HEALTH (CHOLESTEROL) INFORMATION AND ECONOMIC EFFECTS ON THE U. S. BEEF INDUSTRY

by

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ABSTRACT

The objectives of this thesis were to econometrically estimate and test the impacts of health (cholesterol) information as an exogenous shifter of retail beef demand, and to translate these shifts to structural inverse demands and supplies of the boxed beef, slaughter cattle, and feeder cattle sectors. Given the theoretical model, the empirical work consisted of three stages. First, shifts in retail beef demand were estimated through a retail beef demand index equation by OLS. Second, the system of inverse demand and supply equations for all beef industry sectors was estimated using a full information systems estimator (3SLS) to identify relationships, which were used to calculate reduced form, equilibrium multipliers. The last stage was to calculate long term impacts of health information on the beef industry sectors via a combination of beef demand index elasticities and system equilibrium multipliers.

The majority of the model estimates were statistically significant. The health (cholesterol) information elasticity of the retail beef demand index was estimated to be -0.322. Based on equilibrium multipliers, the 1970-2000 trend in the retail demand index decreased revenues in the boxed beef, fed slaughter cattle, non-fed slaughter cattle, and feeder cattle sectors by 2.6%, 1.1%, 1.3%, and 1.7% annually (as a percent of the sample mean). Cholesterol information, as a driver of the retail demand index, was responsible for 1.6%, 0.7%, 0.8%, and 1.1% decreases in total revenues of the boxed beef, fed slaughter cattle, non-fed slaughter cattle, and feeder cattle sectors annually. Combined, the beef industry sectors experienced a real total revenue reduction of $727 million annually due to the negative long run effects of cholesterol information. Impacts of shifts in retail demand are distributed across all sectors of the beef industry, albeit somewhat unevenly. Implications are that beef industry revenues can be increased by positive information concerning health effects of beef consumption.

CHAPTER 1

INTRODUCTION

Background and Problem

Retail beef demand in the United States declined sharply (about 60 percent) from 1976 through 1997 (Marsh 2003). The decline in real retail beef prices and per capita consumption suggests structural shifts occurred in consumer beef demand. Much of this phenomenon has been attributed to changing demographics, relative meat prices, and tastes and preferences (Genho 1998; Purcell 1989; Schroeder 2000). In addition, changing consumer knowledge and perceptions concerning food safety, inconsistent quality, and health effects have important implications for the U. S. beef industry (Kinnucan, Xiao, Hsia, and Jackson 1997). Information concerning health effects of beef consumption will be the focus of this research.

Health information is a potential shifter of retail beef demand, particularly as it affects consumer attitudes and perceptions about nutrition attributes of beef. Over the past three decades, the health research community has released findings showing correlation between blood serum cholesterol levels and subsequent heart disease problems. A compilation of such studies can be built through Medline, which is an internet resource sponsored by the National Library of Medicine to track all medical journal articles worldwide. Results of these studies are most often first published in medical journals, from which doctors and the popular press obtain the story and share it directly with consumers. Consumers often base their health information knowledge upon information from medical studies, the popular press, medical professionals, nutritionists, and advertising. The role of health information knowledge is the subject of several recent studies by government agencies and others studying the link between health information and its role in American dietary choices (Variyam and Golan; Park and Davis; USDA: Diet and Health Knowledge Survey). Given the current prevalence of cardiovascular disease in the United States, information regarding cholesterol's health effects is likely to have significant impacts on consumer beef demand due to medical assertions of the link between cholesterol and red meat consumption.

Objectives

This thesis has three main objectives. The primal objective is to estimate factors including health information that explain shifts in retail beef demand. Shifts in retail beef demand in this study will be approximated by an estimated retail beef demand index (Genho; Marsh 2003; Schroeder). Retail beef demand and supply are necessarily specified in theoretical models of the red meat sector; however, the beef demand index contains information on both primary retail demand prices and derived retail supply responses. Several research articles have supported the phenomenon of negative structural shifts in retail beef demand (Braschler; Chavas; Eales and Unneveher 1988, 1993; Dahlgran; Moschini and Meilke; Purcell; Schroeder). Little work, however, has focused on estimating the arguments that characterize the behavior of the beef demand index.

