Agricultural & Applied Economics Association

Demand for Farm Output in a Complete System of Demand Functions
Author(s): Michael K. Wohlgenant
Source: *American Journal of Agricultural Economics*, Vol. 71, No. 2 (May, 1989), pp. 241-252
Published by: Blackwell Publishing on behalf of the Agricultural & Applied Economics Association
Stable URL: http://www.jstor.org/stable/1241581
Accessed: 04/12/2008 16:18

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/page/info/about/policies/terms.jsp. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/action/showPublisher?publisherCode=black.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is a not-for-profit organization founded in 1995 to build trusted digital archives for scholarship. We work with the scholarly community to preserve their work and the materials they rely upon, and to build a common research platform that promotes the discovery and use of these resources. For more information about JSTOR, please contact support@jstor.org.

Agricultural & Applied Economics Association and *Blackwell Publishing* are collaborating with JSTOR to digitize, preserve and extend access to *American Journal of Agricultural Economics.*

http://www.jstor.org

Articles

Demand for Farm Output in a Complete System of Demand Functions

Michael K. Wohlgenant

Demand interrelationships for farm outputs that are theoretically consistent with consumer demand and marketing group behavior provide important linkages between retail and farm prices. A conceptual model, based on reduced-form specifications for retail and farm prices, is formulated and applied empirically to a set of eight disaggregated food commodities. This approach circumvents the need for retail quantities, which are frequently unavailable for disaggregated food commodities. The results are consistent with theory and generally indicate significant substitution between farm and marketing inputs. Except for poultry, derived demand elasticities are at least 40% larger compared to those derived assuming fixed proportions.

Key words: demand interrelationships, food, input substitution, marketing margins.

Much research has focused on demand interrelationships at the retail level (Brandow, George and King, Heien, Huang 1985) and on supply interrelationships for agricultural commodities at the farm level (Lopez, Weaver, Shumway). Except for George and King, and Dunn and Heien, sets of demand interrelationships do not exist for food commodities at the farm level, which are theoretically consistent with consumer demand behavior and marketing group behavior. Theoretically consistent estimates of demand interrelationships for farm outputs are important in providing linkages between retail and farm prices so that the effects of changes in retail demand, farm product supplies, and costs of food marketing on retail and farm prices can be consistently estimated. The purpose of this paper is to develop a conceptual and empirical framework on retail-to-farm demand linkages similar to the framework provided for consumer demand and producer supply interrelationships.

The model developed in this study extends previous work in two ways. First, the behavioral equations are specified without imposing any restrictions on input substitutability or diversity among firms in the industry. Second, by focusing on specification of reduced-form retail and farm price equations, the modeling approach allows estimation of the food-marketing sector's supply/demand structure without direct information on retail food quantities. This capability is important because direct estimates of retail quantities for disaggregated food commodities are frequently unavailable.

The conceptual model is applied to a set of eight food commodities: (*a*) beef and veal, (*b*) pork, (*c*) poultry, (*d*) eggs, (*e*) dairy products, (*f*) fresh fruits, (*g*) fresh vegetables, and (*h*) processed fruits and vegetables. Consistency of the empirical model with competitive marketing group behavior is evaluated through imposing and testing the parametric restrictions of symmetry and constant returns to scale implied by theory. Flexibilities and elasticities of demand for farm outputs are then derived. Finally, the derived demand elasticities for the interrelated farm outputs are compared with the elasticities derived using the traditional methodology based on fixed input proportions.

Michael K. Wohlgenant is a professor, Department of Economics and Business, North Carolina State University.

This article is based upon work supported by the U.S. Department of Agriculture under Agreement No. 58-3J23-4-00278. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the view of the U.S. Department of Agriculture. Earlier versions of this paper were presented at seminars at the University of California, Berkeley, North Carolina State University, U.S. Department of Agriculture, and the University of Wisconsin.

Appreciation is expressed by the author ro R. C. Haidacher, V. K. Smith, W. N. Thurman, and anonymous reviewers for insightful comments.

Copyright 1989 American Agricultural Economics Association

A Conceptual Framework

The traditional approach to modeling derived demand for food at the farm level assumes fixed proportions between the farm product and marketing inputs in producing the retail product. Derived demand for the farm product is obtained by subtracting per unit marketing costs from the retail demand function for the product (Tomek and Robinson, chap. 6). Because changes in per unit marketing costs correspond to changes in the farm-retail price spread, derived demand for the farm output can be obtained directly by subtracting the marketing margin from the retail demand function. By assuming that price spreads are a combination of constant absolute amounts and constant percentages of the retail price, derived demand elasticities can be obtained as products of elasticities of demand at the retail level and elasticities of price transmission between the retail and farm prices. This procedure is explained in George and King.

Using a market equilibrium model of the food-marketing sector, Gardner criticized the traditional methodology by demonstrating (p. 406) "that no simple markup pricing rule—a fixed percentage rule, a fixed absolute margin, or a combination of the two—can in general accurately depict the relationship between the farm and retail price." Only for fixed proportions is this approach expected to be valid. Moreover, the traditional approach to obtaining derived demand elasticities by multiplying retail elasticities by elasticities of price transmission is correct only if input proportions are fixed.[1]

It is conceptually appealing to view farm output as an input in food processing and marketing. The food-marketing sector produces a plethora of products (for at-home and away-from-home consumption) from any given raw material, so opportunities for substitution between marketing services and raw food quantities appear to exist. Unfortunately, for most disaggregated food commodities data are not available on the final quantities consumed, so knowledge of the food-marketing sector's technology cannot be obtained through estimation of the parameters of the cost function, as in Dunn and Heien. Rather, knowledge of the aggregate technology must be inferred through estimation of reduced-form behavioral equations of the marketing sector.

