5440	.0710	.9536
(1.67)		(.94)			(4.33)					(.30)	(.36)	(4.76)
r^2 = .798, d = 1.561, F(5, 18) = 14.245												
(4) Supply of retail food products equation [$\ln Q^r$ as LHS]												
2.2572	-.9114	1.5968	-.8238	--	--	-.0022	-.0093	--	.1812	--	--	.6059
(2.38)	(.95)	(.93)	(1.19)			(.02)	(.31)		(.69)			(3.44)
r^2 = .964, d = 1.829, F(7, 16) = 61.498												

Figures in the parentheses indicate ratios of the estimated regression coefficient to its estimated standard error.

(1) The derived demand for food marketing services equation

All the variables in Equation (1) have the correct signs, i.e., they are consistent with the postulated relationship. The estimated coefficient of ln P^r and ln Q^m_{-1} are significantly different from zero at the 10 percent and the 1 percent level, respectively. The coefficient of ln P^f is significant at the 10 percent level by the two-tail test. The over-all test of the significance of the regression line rejects the null hypothesis that all the coefficients are not different from zero at the 1 percent level. The Durbin-Watson d value is significant that there is no serial correlation at the 5 percent significance level by the two-tail test. It should be noted that r^2, d, F-statistic, and the ratio of estimated coefficient to its standard error become approximate procedures for evaluating a simultaneous equation model. In the final analysis, we are more concerned about the sign and the magnitude of the estimated coefficients.

No previous study derived the demand for food marketing services, hence it is not possible to compare the results of this study with those reported in the literature. Being between zero and one, the magnitude of the estimated coefficients of ln Q^m_{-1} is reasonable. Those of the various price variables indicate that the producers' demand for services is elastic with respect to own price, to output price and to food price at the farm. Technology has little effect upon the producers' demand for service.

(2) The supply of food marketing services equation

All the variables in Equation (2) have the expected signs. Estimated coefficient of ln Q^m_{-1} is significant at the 1 percent level. F-test rejects the hypothesis that all the estimated coefficients are not different from zero at the 1 percent significance level. The Durbin-Watson d value is significant at the 5 percent level by the two-tail test. Although no previous results are available for comparison, the magnitudes of the estimated coefficients seem reasonable to us. We did try introducing ln P^o as an additional explanatory variable but came up with wrong signs for both ln P^m and ln P^o.

The negative sign of the ln P^f variable in both the derived demand and the supply of food marketing services equations indicates that food and marketing services are complementary in the production of the final product which is to be expected.

(3) The demand for retail food products equation

Only the estimated coefficients of the trend and the lagged quantity variables are significant (at 1 percent level). The F-test rejects the null hypothesis that all the estimated coefficients are not significantly different from zero at the 1 percent level. The solution of the estimated equation results in the following

$$\ln Q^r_t = -1.8522 - .4557 \ln P^r_t - .0108\, t + .5440 \ln P^{nf}_t + .3698 \ln Y_t - .0710 \ln Y_{t-1} + .9536 \ln Q^r_{t-1} \qquad (3')$$

All the signs in Equation (3') except those of t and ln Y_{t-1} are consistent with the postulated relationship. The previous year's income is less than one fifth of the elasticity of current income, which means that the effect of lagged income on current consumption dies out quickly. The direct price elasticity of .4557 is less than Tobin's estimate of .51 to .53 as we expected, because the latter is the estimated elasticity of all foods plus beverages. The estimated coefficient of ln P^{nf} indicates that retail food and non-food consumers' goods and services are not perfect substitutes of each other.

(4) The supply of retail food products equation

The coefficient of ln Q^r_{-1} is the only one that is significant (at the 1 percent level). F-test rejects the null hypothesis at the 1 percent significance level. d value is significant at the 5 percent level by the two-tail test. Variable ln P^o is the only one carrying the wrong sign. The estimated coefficients of ln P^r, ln P^m, and ln P^f indicate that the food marketing industry's supply of retail food is elastic with respect to its own price, but inelastic with respect to service price and farm price. The cost of the other intermediate inputs, P^o is of minor importance. The positive sign indicates marketing firms care little about a change in their prices.

V. Summary

The market for food marketing services is in equilibrium if and only if both marketing services and retail food are in equilibrium. Therefore, the model was formulated as a simultaneous equation system of derived demand for, and supply of, services, and demand for, and supply of, retail food.

The empirical analysis yields reasonable results with respect to sign and magnitude of the estimated coefficients. The marketing industry's demand for services is elastic with respect to its own price (-1.1382), to the final product price (+2.3969) and to the price of the complement in production (-1.1130). The supply of marketing services has a price elasticity of +.3515 while the supply of retail food has a price elasticity of +1.5968. The demand for retail food is inelastic with respect to its own price (-.4557), to price of non-food items (+.5440) and to current year's income (+.3698).

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