The second objective is to estimate the effects of health information on the wholesale (boxed beef) sector, fed and nonfed cattle slaughter sectors, and the feeder cattle sector. This requires specifying a structural model of primary and derived supplies and primary and input (derived) demands. The model specification allows for the effects of shifts in retail beef demand (proxied by the demand index) on prices and quantities in the boxed beef, fed and nonfed cattle, and feeder cattle markets through its recursive relationship with these sectors. A few papers in recent years have investigated health information's role in decreasing beef demand (Kinnucan, Xiao, Hsia, and Jackson; Robenstein and Thurman 1996). However, most have analyzed generalized health impacts on the retail beef market with little delineation of demand and supply responses specific to market-level producers and agricultural marketers.

The third objective is to estimate reduced form (total) elasticities and the comparative statics so as to simulate price, quantity and revenue effects of health information on the beef supply chain levels of the industry. To date, estimation of health information's beef revenue effects has not been separated among the vertical levels of the beef industry. This additional detail will permit evaluation of the distribution of revenue effects from shifting primary demand (including health information's effects) on various industry sectors. Based on the structural model and information from the total elasticities, the simulated impacts also may be useful for analyzing other problems such as disease-related BSE (Bovine Spongiform Encephalopathy) and Foot and Mouth Disease (FMD).

Procedures

The retail beef demand index will be specified as an autonomous equation with explanatory (shifter) variables. The equation will be estimated by OLS to establish the statistical significance of arguments in retail beef demand behavior. If a statistically significant coefficient estimate for health information (formulated as an index) occurs, then impact multipliers of health information can be derived and impacts on producers and marketers of beef can be analyzed.

Inverse demand and supply equations for the boxed beef, fed and nonfed slaughter cattle, and feeder cattle sectors are specified as a systems structural model. The structural model and systems estimation approach captures information about market-level linkages and cross-equation stochastic errors. Due to the use of separate demand and supply equations for each sector of the beef industry, this model will allow identification of the estimated effect of health information on prices and production for the fed, nonfed and feeder cattle markets. Health information elasticities will be estimated, and beef revenue impacts by sector can be estimated through comparative statics.

Analysis of the model results will primarily include calculating total elasticities via the reduced form multipliers (equilibrium multipliers). The total elasticities in turn will be used to calculate price, quantity and revenue impacts of shocks to the health information index. Revenue impacts will be calculated with the estimated long-term industry responses to a permanent one-time shock in cholesterol information. Calculations will utilize a shock of the magnitude by which the health information index has shifted over thirty-one years. The impact of the conditional variance of selected exogenous variables on beef prices and quantities will also be calculated.

CHAPTER 2

LITERATURE REVIEW

Beef Demand

Research over the past two decades has established that retail beef demand has experienced downward structural shifts between 1976 and 1997 (Braschler and Chavas; Dahlgren; Moschini and Meilke; Purcell; Schroeder; Genho). Some research has questioned whether structural change has occurred because of the failure to allow for supply responses (Eales and Unneveher); however, recent papers have considered supply responses and also found significant estimates of structural shift in retail beef demand. The Beef Demand Study Group (BDSG) economists developed an annual retail beef demand index beginning with a base year of 1980 (Genho). The index measures yearly shifts in retail beef demand, and has been utilized in recent work to analyze effects of shifting retail beef demand on the beef industry (Marsh 2003). The index, however, does not identify the factors related to the shifts, nor does it ascribe to quality attributes (i.e., table cuts versus ground beef).

