Consumer Price Formation with Demographic Translating

Nicholas PIGGOTT

Contributed paper prepared for presentation at the
International Association of Agricultural Economists Conference,
Gold Coast, Australia, August 12-18, 2006

CONSUMER PRICE FORMATION WITH DEMOGRAPHIC TRANSLATING

Abstract

We investigate how to theoretically and empirically incorporate demographic translating in consumer distance functions. Consumer distance functions yield inverse demand systems that are of interest when attempting to better understand questions of price formation. Translating procedures are important when incorporating pre-committed quantities, pre-allocated factors, or demographic variables (e.g., advertising, health or food safety information) in the inverse demand system. Examples are included for illustrative purposes.

Key words: distance function, price formation, food demand, translating

JEL Classifications: D1 — Household Behavior, Q11 — Demand Analysis, Q13 — Agricultural Markets

Introduction

In this paper we investigate translating and scaling consumer distance functions, which are of interest when incorporating pre-committed, pre-allocated, demographic, or other shift variables into inverse demand systems. Consumer distance functions that yield inverse demand systems are relevant when attempting to better understand questions of price formation at the market level. Translating procedures provide theoretically consistent means to incorporating pre-committed quantities, pre-allocated factors, or demographic variables in inverse demand systems. An empirical example on US meat demand is included to illustrate the economic approach and econometric testing procedures.

Our empirical application focuses on estimating own- and cross-commodity effects of public food safety information on retail price formation for beef, pork, and poultry. Examining the impact of food safety information reported in the media and product recall information on demand for food and agricultural markets has been a topic of considerable interest to economists, e.g. Piggott and Marsh (2004), Marsh, Schroeder, and Mintert (2004), Brown (1969), Johnson (1988), Smith, van Ravenswaay and Thompson (1988), van Ravenswaay and Hoehn (1991), Robenstein and Thurman (1996), Lusk and Schroeder (2000), McKenzie and Thomsen (2001), Thomsen and McKenzie (2001), Dahlgran and Fairchild (1987). Public information pertaining to food safety and health concerns through the media have previously been shown to affect demand, e.g., van Ravenswaay and Hoehn (1991), Smith, van Ravenswaay and Thompson (1988), and Dahlgran and Fairchild (1987). Several of these studies have been concerned with the U.S. meat market and analyzing how public information concerning health information and product recalls impact futures markets and publicly traded companies. For example, Dahlgran and Fairchild (1987) found that adverse publicity about salmonella contamination of chicken depressed demand for chicken, but the effects were small (less than 1%), with consumer's soon forgetting this adverse publicity and reverting back to previous consumption levels.

The paper proceeds in the following manner. First, for illustrative purposes, the distance function is reviewed and then specified with demographic translation. Here, the translated distance function is derived from the primal utility maximization problem. Second, an illustrative empirical example of meat demand is specified and estimated using a generalized inverse almost ideal demand system. Finally, concluding comments are provided.

Distance Function

The consumer's distance function can be defined by

(1) $$D(\mathbf{x},u) = \sup_{\delta}\left\{\delta > 0 \mid (\mathbf{x}/\delta) \in S(u), \forall y \in \mathbf{R}_{+}^{1}\right\}$$

where $\delta \geq 1$. In (1), u is a (1× 1) scalar of utility, $\mathbf{x} = (x_1,\ldots,x_k)'$ is a (n × 1) vector of goods and $S(u)$ is the set of all good vectors $\mathbf{x} \in \mathbf{R}_{+}^{n}$ that can produce the utility level $u \in \mathbf{R}_{+}^{1}$. The underlying behavioral assumption is that the distance function represents a rescaling of all goods consistent with a target utility level. Intuitively, δ is the maximum value by which one could divide **x** and still produce u. The value δ places $\mathbf{x}/\delta$ on the boundary of $S(u)$ and on the ray through **x**. Investigating the distance function is interesting because it is a dual representation of the expenditure and indirect utility functions. Moreover, the input distance function provides direct estimates of inverse demand relationships and price flexibilities that are informative economic measures of price formation.