Conceptually, the complete structural model for a particular commodity,[2] assuming perfect competition in the output and input markets, takes the following form:

(1a) $Q_r^d = D_r(P_r, Z)$ (retail demand)

(1b) $Q_r^s = \Sigma S_r^i(P_r, P_f, W)$, (retail supply)

(1c) $Q_f^d = \Sigma D_f^i(P_r, P_f, W)$, (farm-level demand)

(1d) Q_f^s *predetermined*, (farm-level supply)

(1e) $Q_r^d = Q_r^s = Q_r$ (retail market clearing)

(1f) $Q_f^d = Q_f^s = Q_f$, (farm-level market clearing),

where Q_r^d is quantity of the retail product demanded, P_r is the retail price, Z is an exogenous retail demand shifter, Q_r^s is quantity of the retail product supplied, P_f is the farm price, W is an index of marketing input prices in food marketing, Q_f^d is the quantity of the farm product demanded, and Q_f^s is the quantity of the farm product supplied. The retail supply and farm-level demand functions are explicitly obtained as horizontal summations of the supply and demand functions of individual firms, where i denotes an individual firm. If some inputs are held fixed, the functions could be expanded to include these fixed inputs as parameters. For convenience, these fixed inputs are subsumed in the supply and demand functions. Finally, in (1d) the quantity of the farm output is assumed to be predetermined with respect to the current period farm price. The assumption that supply of the farm product is a function of lagged, rather than current year, prices is based on biological lags in agricultural production processes.

Using equations (1a) and (1b) to eliminate Q_r, the system (1a)–(1f) may be written as the two-equation system:

(2a) $\Sigma S_r^i(P_r, P_f, W) - D_r(P_r, Z) = 0$,

(2b) $Q_f - \Sigma D_f^i(P_r, P_f, W) = 0$.

[1] An extensive critique of the traditional methodology for estimating derived demand for food commodities is found in Wohlgenant.

[2] Dunn and Heien, in econometric analysis of the major food groups (meat, dairy, poultry and eggs, and fruits and vegetables), find no evidence of jointness among the retail commodities produced. The assumption of nonjointness in production is maintained in the present study.

Totally differentiating (2a) and (2b) and writing these total differentials in elasticity form yields

(3a) $$(\xi_{rr} - e) \cdot d\ln P_r + \xi_{rf} \cdot d\ln P_f = e_z \cdot d\ln Z - \xi_{rw} \cdot d\ln W,$$

(3b) $$-\xi_{fr} \cdot d\ln P_r - \xi_{ff} \cdot d\ln P_f = \xi_{fw} \cdot d\ln W - d\ln Q_f,$$

where ξ_{rr} is the elasticity of retail supply with respect to retail price, e is the elasticity of retail demand with respect to retail price, ξ_{rf} is the elasticity of retail supply with respect to farm price, e_z is the elasticity of retail demand with respect to Z, ξ_{rw} is the elasticity of retail supply with respect to W, ξ_{fr} is the elasticity of farm-level demand with respect to retail price, ξ_{ff} is the elasticity of farm-level demand with respect to farm price, and ξ_{fw} is the elasticity of farm-level demand with respect to W. The elasticities of aggregate retail supply and aggregate farm-level demand are appropriately defined as quantity-share-weighted sums of the respective elasticities of supply and demand for individual firms. For example, $\xi_{rr} = \Sigma\xi_{rr}{}^i(Q_r{}^i/Q_r)$, where $\xi_{rr}{}^i = (\partial S_r{}^i/\partial P_r)(P_r/Q_r{}^i)$ is the price elasticity of retail supply of the ith firm.

Restrictions among the elasticities at the firm level imply restrictions among the elasticities for the industry-level behavioral relations. First, the condition that output supply and input demand functions are homogenous of degree zero in prices at the firm level implies that the industry behavioral equations will be homogenous of degree zero in prices. Because retail demand functions are also homogenous of degree zero in prices and income, this restriction implies that (3a) and (3b) are invariant to proportional changes in P_r, P_f, W, and to proportional changes in those elements of Z which are retail prices of other consumer goods and consumer income. Second, the symmetry relationship between the effects of changes in the farm price on retail supply and the negative of changes in retail price on farm-level demand (Mosak, Samuelson) holds at the industry level as well. For an individual firm symmetry between retail supply and farm-level demand implies that

(4) $$\frac{\partial S_r{}^i}{\partial P_f} = -\frac{\partial D_f{}^i}{\partial P_r}.$$

Summing over all firms and converting to elasticities yields

(5) $$\Sigma\xi_{rf}{}^i \frac{Q_r{}^i}{P_f} = -\Sigma\xi_{fr}{}^i \frac{Q_f{}^i}{P_r},$$

or after multiplying the left-hand side of (5) by Q_r/Q_r, the right-hand side of (5) by Q_f/Q_f, and rearranging terms yields

(6) $$\xi_{rf} = -S_f\xi_{fr},$$

where S_f is the farmer's share of the retail dollar ($S_f = P_fQ_f/P_rQ_r$). Equation (6) is precisely the aggregate counterpart to (4) expressed in elasticity form.

The comparative statics of the reduced-form equations

(7a) $$P_r = P_r(Z, W, Q_f),$$

(7b) $$P_f = P_f(Z, W, Q_f),$$

can be determined by solving the system of equations (3a) and (3b) for $d\ln P_r$ and $d\ln P_f$. These solutions are

(8a) $$d\ln P_r = A_{rz} \cdot d\ln Z + A_{rw} \cdot d\ln W + A_{rf} \cdot d\ln Q_f,$$

(8b) $$d\ln P_f = A_{fz} \cdot d\ln Z + A_{fw} \cdot d\ln W + A_{ff} \cdot d\ln Q_f,$$

where

(9a) $$A_{rz} = -\xi_{ff}e_z/D,$$

(9b) $$A_{rw} = (\xi_{ff}\xi_{rw} - \xi_{rf}\xi_{fw})/D,$$

(9c) $$A_{rf} = \xi_{rf}/D,$$

(9d) $$A_{fz} = \xi_{fr}e_z/D,$$

(9e) $$A_{fw} = (-\xi_{fr}\xi_{rw} + (\xi_{rr} - e)\xi_{fw})/D,$$

(9f) $$A_{ff} = -(\xi_{rr} - e)/D,$$

(9g) $$D = -(-\xi_{rr} - e)\xi_{ff} + \xi_{rf}\xi_{fr}.$$

To determine the signs of the reduced-form parameters of (8a) and (8b), first observe that the reciprocal of A_{ff} is the industry derived demand elasticity for the farm product, holding prices of other inputs constant. Heiner showed that this elasticity is unambiguously negative in the short run, even with diverse firms in the industry. Moreover, because the retail supply elasticity (ξ_{rr}) is positive and the retail demand elasticity (e) is expected to be negative in all normal cases, this situation implies by (9f) that $D > 0$. This result immediately implies, because $\xi_{ff} < 0$, that A_{rz} has the same sign as e_z, which should be positive in all normal cases. If the farm product is a normal input—which seems plausible for the commodity aggregates analyzed in this study—then ξ_{rf} is negative (Ferguson), and ξ_{fr} is positive in view of (6). This implies by (9c) that $A_{rf} < 0$, and by (9d) that A_{fz} takes the same sign as e_z. Finally, the signs of A_{rw} and A_{fw} are generally indeterminate because of the sign of ξ_{fw} is ambiguous.