Health Information

Information plays an important role in consumer decision making. Continuing advances in telecommunications have made information less expensive to obtain. Consequently, consumers are becoming increasingly well informed about products. The USDA's Human Nutrition Information Service has monitored the level of health information knowledge consumers possess through their Diet and Health Knowledge Survey as well as consumption patterns through their Continuing Survey of Food Intakes by Individuals (1994-1996). This information has been useful in testing whether health information affects specific nutrient demands, such as fiber, calcium, cholesterol, and total fat (Park, Davis). Several papers have made use of Becker and Lancaster's household production model to investigate health information's role in nutrient consumption decisions (Variyam). Although estimates of the magnitude of health information's role in nutrient choice tend to vary according to the different economic models and estimation methods used, cholesterol information has consistently produced statistically significant estimates of its role in nutrient choice.

Brown and Schrader (1990) developed an index for cholesterol information which they initially used to investigate cholesterol information's link to falling shell egg consumption. The index is cumulative, tracking the number of professional health journal articles supporting or questioning the linkage between blood serum cholesterol levels and arterial disease. Their source for journal articles is Medline, which tracks medical journal articles worldwide. This index was utilized in subsequent papers by Chang and Kinnucan (1991) to question health effects on butter consumption, and Capps and Schmitz (1991), Yen and Chern (1992), Kim (1993), and Chern, Loehman, and Yen (1995) to test cholesterol health effects in the context of food (specifically meat, fish, and fats/oils) consumption trends.

Kinnucan, Xiao, Hsia, and Jackson (1997) used Brown and Schrader's cholesterol information index to set up a model of U.S. meat consumption. Prior to this work, generic advertising and health information had not been jointly specified in a model of meat demand. This meat consumption model included demand data for beef, pork, poultry and fish and results indicated that beef demand did indeed appear to have shifted downward, due in part to cholesterol information. The demand for poultry increased with this health information as poultry was cast in a positive light by cholesterol information. Overall results of the model indicated that meat consumption patterns are influenced by relative prices, total meat expenditures, and health information. Generic advertising expenditures appeared to have little significant effect on consumer demand. The elasticity estimates for cholesterol information in poultry and beef equations exceeded own-price or cross-price elasticities, suggesting that small changes in health information had greater effects on beef and poultry demand quantities than proportional changes in prices.

Kinnucan, Myrland, and Paudel estimated the impacts of health information and advertising on U.S. meat markets. This paper also included a discussion of attribution theory concerning consumer response to positive and negative information. The theory suggests that consumers perceive negative information as more accurate due to its source (studies, journals etc.) than positive information which typically flows from sources with a vested interest in the profitability of the market (Mizerski 1982).

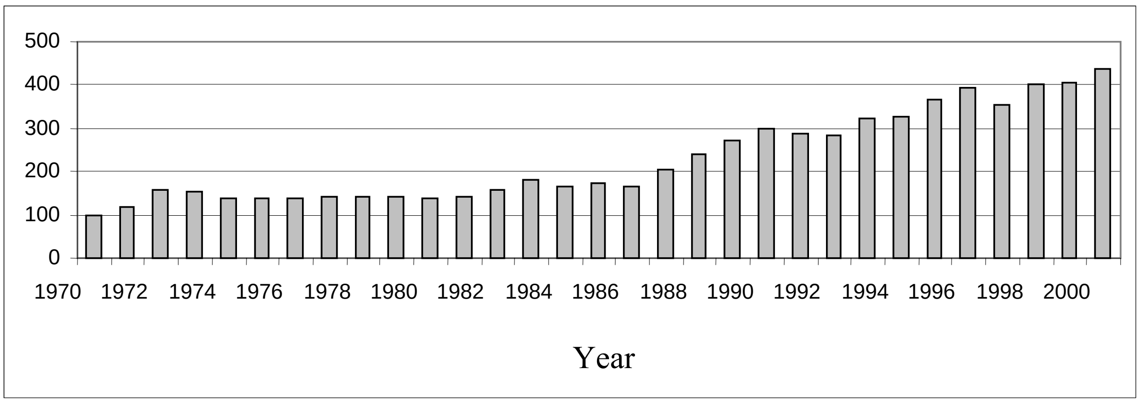
In Kinnucan, et al.'s follow-up study, a variety of meat demand specifications are estimated to compare results with Brown and Schrader's cholesterol information index against results using Kim and Chern's 1999 updated cholesterol index. Specification of the rest of the model is the same as Kinnucan, et al. (1997) with the exclusion of advertising, which as a group was found insignificant in the 1997 model.