The standard properties of a distance function are that it is homogenous of degree one, nondecreasing, and concave in input quantities **x**, as well as nonincreasing and quasi-concave in utility u (Shephard 1970; Färe and Primont 1995). From this framework, inverse demand equations may be obtained by applying Gorman's Lemma

(2)
$$\frac{\partial D(\mathbf{x},u)}{\partial \mathbf{x}} = \tilde{\mathbf{p}}(\mathbf{x},u)$$

where $M = \sum_{i=1}^{n} p_i x_i$ and $\tilde{\mathbf{p}}=(\tilde{p}_1,\ldots,\tilde{p}_n)$ is a ($n \times 1$) vector of expenditure normalized prices or $\tilde{p}_i = p_i / M$. The Hessian matrix is given by the second order derivatives of the distance function (Antonelli matrix)

(3)
$$A = \begin{bmatrix} \dfrac{\partial^2 D(\mathbf{x},u)}{\partial \mathbf{x}\partial \mathbf{x}'} & \dfrac{\partial^2 D(\mathbf{x},u)}{\partial \mathbf{x}\partial u} \\ \dfrac{\partial^2 D(\mathbf{x},u)}{\partial u\partial \mathbf{x}'} & \dfrac{\partial^2 D(\mathbf{x},u)}{\partial u\partial u} \end{bmatrix}$$

Demographic Translating

The primal utility maximization problem is

(4)
$$\max_{x} \left\{ u\left(\mathbf{x}\right) \ st \ \mathbf{p}'\mathbf{x} = M \right\}$$

Pollak and Wales define demographic scaling of $\mathbf{x}$ for some pre-committed consumption vector $\mathbf{c}$ as $\mathbf{x}^* = \mathbf{x} - \mathbf{c}$ such that the utility function is rewritten as

(5)
$$u\left(\mathbf{x}^*\right) = u\left(\mathbf{x} - \mathbf{c}\right)$$

Then the translated primal problem can be specified as

(6)
$$\max_{\mathbf{x}^*} \left\{ u\left(\mathbf{x}^*\right) \ st \ \mathbf{p}'\mathbf{x}^* = M^* \right\}$$

where $M^* = M - \mathbf{p}'\mathbf{c}$ is supernumerary expenditure and $\mathbf{p}'\mathbf{c}$ is pre-committed expenditure. Importantly, under demographic translation, dual identities, relationships, and properties follow for (6). It is well known that the dual indirect utility function is then $V = V\left(\mathbf{p},\ M^*\right)$ and the expenditure function is $E = \mathbf{p}'\mathbf{c} + E^*\left(\mathbf{p},\ M^*\right)$ (Pollak and Wales). The distance function also can be defined through the dual relationship with the utility function as

(7) $$D\left(\mathbf{x}^*, u\right) = \arg_d \left\{u(\mathbf{x}^*/d) = 1\right\}$$

Equivalently $D\left(\mathbf{x}-\mathbf{c}, u\right) = D\left(\mathbf{x}^*, u\right)$ with $\mathbf{x}^* = \mathbf{x}-\mathbf{c}$. A *modified* Gorman's Lemma can be derived using the Envelope Theorem and a dual identity defining the distance function through the normalized expenditure function $D\left(\mathbf{x}^*, u\right) = \min_{\widehat{\mathbf{p}}} \left\{\widehat{\mathbf{p}}'\mathbf{x}^*\ st\ E^*\left(\widehat{\mathbf{p}}, u\right) = 1\right\}$ such that

(8) $$\frac{\partial D\left(\mathbf{x}^*,\ u\right)}{\partial \mathbf{x}^*} = \widehat{\mathbf{p}}\left(\mathbf{x}, u\right)$$

where $\widehat{\mathbf{p}} = \left(\widehat{p}_1, ..., \widehat{p}_n\right)$ is a $n \times 1$ vector of prices normalized by supernumerary expenditure, or $\widehat{p}_i = p_i / M^*$.[1] The Antonelli matrix of second derivatives is defined in the standard way.[2]

Example: Cobb-Douglas Utility Function

For illustrative purposes we include an example using the Cobb-Douglas utility function $u = \left(x_1 x_2\right)$ with two goods. The generalized Cobb-Douglas utility function can be defined as $u = \left(x_1 - c_1\right)(x_2 - c_2)$. Following standard dual relationships the following dual functions can be derived: (a) the expenditure function $E\left(\mathbf{p}, u\right) = \mathbf{p}'\mathbf{c} + \left(4up_1 p_2\right)^{1/2}$, (b) the indirect utility function $V\left(\mathbf{p}, M^*\right) = \left(\frac{M^*}{2p_1}\right)\left(\frac{M^*}{2p_2}\right)$, and (c) the distance function $D\left(\mathbf{x}-\mathbf{c}\right) = \left(\frac{\left(x_1 - c_1\right)\left(x_2 - c_2\right)}{u}\right)$. Further, and considering good 1 for convenience, dual relationships yield the Marshallian demand

[1] Note that the expenditure value normalizing prices is the supernumerary expenditure M^*, which leads to a modified Gorman's Lemma.

