DEMAND AND SUPPLY OF VEGETABLE OIL PRODUCTS IN THE UNITED STATES: A SHORT-RUN ANALYSIS*

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Over the last decade consumption of vegetable oil products in the United States has increased enormously. Per capita consumption of vegetable oil products rose from 30.6 pounds in 1965 to 43.1 pounds in 1975—an increase of more than 40 percent. This expansion continues a historic trend and represents the single largest ten-year increment in the last fifty years [1, 2, 3]. The principal vegetable oils used in domestic products are soybean, cottonseed and corn oil. For this reason the increase in consumer demand for vegetable oil products over the last decade has had an important effect on the derived demand for soybeans, cottonseed and corn.

This paper reports the results of a study performed to determine the levels of the short-run demand and supply parameters of the domestic vegetable oil products industry. Section one discusses the derivation of an inventory stock and production flow model of supply. This supply model is combined with a classical static demand relation to give a general simultaneous commodity system model. Section two discusses the empirical implementation of this model. The markets for cooking oil, shortening and margarine are considered. Section three reports the results of estimation. Concluding remarks are made in section four.

THE MODEL

The maximization of profit $u = p'q - v'x$ subject to the multi-input, multi-output production function $f(q,x)$ gives solutions of the form

$$q^*_i = s_i(p, v) \qquad (1)$$

where:

- p = nxl vector of commodity prices,
- q = nxl vector with the ith element representing quantity of the ith commodity produced,
- v = mxl vector of input prices,
- x = mxl vector of input quantities,
- $*$ = optimizing value for the problem.

Relation (1) represents the basic static supply function.

The supply function given in (1) is somewhat limiting in generality. Not only does it neglect the impact of past prices on current production but also allows no explicit role for commodity storage. The static supply framework assumes that commodities are produced and marketed instantaneously. An alternative and more realistic approach is to consider the role of storage explicitly in the problem formulation.

One way of including a role for storage in the supply function is to redefine supply as a dynamic identity which requires that the quantity of a commodity marketed in time period t equal the sum of quantity produced in t and the net change in inventory level over t. This dynamic supply identity is written explicitly as

$$q_t = s_{t-1} - s_t + z_t \qquad (2)$$

where:

- s_t = nxl vector representing stock of commodities held by the firm at the end of time period t,

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z_t = nxl vector representing firm production in t.

This identity has been discussed by [13, 16, 17] and used in dynamic commodity models by [6, 12] and others as a "market clearing" relation.

Substituting (2) in the firm profit identity gives

$$u_t = p_t' (s_{t-1} - s_t + z_t) - v_t' x_t. \quad (3)$$

Using this relation, expected profit in period t + 1 is

$$E(u_{t+1}) = E(p_{t+1})' [s_t - E(s_{t+1}) + E(z_{t+1})] - E(v_{t+1})' E(x_{t+1}) \quad (4)$$

where E(...) represents mathematical expectation. Redefining the firm's multi-input, multi-output production function implicitly in terms of s_t and z_t gives

$$f(s_t, z_t, x_t) = 0. \quad (5)$$

The firm's decision problem is defined as the simultaneous maximization of profit (3) and expected profit (4) in t subject to the production constraint (5). The Lagrangian function to be optimized is

$$L(s_t, z_t, x_t, \lambda) = p_t'(s_{t-1} - s_t + z_t) - v_t' x_t + \lambda f(s_t, z_t, x_t) + E(p_{t+1})' [s_t - E(s_{t+1}) + E(z_{t+1})] - E(v_{t+1})' E(x_{t+1}). \quad (6)$$

Taking all expected values as parameters, the necessary conditions for a maximum require that

$$\partial L/\partial s_{it} = -p_{it} + \lambda \partial f/\partial s_{it} + E(p_{it+1}) = 0 \qquad i = 1,...,n \quad (7)$$

$$\partial L/\partial z_{it} = p_{it} + \lambda \partial f/\partial z_{it} = 0 \qquad i = 1,...,n \quad (8)$$

$$\partial L/\partial x_{jt} = -v_{jt} + \lambda \partial f/\partial x_{jt} = 0 \qquad i = 1,...,m \quad (9)$$

$$\partial L/\partial \lambda = f(s_t, z_t, x_t) = 0 \quad (10)$$

The optimal values s_{it}^*, z_{it}^*, x_{it}^*, λ^*, when they exist, are functions of the parameters of the system and can be written generally as