A question of interest in the present study is whether or not it is possible to obtain unique values for the ξ's and e's from the reduced-form parameters in (9a)–(9f). In general, the answer is no because the system is underidentified; that is, there are six reduced-form parameters and eight elasticities of the structural equations. However, if values of the retail demand elasticities (e and e_z) are known, then unique estimates of the ξ's can be obtained. Estimates for the structural retail supply and farm-level demand elasticities, given values for the retail demand elasticities, are

(10a) $\xi_{rr} = e + A_{ff}e_z/B,$

(10b) $\xi_{rf} = -A_{rf}/B,$

(10c) $\xi_{rw} = (A_{rf}A_{fw} - A_{ff}A_{rw})/B,$

(10d) $\xi_{fr} = -A_{fz}/B,$

(10e) $\xi_{ff} = A_{rz}/B,$

(10f) $\xi_{fw} = (A_{fz}A_{rw} - A_{fw}A_{rz})/B,$

where

(10g) $B = A_{rz}A_{ff} - A_{rf}A_{fz}.$

Even if the retail demand elasticities are not known, values for the supply and demand elasticities (except ξ_{rr}) can still be determined from the reduced-form estimates. Also, when $e_z = 1$ (that is, when $d\ln Z$ is defined as the proportional shift in retail demand from a 1% increase in demand), then by the symmetry restriction (6)

(11) $A_{rf} = -S_f A_{fz}.$

This restriction is a linear cross-equation restriction on the reduced-form retail and farm price equations for given values of the farmer's share of the retail dollar (S_f).

Another parameter of interest is n, the elasticity of price transmission between the farm and retail prices. Upon solving (8b) for $d\ln Q_f$ and substituting into (8a), it can be shown that the elasticity of price transmission is related to the reduced-form parameters as follows:

(12) $n = A_{rf}/A_{ff}.$

In this study, there is also interest in testing for a constant-returns-to-scale aggregate production function in light of the extensive use of this model in past research (e.g., Gardner). The implications of constant returns to scale for the relationship among elasticities in the reduced-form equations (8a) and (8b) can be derived through use of the equations provided by Muth in the special case where the supply elasticity of the farm output is zero and the supply curve of marketing inputs is perfectly elastic. Expressions for proportional changes in retail price and farm price in this case can be characterized as

(13a) $d\ln P_r = (S_f \cdot e_z/D') \cdot d\ln Z + ((1 - S_f) \cdot \sigma/D') \cdot d\ln W - (S_f/D') \cdot d\ln Q_f,$

(13b) $d\ln P_f = (e_z/D') \cdot d\ln Z + (S_f(\sigma + e)/D') \cdot d\ln W - (1/D') \cdot d\ln Q_f,$

(13c) $D' = (1 - S_f)\sigma - S_f e,$

where σ is the elasticity of substitution between the farm output and marketing inputs. Equations (13a) and (13b) imply, when $e_z = 1$, that for (8a) and (8b)

(14a) $A_{rz} = -A_{rf},$

(14b) $A_{fz} = -A_{ff}.$

This restriction could also be obtained by assuming the retail supply curve is perfectly elastic. (Note that the limit of ξ_{rr} goes to infinity as B approaches zero, as implied by 14a–14b.)

Empirical Specification

In going from the conceptual framework in the previous section to an empirical specification of retail and farm price behavior, three separate issues must be resolved. These issues are (a) selection of appropriate functional forms for equations (7a) and (7b), (b) specification of retail demand shifters subsumed in the variable Z, and (c) development of formulas to calculate total effects of exogenous retail demand shifters, marketing costs, and farm output quantities on retail and farm prices.

In general, the functional form specification for econometric analysis of (7a) and (7b) is an open question. For pragmatic reasons, the approach taken here is to assume the elasticities in (8a) and (8b) are approximately constant and to replace instantaneous relative changes in the variables by first-differences in the logarithms; that is,

$$(15a)\quad \Delta\ln P_{rt} = A_{rz} \cdot \Delta\ln Z_t + A_{rw} \cdot \Delta\ln W_t + A_{rf} \cdot \Delta\ln Q_{ft} + A_{ro} + U_{rt},$$

$$(15b)\quad \Delta\ln P_{ft} = A_{fz} \cdot \Delta\ln Z_t + A_{fw} \cdot \Delta\ln W_t + A_{ff} \cdot \Delta\ln Q_{ft} + A_{fo} + U_{ft},$$

where t denotes the time period, U_{rt} and U_{ft} denote random disturbance terms, and A_{ro} and A_{fo} are intercept values which reflect changes in prices due solely to trend. The approximate nature of this form is apparent in light of the symmetry restriction (11), which only holds for a given value for the farmer's share of the retail dollar, S_f. By the results of the previous section, the homogeneity restriction is imposed by deflating all nominal values in (15a) and (15b) by the consumer price index (CPI) for all items. Imposing the homogeneity restriction and symmetry restriction (11) makes the parameter estimates of (15a) and (15b) consistent with the theories of industry behavior specified previously. Also, given the homogeneity and symmetry restrictions, it is possible to impose and test for the implications of a constant-returns-to-scale industry production function according to (14a) and (14b).