[2] Demographic scaling, Gorman, and inverse Gorman form approaches also can be integrated into distance function specifications.

function $x_1^m = c_1 + \frac{M^*}{2p_1}$ (using Roy's Identity), Hicksian demand function $x_1^h = \left(u\frac{p_2}{p_1}\right)^{1/2}$ (from Shephard's Lemma), the inverse Hicksian demand function $\tilde{p}_1^h = \frac{1}{2}\left(\frac{(x_2 - c_2)}{(x_1 - c_1)u}\right)^{1/2}$ (from a modified Gorman's Lemma), and the inverse Marshallian demand function $\tilde{p}_1^m = \frac{1}{2}\frac{1}{(x_1 - c_1)}$.

Finally, note that with the Cobb-Douglas specification, it is straight forward to derive the inverse Marshallian demand function directly from the Marshallian demand function.

Empirical Application

For an empirical application we examine the impacts of food safety information on price formation for meat using an inverse demand system approach. Arguably the most popular choice in applied demand analysis has been to employ the Almost Ideal (AI) model (Deaton and Muellbauer) when estimating a complete system of demand equations. The AI model has been used extensively since it is a locally flexible functional form; is appropriate for aggregate and individual consumer analysis; and allows restrictions from theory such as homogeneity, adding-up, and symmetry to be imposed. The generalized almost ideal demand system (GAIDS) incorporating precommitted quantities was first proposed by Bollino (1990). Piggott and Marsh (2004) examined the impact of food safety information on consumer demand for meat using the generalized almost ideal demand system (GAIDS) with pre-committed quantities and demographic translation. They found significant but small effects of public food safety information on meat demand.

Data

Food safety indices are based on newspaper articles from the popular press constructed by Piggott and Marsh (2004). Food safety indices are constructed separately for beef, pork, and poultry. Data for the series were obtained by searching the top fifty English language newspapers in circulation from 1982 to 1999 using the academic version of the Lexis-Nexis search tool. Keywords searched were food safety or contamination or product recall or outbreak or salmonella or listeria or E. coli or trichinae or staphylococcus or foodborne. From this information base, the search was narrowed to collect beef, pork, and poultry information separately by using additional terms a) beef or hamburger, b) pork or ham, and c) chicken, turkey, or poultry, respectively. The newspaper articles were then linearly aggregated to construct quarterly beef, pork, and poultry media indices.

Meat data used in the analysis are quarterly observations over the period 1982(1)-1999(3), providing a total of 71 observations. The basic quantity data are per capita disappearance data from the United States Department of Agriculture (USDA), Economic Research Service (ERS) supply and utilization tables for beef, pork, and poultry (broiler, other-chicken, and turkey) published in the Red Meats Yearbook and Poultry Yearbook with data after 1990 taken from updated revisions of these publications made available online. The beef price is the average retail choice beef price, the pork price is average retail pork price, and the poultry price was calculated by summing quarterly expenditures on chicken, using the average retail price for whole fryers, and quarterly expenditures on turkey, using the average retail price of whole frozen birds, divided by the sum of quarterly per capita disappearance on chicken and turkey. All of the price variables are published in the same USDA, ERS sources with the original sources identified as the ERS (Animal Products branch) for the beef and pork prices (variable names BFVRCCUS and PKVRCCUS, respectively) and the Bureau of Labor Statistics, U.S. Department of Labor for the whole fryers (chicken) and whole frozen bird (turkey) prices. Food safety variables for beef, pork, and poultry used in the analysis are quarterly data over the same period, constructed as discussed in a previous section. Finally, effects of time on meat demand are incorporated in the model through the use of quarterly demand shift (binary) variables for seasonality and a linear trend variable as discussed in the previous section. Table 1 provides descriptive statistics of the non-binary variables.

Empirical Model

Capturing the own- and cross-commodity impacts on price formation from food safety concerns, as well as the pure food safety and indirect effects, motivate the subsequent model specification. Like traditional own/cross quantity and scale effects, food safety effects can be addressed within a theoretically consistent inverse demand system. We attempt to accomplish this by using a standard inverse demand model generalized to include pre-committed quantities and then adopt a demographic translation procedure.