$$s_{it}^* = g_i[p_t, v_t, E(p_{t+1})] \qquad i = 1,...n \quad (11)$$

$$z_{it}^* = h_i[p_t, v_t, E(p_{t+1})] \qquad i = 1,...,n \quad (12)$$

$$x_{jt}^* = b_j[p_t, v_t, E(p_{t+1})] \qquad j = 1,...,m \quad (13)$$

$$\lambda^* = c\,[p_t, v_t, E(p_{t+1})] \quad (14)$$

Expression (11) is the inventory stock function, (12) is the production flow function, and (13) is the derived demand function. Sufficient conditions for a stationary maximum require that the production function be strictly convex in the neighborhood of the extreme points given in (11) through (14).

To complete a simultaneous equation model of the market for the ith commodity requires addition of a demand function. Maximization of individual utility subject to a budget constraint in a static environment yields the conventional demand function $q_i^* = d_i\,(p,y)$ where y is income. Disregarding aggregation problems, it follows that addition of this function allows the demand and supply system for the ith commodity to be written as

$$q_{it} = d_i\,(p_t, y_t) \quad (15)$$

$$q_{it} = s_{i,\,t-1} - s_{it} + z_{it} \quad (16)$$

$$s_{it} = g_i[p_t, v_t, E(p_{t+1})] \quad (17)$$

$$z_{it} = h_i[p_t, v_t, E(p_{t+1})] \quad (18)$$

where all prices and quantities are now market prices and quantities. This system serves as a foundation for the empirical models discussed in the remainder of this paper.

EMPIRICAL IMPLEMENTATION OF THE MODEL

Evidence presented in [8, 9, 10] indicates that the vegetable oil products industry is effectively competitive. This is a necessary condition for application of the simultaneous equation model developed in the preceding section. Three markets are considered in the empirical implementation of the system described by relations (16), (17) and (18). These are the domestic cooking oil, shortening and margarine markets. Data on variables used in the study were obtained from the Economic Research Service tape library and accumulated on a monthly basis from January 1965 to April of 1976—providing a total of 136 observations.

The variables included in the analysis are defined as follows:

p_1 = monthly average retail price of cooking oil in cents per pound for leading U.S. cities
p_2 = monthly average wholesale price of shortening in cents per three-pound unit
p_3 = monthly average retail price of margarine in cents per pound for leading U.S. cities
p_4 = monthly average retail price of lard in cents per pound for leading U.S. cities
p_5 = monthly average retail price of butter in cents per pound for leading U.S. cities
p_6 = monthly price of refined soybean oil
q_1 = monthly domestic consumption of cooking oil in thousands of pounds
q_2 = monthly domestic consumption of shortening in thousands of pounds
q_3 = monthly domestic consumption of margarine in thousands of pounds
q_4 = population of the U.S. in thousands
y = monthly personal income of the U.S.
s_1 = end of month stocks of cooking oil in thousands of pounds
s_2 = end of month stocks of shortening in thousands of pounds
s_3 = end of month stocks of margarine in thousands of pounds
z_1 = monthly production of cooking oil in thousands of pounds
z_2 = monthly production of shortening in thousands of pounds
z_3 = monthly production of margarine in thousands of pounds and
r = monthly average interest rate on 4-6 month commercial paper.

Markets for cooking oil, shortening and margarine are represented by the hypothesized relations:

$$q_1 = d_1 (p_1, y, q_4) \quad (19)$$

$$s_1 = g_1 (p_1, r, z_{1,-1}, s_{1,-1}) \quad (20)$$

$$z_1 = h_1 (p_1, p_6, z_{1,-1}, s_{1,-1}) \quad (21)$$

$$q_2 = d_2 (p_2, p_4, y, q_4, q_{2,-1}) \quad (22)$$

$$s_2 = g_2 (p_2, r, z_{2,-1}, s_{2,-1}) \quad (23)$$

$$z_2 = h_2 (p_2, p_6, z_{2,-1}, s_{2,-1}) \quad (24)$$

$$q_3 = d_3 (p_3, p_5, y, q_4, q_{3,-1}) \quad (25)$$

$$s_3 = g_3 (p_3, r, z_{3,-1}, s_{3,-1}) \quad (26)$$

$$z_3 = h_3 (p_3, p_6, z_{3,-1}, s_{3,-1}) \quad (27)$$

where the subscript -1 is used to represent a lagged variable. Expressions (19), (20) and (21) describe the cooking oil market; (22), (23) and (24) represent the shortening market; and (25), (26) and (27) represent the margarine market. Identity (16) is assumed to hold for each market and the functional forms of relations (19) through (27) are assumed to be linear. Lagged quantities are added to the relations under the assumption of quantity rigidity—production is contracted ahead beyond the present period.