Specification of the form of Z is particularly important in order to make the parameter estimates of (15a) and (15b) internally consistent with the consumer demand estimates. Theoretically, in the context of a system of consumer demand functions, the total differential of retail demand for the ith commodity in elasticity form can be written

$$(16)\quad d\ln Q_{ri} = e_{ii} \cdot d\ln P_{ri} + \sum_{j\neq i} e_{ij} \cdot d\ln P_{rj} + e_{iy} \cdot d\ln Y + d\ln POP,$$

where e_{ii} is the own-price elasticity of demand for commodity i, e_{ij} is the cross-elasticity of demand for good i with respect to the price of good j, e_{iy} is the income elasticity of good i, Y is per capita consumer total expenditures (income), and POP is the total consuming population. In order to have internally consistent estimates of retail demand shifters in (15a) and (15b), the variable $\Delta\ln Z_t$ is defined as the sum of the last three groups of terms in (16) expressed in first-differences in logarithms; that is, for the ith good,

$$(17)\quad \Delta\ln Z_{it} = \sum_{j\neq i} e_{ij} \cdot \Delta\ln P_{rjt} + e_{iy} \cdot \Delta\ln Y_t + \Delta\ln POP_t.$$

Conceptually, the partial elasticity of Q_r with respect to Z, e_z, should equal one because (17) shows the impact on demand of a 1% increase in demand. However, values for the cross elasticities of retail demand and income elasticity for each commodity are required in order to construct such a variable. The approach taken here is to use internally consistent demand elasticities estimated from previous research.

A point of concern is whether use of extraneous information to construct values for (17) involves circular reasoning, because values for these parameters are typically estimated from retail quantity data which are derived as fixed proportions of farm output disappearance data. This is problematical, but the procedure in obtaining estimates of (17) for arbitrary values of the retail elasticities is theoretically consistent with the theory of consumer behavior and specification of retail and farm price behavior. Moreover, the first part of (17), which depends on related retail prices, may be viewed as a price index in itself. Indeed, this price index may be viewed quite generally as a divisia price index, with weights chosen as cross elasticities of demand instead of commodity consumer expenditure shares. Because in a time-series context, prices and income are typically highly collinear, the index (17) ought to be relatively insensitive to the particular weights chosen for the price and income variables. The validity of this specification is tested using the Hausman specification test, as explained below.

The third issue to consider prior to the empirical analysis is development of formulas to calculate total effects of exogenous changes on retail and farm prices. The problem with using (15a) and (15b) directly is that retail and farm prices for a given commodity depend upon retail prices of other commodities, which also depend on retail price of the commodity in question.[3] Substituting (17) into (15a) and (15b) and rearranging terms yields the following system of retail and farm price equations:

---

[3] This suggests in the econometric specification that retail and farm prices are jointly determined with the retail demand shift variable $\Delta\ln Z$. The assumption that $\Delta\ln Z$ is econometrically exogenous is also tested using the Hausman exogeneity test.

(18a) $$\Delta\ln\underline{P}_r = \underline{A}_{rz} \cdot (\underline{e}^- \cdot \Delta\ln \underline{P}_r + \underline{e}^o \cdot \Delta\ln \underline{P}_r^o + \underline{e}_y \cdot \Delta\ln Y + \underline{1} \cdot \Delta\ln POP) + \underline{A}_{rw} \cdot \Delta\ln W + \underline{A}_{rf} \cdot \Delta\ln \underline{Q}_f,$$

(18b) $$\Delta\ln\underline{P}_f = \underline{A}_{fz} \cdot (\underline{e}^- \cdot \Delta\ln \underline{P}_r + \underline{e}^o \cdot \Delta\ln \underline{P}_r^o + \underline{e}_y \cdot \Delta\ln Y + \underline{1} \cdot \Delta\ln POP) + \underline{A}_{fw} \cdot \Delta\ln W + \underline{A}_{ff} \cdot \Delta\ln \underline{Q}_{ff},$$

where underbars denote vectors and matrices of appropriate dimensions. The matrix $\underline{e}^-$ is the $n \times n$ matrix of price elasticities of retail demand with zero diagonal elements; the matrix $\underline{e}^o$ is the matrix of cross-price elasticities of retail commodities whose prices are taken as exogenous (e.g., nonfood goods); $\underline{e}_y$ is the column vector of income elasticities; and $\underline{1}$ is a column vector of 1's. To obtain total effects of the exogenous variables on retail and farm prices, solve (18a) and (18b) by matrix methods to obtain

(19a) $$\Delta\ln\underline{P}_r = (I_n - \underline{A}_{rz} \cdot \underline{e}^-)^{-1} \cdot (\underline{A}_{rz} \cdot \underline{e}^o \cdot \Delta\ln \underline{P}_r^o + \underline{A}_{rz} \cdot \underline{e}_y \cdot \Delta\ln Y + \underline{A}_{rz} \cdot \underline{1} \cdot \Delta\ln POP + \underline{A}_{rw} \cdot \Delta\ln W + \underline{A}_{rf} \cdot \Delta\ln \underline{Q}_f),$$

(19b) $$\Delta\ln\underline{P}_f = \underline{A}_{fz} \cdot (\underline{e}^- \cdot (I_n - \underline{A}_{rz} \cdot \underline{e}^-)^{-1} \cdot \underline{A}_{rz} + I_n) \cdot (\underline{e}^o \cdot \Delta\ln \underline{P}_r^o + \underline{e}_y \cdot \Delta\ln Y + \underline{1} \cdot \Delta\ln POP) + (\underline{A}_{fz} \cdot \underline{e}^- \cdot (I_n - \underline{A}_{rz} \cdot \underline{e}^-)^{-1} \cdot \underline{A}_{rw} + \underline{A}_{fw}) \cdot \Delta\ln W + (\underline{A}_{fz} \cdot \underline{e}^- \cdot (I_n - \underline{A}_{rz} \cdot \underline{e}^-)^{-1} \cdot \underline{A}_{rf} + \underline{A}_{ff}) \cdot \Delta\ln \underline{Q}_f,$$

where I_n is the nth order identity matrix. Estimates of derived demand elasticities for farm outputs are obtained by inverting the matrix premultiplying $\Delta\ln \underline{Q}_f$ in (19b).

Econometric Analysis of a Complete System of Food Commodities

The commodities included in the econometric analysis are (*a*) beef and veal, (*b*) pork, (*c*) poultry, (*d*) eggs, (*e*) dairy products, (*f*) processed fruits and vegetables, (*g*) fresh fruits, and (*h*) fresh vegetables. Farm output and price data for these commodities were obtained from time-series data and conversion factors published by the U.S. Department of Agriculture (USDA). Farm price data are producer price indexes for crude foodstuffs. Farm prices for beef and veal and pork were adjusted for by-product values. Retail price data are consumer price indexes for the corresponding farm categories; income and population data are total personal consumption expenditures per capita and midyear U.S. civilian population, respectively.