Modifying the pre-committed quantities, the 'c_i's, to depend linearly upon time variables and food safety indices implies the following augmentation of the model outlined in (7) of:

(9) $$\tilde{c}_i = c_{i0} + \tau_i t + \sum_{k=1}^{3} \theta_{ik} qd_k + \sum_{m=0}^{L} \phi_{i,m} bf_{t-m} + \pi_{i,m} pk_{t-m} + \kappa_{i,m} py_{t-m}$$

where t is a linear time trend set equal to 1 for the initial time period; qd_k (k=1, 2, and 3) are seasonal dummies; bf_{t-m} is the beef food safety indices, pk_{t-m} is the pork food safety indices, and py_{t-m} is the poultry food safety indices all lagged m periods. The parameters that must be estimated are the c_{i0}'s, τ_i's, θ_{ik}'s, $\phi_{i,m}$'s, $\pi_{i,m}$'s and $\kappa_{i,m}$'s. There is no way to know *a priori* how long a particular food safety "event" may impact demand. This is an empirical question that can be investigated econometrically by testing alternative lag lengths to determine the appropriate choice of L. This issue is pursued in more detail in the model results section of the paper.

Inverse Almost Ideal Demand System

Following Eales and Unnevehr and Holt and Goodwin the logarithmic distance function may be specified as:

(10) $$\ln D(\mathbf{x},u) = (1-u)\ln a(\mathbf{x}) + u\ln b(\mathbf{x})$$

The inverse almost ideal demand system (IAIDS) is obtained by substituting equations (11) and (12) below into (10) above:

(11) $$\ln a(\mathbf{x}) = \alpha_0 + \sum_{j=1}^{n}\alpha_j \ln x_j + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\tilde{\gamma}_{ij}\ln x_i \ln x_j$$

and

(12) $$\ln b(\mathbf{x}) = \beta_0 \prod\nolimits_{i=1}^{n} x_i^{-\beta_i} + \ln a(\mathbf{x})\,.$$

The share form of the inverse demand function can be written as

(13) $$w_i = \alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln\ \mathrm{x}_\mathrm{j} + \beta_i \ln Q$$

where

(14) $$\ln Q = \alpha_0 + \sum_{j=1}^{n}\alpha_j \ln x_j + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}\ln x_i \ln x_j$$

In (13) and (14), w_i = expenditure share of meat type i ($w_i = \frac{p_i x_i}{M}$) and $\gamma_{ij} = \tfrac{1}{2}\left(\tilde{\gamma}_{ij} + \tilde{\gamma}_{ji}\right)$.

Necessary demand conditions that lead to parameter restrictions of the distance function specification are as follows:

(15a) $$\sum_{i=1}^{n}\alpha_i = 1,\quad \sum_{j=1}^{n}\gamma_{ij} = 0,\quad \sum_{i=1}^{n}\beta_i = 0 \quad \text{adding up}$$

(15 b) $$\sum_{i=1}^{n}\gamma_{ij} = 0 \quad \text{homogeneity}$$

(15c) $$\gamma_{ij} = \gamma_{ji} \text{ symmetry}$$

Price and scale flexibilities provided in Eales and Unnevehr are defined by

(16a) $$\frac{\partial \ln p_i(\mathbf{x})}{\partial \ln x_\ell} = \frac{1}{w_i}\left[\gamma_{i\ell} + \beta_\ell\left(\alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln\ \left(x_j\right)\right)\right] - \delta_{i\ell}$$

and

(16b) $$\frac{\partial \ln p_i\left(\lambda\tilde{\mathbf{x}}\right)}{\partial \ln \lambda} = -1 + \beta_i / w_i$$

where the last equality simplifies due to imposition of general demand restrictions with reference vector $\tilde{\mathbf{x}}$.

Generalized Inverse Almost Ideal Demand System

Using the identity that $\mathbf{x}^* = \mathbf{x} - \mathbf{c}$, the generalized logarithmic distance function may be specified as:

(17) $$\ln D(\mathbf{x}^*, u) = (1-u)\ln a(\mathbf{x}^*) + u \ln b(\mathbf{x}^*)$$

The generalized inverse almost ideal demand system (GIAIDS) then is obtained by substituting

(18) $$\ln a(\mathbf{x}^*) = \alpha_0 + \sum_{j=1}^{n}\alpha_j \ln\left(x_j - c_j\right) + .5\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}\ln\left(x_i - c_i\right)\ln\left(x_j - c_j\right)$$

and

(19) $$\ln b(\mathbf{x}^*) = \beta_0 \prod\nolimits_{i=1}^{n}\left(x_i - c_i\right)^{-\beta_i} + \ln a(\mathbf{x}^*)\ .$$

into equation (17). The supernumerary share form of the inverse demand functions is then