An important goal of the study was to investigate the role of short-term variations in interest rates on vegetable oil product markets. This is evident from the specification of the functions of the models in (19) through (27). On the supply side interest rates represent the cost of capital to the firm. The null hypothesis is that variations in price of capital affect inventory stock and production flow decisions. Another goal of the study was to investigate the impact of changes in soybean oil prices on finished product prices. This is handled by including the price of soybean oil in the firm production flow function.

An important design feature of the simultaneous models described in (19) through (27) is the dynamic role assigned to different functions. The empirical demand relation is not completely static. Consumers are assumed to make decisions on the basis of current, relative and past prices. The argument underlying this proposition is that consumers can easily compare relative prices at the food market and respond to changes in individual price series over time. Preliminary regressions using lagged past prices as independent variables in the demand function supported this assertion. The inventory stock and production flow relations also include lagged dependent variables in their specification to allow for discrete dynamic effects. Producers are assumed to make decisions on the basis of past prices rather than only on current relative prices. The reason is that information is readily available on past own prices for producers, and relative price information is generally available. Again, preliminary regression using lagged prices as independent variables supported this assertion.

RESULTS

The results of estimating linear forms of relations (19) through (27) by ordinary and three stage least squares are presented in Table 1. An examination of the information in this table reveals that estimation by three stage least squares (3SLS) yields estimated parameters considerably different from those obtained from ordinary least squares (OLS) estimation

TABLE 1. ORDINARY AND THREE-STAGE LEAST SQUARES ESTIMATES OF PARAMETERS OF DOMESTIC COOKING OIL, SHORTENING AND MARGARINE MARKETS

Cooking Oil Market				
Equation	Coefficient of	Estimated (OLS)	Coefficient (3SLS)	R^2
(19)	Intercept	-418677. (341143.)	-66218. (251093.)	.7964
	p_1	-7.2816 (3.3144)	1.1504 (3.3215)	
	y	14.9632 (6.6013)	14.6933 (5.2285)	
	q_4	2.9144 (1.9123)	.9882 (1.4071)	
(20)	Intercept	23265. (9610.)	16110. (8816.)	.6049
	p_1	.8240 (1.0653)	.6632 (1.0819)	
	r	-12.8433 (7.0245)	-14.4532 (6.0856)	
	$s_{1,-1}$	.7389 (.0570)	.7751 (.0509)	
	$z_{1,-1}$	.0128 (.0358)	.0332 (.0337	
(21)	Intercept	69614. (17694.)	94994. (14657.)	.6959
	p_1	5.1458 (3.3540)	18.9103 (3.4270)	
	p_6	2.6026 (5.3698)	-13.0006 (5.0861)	
	$s_{1,-1}$	-.0438 (.1029)	-.1877 (.0772)	
	$z_{1,-1}$	.6739 (.0660)	.5004 (.0565)	

Shortening Market				
Equation	Coefficient of	Estimated (OLS)	Coefficient (3SLS)	R^2
(22)	Intercept	517616. (273335.)	401368. (252031.)	.7150
	p_2	-6.2432 (1.2338)	-2.0368 (1.5025)	
	p_4	14.3643 (3.7967)	6.9156 (3.5433)	
	y	20.5517 (5.5536)	12.6188 (5.4714)	
	$q_{2,-1}$	.1409 (.0821)	.2551 (.0725)	
	q_4	-2.3821 (1.5258)	-1.7794 (1.4007)	
(23)	Intercept	30561. (7662.)	24386. (7006.)	.3522
	p_2	-.0670 (.2360)	-.4011 (.2372)	
	r	-2.8988 (4.4065)	-3.2609 (3.9201)	
	$s_{2,-1}$	.5315 (.0719)	.5655 (.0655)	
	$z_{2,-1}$	.0796 (.0265)	.1145 (.0254)	
(24)	Intercept	81124. (16473.)	99768. (14377.)	.6967
	p_2	.7078 (1.0111)	2.8048 (1.1442)	
	p_6	3.3853 (4.2760)	-2.4928 (4.5207)	
	$s_{2,-1}$	-.4484 (.1557)	-.5707 (.1344)	
	$z_{2,-1}$	.7377 (.0566)	.6355 (.0551)	