Kinnucan, et al. points out that the variability associated with the Kim and Chern index (see figure 1) makes it a more desirable measure of cholesterol information than the Brown and Schrader index. Their estimates show a clear statistical relationship between health information and beef and poultry demand. The health information elasticities are uniformly significant and negative for beef and positive for poultry. Estimated negative marginal health effects were 28 to 33 times larger than marginal positive effects of beef advertising. The estimated health information elasticity is -0.583. The authors suggest that supply must be included in a model to correctly capture health information effects.

One of the main differences between the model developed in this thesis and the Kinnucan, et al. (1997) model is that this thesis separates the marketing sectors. Another difference is using the retail beef demand index in this thesis to directly estimate health information as a structural demand shifter. Finally, supply equations are specified in this thesis for each market level to allow for supply response from health-information induced price changes.

Kim and Chern (1997) compared an updated version of Brown and Schrader's index with two alternative cholesterol information indexes. They updated Brown and Schrader's index by adding the keywords 'diet' and 'fat' to the original search words, 'cholesterol' and 'heart disease,' in a Medline search. The second index utilized a cubic weighting function developed by Chern and Zuo (1995). This index was based on the assumption that from the initial publication date of an article, there are both carry-over and decay effects. Kim and Chern assumed the maximum impact in the first month after publication, and specified the carryover duration as 24 months. The third index was based on the assumption that the impact of a published article will last indefinitely following a geometrically declining lag structure developed by Kim and Chern (1997). They assumed a monthly decay rate of 20% and acknowledged that testing the use of a 10% decay rate yielded a very similar trend in the index. They state that "indexes based on diminishing effect schemes provide better measures of the changing health information on fat and cholesterol than the ad-hoc cumulative index" (Kim, Chern 1999).

Figure 1: Kim and Chern Cholesterol Information Index "FCIM."



Kim and Chern provided evidence that health information concerning cholesterol and fat affects consumption of specific nutrients. They showed that their cholesterol and fat indexes were significant drivers of changing Japanese dietary intakes. Specifically, hog grease and beef tallow were among those product demands most significantly affected by health information in Japan. Given Japan has been one of the U. S. beef industry's largest markets for beef tallow and by products, health information may affect the incomes of American beef producers because of reductions in export demand.

Rubenstein and Thurman (1996) considered evidence of health information effects on commodity futures markets. They built a new cholesterol information data set from articles obtained from the Wall Street Journal. This resulted in 36 articles between

1983 and 1990. Most articles supported links between dietary cholesterol and arterial diseases, and a few articles questioned the links. They found that traders, whose profits depend upon accurately forecasting meat demand, do not revise demand forecasts when significant information is released on the negative health implications of eating red meat. Thus, their model failed to find significant evidence of cholesterol information's impacts on Chicago red meats (live cattle, feeder cattle, pork bellies, and live hogs) futures contracts.

CHAPTER 3

THEORETICAL MODEL

A theoretical model linking domestic retail beef demand and derived boxed beef, slaughter cattle, and feeder cattle demands is presented in this chapter. Primary demand and derived supply are initially specified in the retail sector. However, the current model is intended to identify shifters of retail beef demand. Therefore, the retail inverse demand and supply conditions are incorporated into a beef demand index tracking shifts in retail demand because the BDSG index is calculated to include demand changes and supply responses.