(20a) $$w_i^* = \alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln\ \left(x_j - c_j\right) + \beta_i \ln Q^*$$

where $w_i^* = \dfrac{p_i x_i^*}{M^*}$ and

(20b) $$\ln Q^{*} = \alpha_0 + \sum_{j=1}^{n} \alpha_j \ln\left(x_j - c_j\right) + .5\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln\left(x_i - c_i\right)\ln\left(x_j - c_j\right)$$

Rewriting (20a) yields the standard share equation

(21) $$w_i = \frac{p_i c_i}{M} + \frac{M^{*}}{M}\left[\alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln \ \left(x_j - c_j\right) + \beta_i \ln Q^{*}\right]$$

with $w_i = \dfrac{p_i x_i}{M}$. Price, scale, and food safety flexibilities can be derived from (21).

Several important issues regarding parameter restrictions and differences in methodology need to be discussed. First, the necessary demand conditions that lead to parameter restrictions in (15) remain unchanged for the GIAIDS relative to the IAIDS. As in the GAIDS there are no necessary economic restrictions to be imposed on the pre-committed quantities c_i's. Moreover, if we augment the pre-committed quantities using demographic translation as in (9), there are no restrictions on food safety parameters either. Second, and as an aside, this approach offers an alternative means to incorporate habit formation into the IAIDS. Holt and Goodwin augment parameters of the share equations in an effort to incorporate habit formation. Alternatively, one could follow Pollak and Wales and augment the pre-committed quantities themselves to incorporate habit formation.

Results

In the empirical analysis, meat is treated as a weakly separable group comprised of beef, pork, and poultry (chicken and turkey) in which consumption of an individual meat item depends only on the expenditure of the group, the prices of the goods within the group, and certain introduced demand shifters. Current and lagged (1 period) food safety information are included in analysis. Models were estimated using iterated non-linear estimation techniques. Due to the singular nature of the share system one of the equations must be deleted (poultry) with the remaining equations being estimated (beef and pork). Theoretical restrictions such as homogeneity and symmetry were imposed as a maintained hypothesis.

Results are presented in tables 2-4. Price and scale flexibilities are negative, as expected (table 2). Twelve of eighteen coefficients for current and lagged (1 period) food safety information are statistically significant in the price formation equations (table 3). Food safety flexibilities are provided in table 4. Own food safety flexibilities are negative only for pork (short and long run). Cross food safety effects are negative for four out of the six cases. In all, the average food safety impacts are small relative to quantity and scale effects. Nevertheless, during periods coinciding with prominent food safety events, food safety information effects can be economically significant in price formation. It appears that food safety information impacts on price formation are larger in magnitude and longer lasting than on the consumer demand side (see Piggott and Marsh (2004)).

Conclusion

We investigate how to theoretically and empirically incorporate demographic translating in consumer distance functions. Translating procedures are important when incorporating pre-committed quantities, pre-allocated factors, or demographic variables (e.g., advertising, health or food safety information) into distance functions to better understand price formation.

For illustrative purposes the impacts of food safety information on US meat demand were examined. To do so, we specified and estimated a generalized inverse almost ideal demand system with demographic translation. Preliminary results suggest that current and lagged (1 period) food safety information are statistically significant in price formation. The average food safety impacts are small relative to quantity and scale effects. However, food safety information can be economically significant in price formation during periods coinciding with prominent food safety events. Food safety information impacts on price formation are larger in magnitude and longer lasting than on the consumer demand side. Future work would include testing alternative hypotheses, model specifications, and curvature conditions.

Table 1: Summary Statistics of Quarterly Data, 1982(1)-1999(3)

Variable	Average	Std. Dev.	Minimum	Maximum
Beef Consumption (lbs/capita)	17.799	1.353	15.892	20.818
Pork Consumption (lbs/capita)	12.789	0.685	11.562	14.492
Poultry Consumption (lbs/capita)	19.607	3.040	13.674	24.767
Retail Beef Price ($/lb)	2.638	0.240	2.227	3.004
Retail Pork Price ($/lb)	2.067	0.241	1.678	2.481
Retail Poultry Price ($/lb)	0.901	0.086	0.721	1.051
Meat Expenditure ($/capita)	90.951	8.316	75.660	108.436
Beef Expenditure Share	0.516	0.038	0.435	0.586
Pork Expenditure Share	0.290	0.014	0.265	0.323
Poultry Expenditure Share	0.194	0.030	0.133	0.243
Beef Food Safety	162.817	223.358	2.000	1158.000
Pork Food Safety	41.887	40.925	0.000	241.000
Poultry Food Safety	151.296	126.822	6.000	571.000