The matrix of consumer demand elasticities for construction of the retail demand shift variables was provided by K. S. Huang (personal communication, 1986). These elasticity estimates globally satisfy the homogeneity condition and locally satisfy the symmetry and Engel aggregation conditions at the 1967–69 average values for the commodity consumer expenditures. They were estimated using the composite demand system of Huang and Haidacher. The commodities included in his model consist of (*a*)–(*h*) listed above plus (*i*) fish, (*j*) sugar, (*k*) fats and oil, (*l*) cereals, (*m*) beverages, and (*n*) nonfood. Farm price linkages for (*i*)–(*m*) were not included either because appropriate data were lacking or it was impossible to identify a corresponding raw product for the corresponding retail product.

The marketing cost variable is the index of food-marketing costs (Harp). The time period for estimation is 1956–83, with 1955 used to generate the initial values for the first-difference variables. A detailed discussion of data sources, transformations, and data imputations can be found in Wohlgenant (appendix B).

Equations (15a) and (15b) were estimated for the eight different food commodities (*a*)–(*h*) by the joint generalized least-squares technique (Theil) with and without the symmetry restriction (11) and the constant-returns-to-scale restrictions (14a and 14b) imposed.

Unrestricted ordinary least squares (OLS) estimates of (15a) and (15b) for the eight sets of price equations are displayed in table 1. With a few exceptions, the parameter estimates are consistent with prior expectations. Retail demand shifters, measured by $\Delta\ln Z$, and farm output variables are generally highly statistically significant determinants of retail and farm prices. Except for fresh fruit, increases in retail demand are positively related both to retail and to farm prices. With the exception of processed fruits and vegetables and fresh fruit, all farm price flexibilities are larger than one in absolute value. This pattern of change is broadly consistent with previous empirical work (Fox, Waugh, Dunn and Heien). The marketing cost index often displays a sign contrary to prior expectations, but

Table 1. Unrestricted Reduced-Form Econometric Estimates of Retail and Farm Product Prices, 1956–83

		Elasticity of Price with Respect to					
Commodity	Product Price	Farm Quantity (Q_f)	Index of Marketing Costs (W)	Retail Demand Shifter (Z)	Intercept	R^2	D-W
Beef & veal	Retail	−0.921	−0.513	0.664	−0.001	0.54	1.78
		(−4.642)	(−0.742)	(2.153)	(−0.098)		
	Farm	−1.365	−0.879	1.354	−0.018	0.55	1.92
		(−4.333)	(−0.800)	(2.766)	(−0.811)		
Pork	Retail	−0.966	−0.027	1.474	−0.021	0.87	2.15
		(−10.964)	(−0.052)	(4.938)	(−2.010)		
	Farm	−2.070	−0.464	2.046	−0.019	0.89	2.03
		(−13.314)	(−0.502)	(3.884)	(−1.027)		
Poultry	Retail	−1.280	0.217	1.185	0.002	0.81	2.30
		(−6.441)	(0.384)	(8.068)	(0.160)		
	Farm	−2.946	−0.067	1.907	0.073	0.76	2.15
		(−6.698)	(−0.053)	(5.866)	(2.909)		
Eggs	Retail	−4.412	−1.801	5.152	−0.064	0.53	2.28
		(−4.639)	(−1.597)	(2.438)	(−2.287)		
	Farm	−5.777	−4.661	6.246	−0.046	0.48	2.39
		(−3.681)	(−2.505)	(1.791)	(−0.987)		
Dairy	Retail	−0.901	0.241	1.348	−0.023	0.44	2.62
		(−3.467)	(0.832)	(2.253)	(−2.416)		
	Farm	−1.458	0.272	2.200	−0.028	0.37	2.05
		(−3.040)	(0.508)	(1.992)	(−1.590)		
Processed fruits & vegetables	Retail	−0.490	1.065	0.016	−0.001	0.23	2.07
		(−2.192)	(1.741)	(0.038)	(−0.040)		
	Farm	−0.141	0.428	0.177	−0.012	0.05	2.51
		(−0.705)	(0.782)	(0.469)	(−0.928)		
Fresh fruit	Retail	−0.779	−0.782	−0.193	0.014	0.24	2.05
		(−2.477)	(−0.828)	(−0.360)	(0.942)		
	Farm	−0.124	−0.806	−0.350	−0.006	0.04	2.31
		(−0.333)	(−0.717)	(−0.550)	(−0.311)		
Fresh vegetables	Retail	−0.097	−0.575	0.475	0.005	0.03	2.25
		(−0.172)	(−0.646)	(0.495)	(0.255)		
	Farm	−2.205	−1.058	1.919	0.002	0.51	2.40
		(−4.164)	(−1.260)	(2.119)	(0.118)		

Note: Values in parentheses are t-values. Equations (15a) and (15b) estimated by OLS without symmetry or constant-returns-to-scale restrictions imposed.

it is statistically insignificant in virtually every case.[4]

As indicated above, the Hausman specification test can test for the consequences of specification errors in construction of the $\Delta\ln Z$ variables used in the reduced-form retail and farm price equations. Hausman's testing procedure requires an efficient estimator under the null hypothesis and a consistent estimator under the alternative hypothesis. In the present case, the efficient estimator is OLS when $\Delta\ln Z$ is appropriately specified. However, if the wrong weights (i.e., cross elasticities and income elasticities) are chosen in constructing $\Delta\ln Z$, then $\Delta\ln Z$ will be correlated with the disturbance term and OLS will be inconsistent. In this case, a consistent estimator is the instrumental variable estimator. In this application, the instrumental variable for $\Delta\ln Z$ is the least-squares projection of $\Delta\ln Z$ on all the predetermined variables of the model. The predetermined variables are changes in

[4] Lack of statistical significance of the deflated marketing cost index suggests that the marketing cost index could have been used as a deflator rather than the CPI because (15a) and (15b) are homogenous of degree zero in all nominal values. The deflated marketing cost variable was entered as a separate explanatory variable because it was not known prior to estimation how well this variable would account for movements in nonfarm input prices.

logarithms of the quantities of the farm outputs for the eight food commodities, retail prices for the other food and nonfood commodities, per capita income, the marketing cost index, and population.