Margarine Market				
Equation	Coefficient of	Estimated (OLS)	Coefficient (3SLS)	R^2
(25)	Intercept	-27025. (332637.)	310821. (248466.)	.5328
	p_3	-3.4300 (3.3820)	-.9899 (3.3440)	
	p_5	15.9431 (3.5066)	6.2146 (2.1646)	
	y	-3.1886 (6.9476)	5.9044 (5.5681)	
	$q_{3,-1}$	.2083 (.0894)	.3493 (.0740)	
	q_4	1.5696 (1.8099)	-1.4388 (1.3528)	
(26)	Intercept	-668.8 (4652.9)	-3786. (4321.)	.6782
	p_3	.6263 (.4982)	.3989 (.4942)	
	r	-1.9162 (2.8643)	-4.5555 (2.4318)	
	$s_{3,-1}$	.6458 (.0576)	.7114 (.0506)	
	$z_{3,-1}$	.1133 (.0236)	.1222 (.0224)	
(27)	Intercept	69806. (12841.)	90351. (11368.)	.5155
	p_3	6.5404 (2.7649)	9.7305 (2.8334)	
	p_6	-4.0260 (3.6854)	-5.6627 (3.5253)	
	$s_{3,-1}$	-.2774 (.1680)	-.5821 (.1295)	
	$z_{3,-1}$	.6271 (.0698)	.5685 (.0663)	

indicating that simultaneous equation bias may be large. The 3SLS estimates are taken as the relevant parameter set, even though there is a lack of statistical confidence for some of the estimated coefficients.

Following a suggestion by Naylor [15], the inequality coefficient

$$U = [\sum_{j=1}^{J} (P_j - A_j)^2 \,/\, \sum_{j=1}^{J} A_j^2]^{1/2} \qquad (28)$$

is taken as a measure of the validity of the model.

P_j = predicted change in level for a given variable,
A_j = actual change, and
$j = 1,..., J$ = number of observed and predicted changes.

This inequality coefficient is due originally to Theil [18]. A value of the coefficient less than one indicates that the model is performing better than naive no-change extrapolation. Table 2 gives results of determining the root mean square (root of the numerator in (28) over J) and the inequality coefficient for all endogenous variables over five months beyond the sample period. Following an optimal linear correction, all calculated inequality coefficients are less than one. Actual and 3SLS predicted prices for the three products considered are presented in Table 3.

The most interesting results of the study are obtained by solving for the reduced form of each structural market model. The resulting matrix of coefficients on all current exogenous variables is the matrix of impact multipliers. Each multiplier represents the change in the corresponding endogenous variable given a unit change in a specified current exogenous variable. Table 4 presents the estimated impact multipliers for cooking oil, shortening and margarine markets. In general, results indicate that an

TABLE 2. PROSPECTIVE ROOT MEAN SQUARES, INEQUALITY COEFFICIENTS AND PERCENTAGE ERROR IN PREDICTED SIGNS FOR THE COOKING OIL, SHORTENING AND MARGARINE SYSTEM MODELS

Market	Variable	Root Mean Square	Inequality Coefficient	Percentage Error in Predicted Sign
Cooking Oil	q_1	.0220	.8864	.4000
	s_1	.0671	.7122	.2000
	z_1	.0271	.7916	.4000
	p_1	.0069	.8056	.4000
Shortening	q_2	.0491	.9900	.2000
	s_2	.0209	.9888	.4000
	z_2	.0328	.9533	.2000
	p_2	.0277	.7787	.2000
Margarine	q_3	.0243	.4609	.0000
	s_3	.0459	.7312	.2000
	z_3	.0060	.4634	.0000
	p_3	.0115	1.0000	.2000

TABLE 3. PROSPECTIVE PRICE PREDICTIONS FOR COOKING OIL, SHORTENING AND MARGARINE[a]