Table 2. Price and Scale Flexiblities

Inverse Demand Equation

Quantity	Beef	Pork	Poultry
Beef	**-0.1404**	-0.2146	-2.0337
Pork	-0.1141	**-0.0617**	-1.1243
Poultry	-0.1026	-0.1352	**-0.5333**
Scale	**-0.3571**	**-0.4114**	**-3.6913**

Table 3. Food Safety Coefficients

Current Food Safety Index

Equation	Beef	Pork	Poultry
Beef	**0.0004**	**(-0.0057)***	(-0.0001)
Pork	**(-0.0010)***	**(-0.0037)***	**0.0015***
Poultry	0.0005	**0.0167***	**(-0.0038)***

Lagged Food Safety Index

Equation	Beef	Pork	Poultry
Beef	**(-0.0006)****	**(-0.0134)***	**(0.0017)****
Pork	(-0.0003)	**(-0.0045)***	**(0.0009)***
Poultry	0.0008	**(0.0295)***	**(-0.0060)***

Table 4. Food Safety Flexibilities

Short-Run

Equation	Beef	Pork	Poultry
Beef	**0.0036**	-0.0045	-0.2693
Pork	-0.0070	**-0.0033**	-0.0203
Poultry	0.0014	0.0151	**0.6597**

Long-Run

Equation	Beef	Pork	Poultry
Beef	**0.0023**	-0.0154	-0.8672
Pork	-0.0075	**-0.0041**	-0.0830
Poultry	0.0052	0.0421	**2.1560**

References

Bollino C. A. "GAIDS: A Generalized Version of the Almost Ideal Demand System." Economic Letters 33 (1990):127-129.

Brown, J. D. "Effect of a Health Hazard Scare on Consumer Demand. *American Journal of Agricultural Economics* 51(August 1969):676-678.

Centers for Disease Control and Prevention (CDC). December 1999. http://www.cdc.gov/ncidod/diseases/foodborn/foodborn.htm

Dahlgran, R. A. and D.G. Fairchild. "The Demand Impacts of Chicken Contamination Publicity—A Case Study." Agribusiness 18(1987):459-74.

Deaton A. S., and J. Muellbauer. "An Almost Ideal Demand System." American Economic Review 70 (June 1980):312-326.

Eales, J. S. and L. J. Unnevehr, "The Inverse Almost Ideal Demand System," *European Economic Review* 38 (1994), pp:101-115.

Färe, R. and D. Primont. 1995. *Multi-Output Production and Duality: Theory and Applications*. Kluwer Academic Publishers: New York.

Holt M. T. and B. K. Goodwin. "Generalized Habit Formulation in an Inverse Almost Ideal Demand System: An Application to Meat Expenditures in the U.S." *Empirical Economics* 22(1997):293-320.

Johnson, F. R. "Economic Cost of Misinforming about Risk: The EDB Scare and the Media". *Risk Analysis* 8:261-269.

Lusk J. L. and T.C. Schroeder. "Effects of Meat Recalls on Futures Market Prices." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL, April, 2000.

McKenzie, A. M. and M. R. Thomsen. "The Effect of E. Coli 0157:H7 on Beef Prices." *Journal of Agricultural and Resource Economics* 26(December 2001): 431-444.

Piggott, N E. and T L. Marsh. "Does Food Safety Information Impact U.S. Meat Demand?" American Journal of Agricultural Economics 86(1) (February 2004): 154-174.

Pollak R. A. and T. J. Wales. "Demographic Variables in Demand Analysis." *Econometrica* 49(November 1981):1533-51.

Robenstein R.G. and W. N. Thurman. "Health Risk and the Demand for Red Meat: Evidence from Futures Markets." *Review of Agricultural Economics* 18(October 1996): 629-641.

Shephard, R. W. 1970. The Theory of Cost and Production Functions. Princeton University Press.

Smith, M. E., E.O. van Ravenswaay, and S. R. Thompson. "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii." American Journal of Agricultural Economics 70(August 1988):513-520.

Thomsen M.R. and A. M. McKenzie "Market Incentives for Safe Foods: An Examination of Shareholder Losses From Meat and Poultry Recalls." American Journal of Agricultural Economics 82(3)(August 2001):526-538.