The Hausman test is implemented by estimating augmented specifications of the retail and farm price equations with predicted values for $\Delta\ln Z$ included as explanatory variables (Hausman, p. 1260). Under the null hypothesis of no specification bias, the coefficient of the predicted value of $\Delta\ln Z$ will be zero, so a simple t-test can be employed. In addition to testing for the consequences of wrong weights on the price and income variables in $\Delta\ln Z$, the Hausman test in this case is also a test for simultaneous equation bias in the OLS regressions (see fn. 3). This is because the variables used in constructing predicted values for $\Delta\ln Z$ are precisely the predetermined variables one would include in the first-stage regression of the two-stage least squares estimator, which is a consistent estimator when retail and farm prices are jointly determined with $\Delta\ln Z$.

The results of the Hausman test uniformly indicate failure to reject the null hypothesis that $\Delta\ln Z$ is exogenous, with the smallest marginal significance level larger than 0.1. Moreover, in every case the coefficient estimates changed little when predicted values for $\Delta\ln Z$ were added, suggesting that the results are robust to alternative estimators.[5]

Symmetry [equation (11)] and constant-returns-to-scale restrictions [equations (14a) and (14b)], given symmetry, were imposed and tested. Symmetry was imposed at the 1967–69 average values of the farmer's share of the retail dollar.[6] Except for fresh fruits, the computed F-values all had marginal significance levels greater than 0.1. Thus, for the most part, food processing-marketing behavior can be characterized as competitive with constant returns to scale in food processing and marketing.

Fully restricted economic estimates of (15a) and (15b) for the eight sets of price equations are shown in table 2. Except for processed fruits and vegetables and fresh fruit, the parameter estimates are very similar to the unrestricted OLS results presented in table 1. For processed fruits and vegetables and fresh fruit, signs on quantity of the farm output in the farm price equation are reversed from the unrestricted estimates. However, these variables are insignificant and, even for the unrestricted estimates, take on implausibly low values. These inconsistencies suggest aggregation and/or data problems with these two commodities. Processed fruits and vegetables is a very heterogenous category, and fresh fruits includes significant retail products having no U.S. counterparts (e.g., bananas).

Given the maintained hypothesis of constant returns to scale, structural parameters of marketing group behavior are derived for all commodities except processed fruits and vegetables and fresh fruits. (These commodities are excluded because of wrong signs on the farm output variables.) The structural parameter of interest in this case is the elasticity of substitution (σ). Estimates of σ can be obtained from the equation for the elasticity of derived demand for the farm output, which in view of (13b) and (13c) can be written

$$(20) \qquad E_{ff} = -(1 - S_f)\sigma + S_f \cdot e,$$

where $E_{ff} = 1/A_{ff}$. Therefore, for given values of A_{ff}, S_f, and e, the elasticity of substitution can be computed as

$$(21) \quad \sigma = (-E_{ff} + S_f \cdot e)/(1 - S_f) = (-1/A_{ff} + S_f \cdot e)/(1 - S_f).$$

Estimates of A_{ff} are obtained from table 2, estimates of S_f are the average values for 1967–69, and values for the own-price elasticities of retail demand (e) are the extraneous estimates used in estimation of the bahavioral equations. Estimates of these structural parameters are reported in table 3. In all cases, the elasticities of substitution are positive as expected. In some cases (e.g., beef and veal and dairy products), the estimates are quite large suggesting substantial opportunities for input substitution.

In order to determine whether the elasticity of substitution estimates in table 3 are sig-

[5] A referee expressed concern about the assumption of fixed supplies of farm products. For example, Thurman argues that the supply of poultry is not predetermined in a one-year period. The assumption of predetermined supply was tested jointly with the hypothesis of exogenous Z for all commodities except beef and veal, pork, and dairy products. The instruments used were the same as indicated in the text, with one-year lagged values used for the hypothesized endogenous farm quantity variables. The Hausman tests were conducted by including predicted variables for $\Delta\ln Z$ and $\Delta\ln Q_f$ and employing an f-test as described by Nakamura and Nakamura. As in the previous case, the results of the Hausman test uniformly indicate failure to reject the null hypothesis of predetermined supplies and exogenous Z.

[6] Average 1967–69 share values for S_f by commodity are as follows: beef and veal (0.65), pork (0.55), poultry (0.52), eggs (0.62), dairy (0.47), processed fruits and vegetables (0.20), fresh fruits (0.32), and fresh vegetables (0.33).

Table 2. Reduced-Form Econometric Estimates of Retail and Farm Product Prices with Symmetry and Constant-Returns-to-Scale Restrictions Imposed, 1956–83

		Elasticity of Price with Respect to			
Commodity	Product Price	Farm Quantity (Q_f)	Index of Marketing Costs (W)	Retail Demand Shifter (Z)	Intercept
Beef and veal	Retail	−0.858	−0.506	0.858	−0.007
		(−5.275)	(−0.731)	(5.275)	(−0.671)
	Farm	−1.320	−0.896	1.320	−0.017
		(−5.275)	(−0.816)	(5.275)	(−0.999)
Pork	Retail	−1.080	−0.104	1.080	−0.011
		(−15.814)	(−0.200)	(15.814)	(−1.399)
	Farm	−1.963	−0.486	1.963	−0.019
		(−15.814)	(−0.530)	(15.814)	(−1.341)
Poultry	Retail	−1.197	0.173	1.197	−0.002
		(−10.095)	(0.309)	(10.095)	(−0.211)
	Farm	−2.302	−0.129	2.302	0.038
		(−10.095)	(−0.106)	(10.095)	(2.090)
Eggs	Retail	−4.081	−1.886	4.081	−0.053
		(−4.604)	(−1.694)	(4.604)	(−2.805)
	Farm	−6.582	−4.658	6.582	−0.048
		(−4.604)	(−2.535)	(4.604)	(−1.547)
Dairy	Retail	−0.776	0.298	0.776	−0.016
		(−3.712)	(1.033)	(3.712)	(−3.416)
	Farm	−1.652	0.277	1.652	−0.019
		(−3.712)	(0.518)	(3.712)	(−2.188)
Processed fruits and vegetables	Retail	0.025	0.945	−0.025	−0.011
		(0.958)	(1.561)	(−0.958)	(−1.138)
	Farm	0.127	0.418	−0.127	−0.010
		(0.958)	(0.772)	(0.958)	(−1.209)
Fresh fruit	Retail	0.093	−0.881	−0.093	0.008
		(0.902)	(−0.939)	(−0.902)	(0.532)
	Farm	0.289	−0.850	−0.289	−0.009
		(0.902)	(−0.759)	(−0.902)	(−0.486)
Fresh vegetables	Retail	−0.765	−0.619	0.765	0.012
		(−5.637)	(−0.697)	(5.637)	(0.846)
	Farm	−2.319	−1.055	2.319	−0.000
		(−5.637)	(−1.258)	(5.637)	(−0.013)