Months Beyond Sample	Cooking Oil		Shortening		Margarine	
	Actual	Predicted	Actual	Predicted	Actual	Predicted
1	.6240	.6260	1.3170	1.2877	.4310	.3934
2	.6240	.6083	1.2750	1.3473	.4310	.4603
3	.6170	.6164	1.3770	1.3551	.4370	.4562
4	.6160	.6328	1.3800	1.3624	.4550	.4728
5	.6230	.6337	1.4490	1.3876	.4550	.5318

[a]Prices in dollars for twenty-four ounce bottles of cooking oil, three pound cans of shortening and pound packages of margarine.

increase in national income has a positive effect on quantities and prices for all three producers—eleven of twelve impact multipliers for income are positive. The largest price impact of an increase in income is in the shortening market where an increment of one million dollars in income implies an increase of .0240 cents in shortening price. Contrary to the positive impact of rising income is the generally negative impact of rising short-term interest rates. The largest price impact of interest rates is in the cooking oil market where an increase of one percent in short-term rates implies a decline in the price of cooking oil of .0084 cents. Although both income and interest rate impacts are actually quite small, their levels indicate the existence of some degree of dependence of the vegetable oil products industry on national economic aggregates. In particular, estimated impact multipliers indicate that in an economic recession, when national income levels decline and short-term interest rates rise, there is a small negative impact on vegetable oil product prices.

The scale impact of changes in the price of soybean oil on prices of finished products is much greater than that of income and interest rates. This is expected because soybean oil is the major input in production of cooking oil, shortening and margarine. The price impact multipliers for soybean oil indicate a one cent rise in price of soybean oil leads to a .7604 cent rise in price of a twenty-four ounce bottle of cooking oil, a .4754 cent rise in price of a three pound can of shortening, and a .5486 cent rise in price of a pound package of margarine. Large price impacts are also implied for increases in the price of competing goods. The price impact multiplier for lard indicates that a one-cent increase in price of lard leads to a 1.3190 cent increase in price of shortening. Also a one-cent increase in price of butter leads to a .6021 increase in price of margarine.

CONCLUSION

Results of this study indicate that national economic aggregates have some impact on the domestic vegetable oil products industry. Income affects each market through the demand function, and interest rates enter through the inventory-stock func-

TABLE 4. IMPACT MULTIPLIERS FOR THE VEGETABLE OIL INDUSTRY

Endogenous Variable	Exogenous Variable					
	y	r	p_6	p_4	q_4	p_5
			Cooking Oil			
q_1	15.6820	-.0097	.8747	- -	1.0546	- -
s_1	.5699	-.1501	.5043	- -	.0383	- -
z_1	16.2519	-.1598	1.3790	- -	1.0930	- -
p_1	.0085	-.0084	.7604	- -	.0578	- -
			Shortening			
q_2	7.7163	.0136	-.9684	4.2288	-1.0881	- -
s_2	-.9654	-.0301	-.1907	-.5290	.1361	- -
z_2	6.7509	-.0174	-1.1591	3.6997	-.9519	- -
p_2	.0240	-.0062	.4754	1.3190	-.3394	- -
			Margarine			
q_3	5.3381	.0043	-.5430	- -	-1.3008	5.6185
s_3	.2281	-.0473	.2188	- -	-.0556	.2401
z_3	5.5663	-.0429	-.3342	- -	-1.3564	5.8587
p_3	.0057	-.0044	.5486	- -	-.1393	.6021

tion. Interest rates may be a factor which has been neglected in other short-run analyses of commodity markets [4, 14]. Other results of this study indicate a positive relationship between shortening price and the price of lard, and between margarine price and the price of butter. This finding corroborates results obtained by George and King [5] for margarine and shortening using yearly data. In addition, results of this study indicate relatively large impact multipliers on endogenous variables for several exogenous variables. Since the exogenous variables considered are relatively volatile, volatility in finished vegetable oil products quantities and prices is a direct consequence.

An important result of the study on which this paper is based has been development and implementation of a simultaneous demand and supply model, given in relations (15) through (18), that explicitly allows a role for inventory stocks and production flows in supply. Previous attempts to provide a theoretical explanation of stock levels have been made by Lovell, using an extension of the theory of the flexible accelerator [11]. Empirical applications using Lovell's approach have been made by [7, 17]. The difference in Lovell's development and the inventory stocks-production flow approach presented in this paper is that the latter is a direct consequence of firm profit maximization, is compatable with classical supply theory, and does not employ the flexible accelerator argument in its formulation.

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