Note: Equations were estimated by the joint generalized least squares method with symmetry [equation (11)] and constant-returns-to-scale retrictions [equations (14a) and (14b)] imposed. Values in parentheses are t-values.

nificantly different from zero, observe from (21) that when $\sigma = 0$, $E_{ff} = S_f \cdot e$ or $1/A_{ff} = S_f \cdot e$. Thus, for given values of S_f and e, an approximate test for Ho: $\sigma = 0$ is the t-statistic.

$$t = (A_{ff} - 1/(e \cdot S_f))/SE(A_{ff}),$$

where $SE(A_{ff})$ is the estimated standard error for A_{ff} derived from table 2. The estimated t-values for the six commodities are reported in table 3. Only for poultry is the null hypothesis of fixed input proportions not rejected. Therefore, it is important to allow for input substitutability between farm outputs and marketing inputs in food processing and marketing.

Flexibilities and Elasticities

Using the equations in table 2 and extraneous estimates of the consumer demand elasticities for the food products, the set of equations shown in (19b) is used to calculate a matrix of total effects of exogenous demand and supply shifters on farm-level prices. This estimated matrix for beef and veal, pork, poultry, eggs, dairy products, and fresh vegetables is shown in table 4. While total effects of demand and supply changes on prices for processed fruits and vegetables and fresh fruits are not included here, the unrestricted retail price equation estimates from table 1 were included in

Table 3. Estimates of Elasticity of Substitution

	Parameter Values		
Commodity	Elasticity of Retail Demand (e)	Farmers' Share of the Retail Dollar (S_f)	Elasticity of Substitution (σ)
Beef and veal	−0.78	0.65	0.72 (2.60)
Pork	−0.64	0.55	0.35 (7.09)
Poultry	−0.73	0.52	0.11 (1.45)
Eggs	−0.09	0.62	0.25 (7.93)
Dairy	−0.21	0.47	0.96 (19.05)
Fresh vegetables	−0.22	0.33	0.54 (11.45)

Note: Elasticities of retail demand are extraneous estimates furnished by Kuo S. Huang of USDA. Elasticity of substitution estimates obtained through use of equation (21) and price flexibilities in table 2. Values in parentheses are t-values for the null hypothesis that $\sigma = 0$.

the model when deriving the flexibilities and elasticities for the other commodities. Also, in order to conserve space, only total effects of farm quantities, marketing costs, and income are presented.

Overall, the results in table 4 are consistent with previous results indicating that (a) all own-price flexibilities are larger than one in absolute value, (b) the majority of cross-price flexibilities display negative terms indicating substitutability among farm outputs, (c) all marketing cost variables except dairy show negative signs, and (d) all income flexibilities are positive.

By solving the system of equations (19b) for percentage changes in farm quantities, we obtain total elasticities of derived demand for the farm outputs. These values are shown as the first elements of each column in table 5. Again, the results are broadly consistent with previous findings. All own-price elasticities are less than one in absolute values; and the majority of the cross-price elasticities are positive, indicating substitutability among farm outputs. The main difference from previous results is that, except for poultry, farm-level demands are nearly as large as or larger than the corresponding retail elasticities. This difference occurs because of substantial substitution opportunities as indicated in table 3. This result is consistent with the analysis of Gardner, who showed that derived demand for the farm product can be more elastic than retail demand.

The traditional methodology for obtaining derived demand elasticities for farm products is to multiply elasticities of price transmission times retail demand elasticities (George and

Table 4. Matrix of Flexibilities for Reduced-Form Farm-Level Prices

	Quantity							
Farm Price	Beef and Veal	Pork	Poultry	Eggs	Dairy	Vegetables	Marketing Cost Index	Income
Beef and veal	−1.37	−0.17	−0.10	−0.14	0.04	0.00	−1.06	1.42
Pork	−0.27	−2.05	−0.22	0.10	0.00	−0.02	−0.57	1.64
Poultry	−0.50	−0.66	−2.42	−0.34	0.06	−0.18	−1.73	1.68
Eggs	−0.70	0.07	−0.33	−6.71	−0.10	0.07	−5.00	0.29
Dairy	0.00	−0.03	0.01	−0.02	−1.65	−0.02	0.39	0.24
Vegetables	−0.07	−0.12	−0.22	0.11	−0.09	−2.34	−0.98	0.20

Note: Flexibilities show percentage changes in farm prices to 1% changes in quantities, marketing cost index, and income. These are total flexibilities calculated from equation (19b).

Table 5. A Comparison of Farm-Level Derived Demand Elasticities Under Variable and Fixed Input Proportions

	Price							
Farm Quantity	Beef and Veal	Pork	Poultry	Eggs	Dairy	Vegetables	Marketing Cost Index	Income
Beef and veal	−0.76	0.06	0.02	0.02	−0.02	0.00	−0.76	1.02
	(−0.50)	(0.06)	(0.02)	(0.02)	(−0.02)	(0.00)		(0.95)
Pork	0.09	−0.51	0.04	−0.01	0.00	0.00	−0.29	0.64
	(0.09)	(−0.36)	(0.04)	(−0.01)	(0.01)	(0.00)		(0.64)
Poultry	0.10	0.14	−0.42	0.02	0.01	0.05	0.74	1.13
	(0.12)	(0.13)	(−0.38)	(0.02)	(−0.02)	(0.03)		(0.32)
Eggs	0.08	−0.02	0.02	−0.15	0.01	−0.01	−0.73	−0.05
	(0.07)	(−0.02)	(0.02)	(−0.05)	(0.01)	(0.00)		(−0.06)
Dairy	0.00	0.01	0.00	0.00	−0.61	0.01	0.19	0.08
	(0.00)	(0.01)	(0.00)	(0.00)	(−0.10)	(0.00)		(0.14)
Vegetables	0.01	0.01	0.06	−0.01	0.03	−0.43	−0.16	−0.21
	(0.01)	(0.01)	(0.04)	(−0.01)	(0.03)	(−0.07)		(−0.03)

Note: Elasticities are total derived demand elasticities calculated through inversion of the matrix of flexibilities in table 4. Values in parentheses are derived demand elasticities calculated under the fixed proportions assumption.

King). When there are constant returns to scale, the elasticity of price transmission equals the farmers' share of the retail dollar. This relationship can be seen by using (11) and (14b) in (12). The equivalent of the traditional methodology to assuming $\sigma = 0$ can be seen from (21). The own-price elasticities of derived demand by this procedure are shown in parentheses in table 5. They are considerably smaller than those when fixed proportions restriction is not imposed. Indeed, except for poultry, the own-price elasticities in table 5 are at least 40% larger in absolute value. Given the magnitude of the errors from using the traditional formulas, special care should be taken in using this methodology for calculating derived demand elasticities.

Conclusions

In this paper, a conceptual and empirical framework for estimating demand interrelationships at the farm level is presented. The modeling approach is quite flexible in that no restrictions need be placed on input substitutability or diversity among firms in the industry. Moreover, by imposing the restrictions of theory on reduced-form retail and farm price equations, the parameters of the marketing sector's supply/demand structure can be estimated without direct information on retail quantities. This finding is important because direct estimates of retail quantities for disaggregated food commodities are frequently unavailable.

The modeling approach was applied to estimation of retail and farm prices for eight separate food commodities. The empirical results were consistent with the theoretical specification of competitive marketing group behavior. Moreover, except for one commodity (fresh fruits), the results were consistent with an aggregate technology for food processing and marketing that is characterized by constannt returns to scale. The results also indicate that an important parameter characterizing food-marketing behavior is the elasticity of substitution between the farm product and marketing inputs. Estimates of elasticities of substitution were derived for beef and veal, pork, poultry, eggs, dairy products, and fresh vegetables. Except for poultry, these elasticity of substitution estimates indicate substantial substitution possibilities in food-marketing industries.

A significant implication of input substitutability among farm outputs and marketing inputs is that the derived demand elasticities for farm outputs are considerably larger (in absolute value) than when the assumption of fixed input proportions is imposed. Indeed, except for poultry—where insignificant input substitutability was found—the own-price elasticities of derived demand for farm outputs were at least 40% larger in absolute value than those obtained under no input substitution. This finding implies that the traditional methodology of obtaining derived demand elasticities by multiplying elasticities of price transmission by elasticities of retail demand can lead to substantial underestimation of derived demand elasticities. Thus, analysts should use reduced-form derived demand specifications for farm outputs in order to obtain more realistic estimates of derived demand elasticities.

[Received February 1988; final revision received August 1988.]

References

Brandow, G. E. *Interrelationships among Demands for Farm Products and Implications for Control of Market Supply*. Pennsylvania State University Tech. Bull. No. 680, 1961.

Dunn, J., and D. Heien. "The Demand for Farm Output." *West. J. Agr. Econ.* 10(1985):13–22.

Ferguson, C. E. "Production, Prices, and the Theory of Jointly Derived Input Demand Functions." *Economica* 33(1966):454–61.

Fox, K. A. "Factors Affecting Farm Income, Farm Prices, and Food Consumption." *Agr. Econ. Res.* 3(1961):65–82.

Gardner, B. L. "The Farm-Retail Price Spread in a Competitive Food Industry." *Amer. J. Agr. Econ.* 57(1975):399–409.

George P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections for 1980*. Giannini Foundation Monograph No. 26, University of California, Berkeley, 1971.

Harp, H. *The Food Marketing Cost Index: A New Measure for Analyzing Food Price Changes*. Washington DC: U.S. Department of Agriculture Tech. Bull. No. 1633, 1980.

Hausman, J. A. "Specification Tests in Econometrics." *Econometrica* 46(1978):1251–71.

Heien, D. M. "The Structure of Food Demand: Interrelatedness and Duality." *Amer. J. Agr. Econ.* 64(1982):213–21.

Heiner, R. A. "Theory of the Firm in 'Short-Run' Industry Equilibrium." *Amer. Econ. Rev.* 82(1982):555–62.

Huang, K. S. *U.S. Demand for Food: A Complete System of Price and Income Effects*. Washington DC: U.S. Department of Agriculture Tech. Bull. No. 1714, 1985.

Huang, K., and R. C. Haidacher. "Estimation of a Composite Food Demand System for the United States." *J. Bus. and Econ. Statist.* 1(1983):285–91.

Lopez, R. "The Structure of Production and the Derived Demand for Inputs in Canadian Agriculture." *Amer. J. Agr. Econ.* 62(1980):38–45.

Mosak, J. L. "Interrelations of Production, Price, and Derived Demand." *J. Polit. Econ.* 46(1938):761–87.

Muth, R. F. "The Derived Demand for a Productive Factor and the Industry Supply Curve." *Oxford Econ. Pap.* 16(1964):221–34.

Nakamura, A., and M. Nakamura. "On the Relationships among Several Specification Error Tests Presented by Durbin, Wu, and Hausman." *Econometrica* 49(1981):1583–88.

Samuelson, P. A. *Foundations of Economic Analysis*. Cambridge MA: Harvard University Press, 1947.

Shumway, C. R. "Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops." *Amer. J. Agr. Econ.* 65(1983):748–60.

Theil, H. *Principles of Econometrics*. New York: John Wiley & Sons, 1971.

Thurman, W. N. "The Poultry Market: Demand Stability and Industry Structure." *Am. J. Agr. Econ.* 30(1987):30–37.

Tomek, W. G., and K. L. Robinson. *Agricultural Product Prices*. chap. 6. Ithaca NY: Cornell University Press, 1981.

Waugh, F. V. *Demand and Price Analysis: Some Examples from Agriculture*. Washington DC: U.S. Department of Agriculture Tech. Bull. No. 1316, 1964.

Weaver, R. D. "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region." *Amer. J. Agr. Econ.* 65(1983):45–56.

Wohlgenant, M. K. "Retail to Farm Linkage of a Complete Demand System of Food Commodities." Combined final report on USDA cooperative agreement No. 58-3J23-4-00278, Dec. 1987.