Shifts in primary beef demand in the retail sector are treated as autonomous (i.e., consumption expenditures, substitute prices, health factors, etc.). Subsequently, derived level demands are assumed to respond to shocks in primary demand. Primary supply (quantity supplied) at the feeder cattle level responds to demand changes. Derived supplies at the slaughter and boxed beef levels are expected to change with primary supply. Each sector of the beef industry (boxed beef, slaughter, and feeder) consists of an aggregate of independent firms. These entities are assumed to act within an optimization framework, i.e., firms seek to maximize profits through optimal input purchases and output sales. Firms are assumed to produce a single output with several inputs. Some firms have secondary (joint product) outputs such as beef by-products of meat packing plants and commercial compost products of cattle feedyards.

Firms in these markets are assumed to face competitive conditions. For example, individual cow-calf producers face perfectly elastic demands, i.e., a given output price for their product (calves). Feedlots face perfectly elastic supplies, given input prices for feedlot placements. Constraints may exist in shorter term production processes such as technology and biological growth in the production of feeder calves or in the finishing of feeder cattle. Production constraints are less binding in the long run as genetic changes, breeding herd size, health and nutrition management are more flexible.

The relevant objective function for deriving firms' optimum input and output decisions is a profit function (π), or total revenues less total costs:

(3.1) $\pi = TR - TC$.

Total revenue (TR) in the case of one output is the product of output quantity (Y) and output price (P). Total cost (TC) is the sum of all input costs, based upon input quantities (x) and input prices (w):

(3.2) $\pi = P \bullet Y - \Sigma[w_i (x_i)]$. $i = 1, 2, \ldots, n$

First order conditions in maximizing the profit function of equation (3.2) result in conventional marginal revenue (MR) and marginal cost (MC) functions (Hirschleifer and Hirschleifer). Under price certainty, firms will increase output as long as each additional unit sold increases marginal revenue by more than marginal cost. Inputs are assumed to exhibit diminishing marginal returns. Profit is maximized at the point where marginal revenue equals marginal cost, or

(3.3) $d\pi = MR - MC = 0$.

Given firms are using multiple inputs, a set of first-order conditions for optimization specifies that the first partial derivative of the objective function with respect to each individual input must be equal to zero:

(3.4) $\partial \pi / \partial x_i = P \bullet (\partial Y / \partial x_i) - w_i = 0$ for all $i = 1, \ldots, n$.

The first order conditions result in n equations in the n input decision variables x_1, …., x_n and n + 1 price parameters w_1, …., w_n, P. If the appropriate conditions on the Hessian matrix required for the Implicit Function Theorem to hold are satisfied[1], then at this stationary point the first order equations can be solved for the input factor demand curves,

(3.5) $x_i = x_i^*(w_1,\ldots,w_n, P)$ for $i = 1,\ldots,n$.

The x_i^* signifies the optimal amount of input i for the given set of input and output price parameters.

Supply equations are also derived from the firm's objective (profit maximization) function. Once a firm's optimal input factor demands are defined, they are included in the objective function. Thus, by definition a firm's output is produced using the profit-maximizing level of inputs. The optimal supply function is derived from the objective function and shows how output responds to changes in output price. This can also show how output (y) will respond to changes in input prices.

(3.6) $y^* = f[\underline{x}^*(\underline{w}, p)]$.

The star (*) denotes the optimal (profit maximizing) input and output levels for any given set of parameters.

These first-order conditions are necessary but not sufficient for a maximum. The first partial derivatives of the objective function could equal zero at a minimum point or a "saddle point" as well. Thus, the second-order partial derivatives must meet second-order (non-positive) conditions to guarantee the objective function has been maximized

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[1] A negative definite Hessian matrix (with a positive determinant and negative diagonal terms) shows strict concavity of the profit function, which guarantees that second order conditions are satisfied.

Relationship to the Beef Market

Input demand and output supply relationships for beef at each market level are based on optimization conditions (above) as firms determine production levels based upon input supply conditions and demand for their product. Thus, supply and demand behavior in the vertical market channel is interrelated as cow-calf producers, feedlots, and meat processors engage in market exchange. The system of market equations permits quantifying farm-to-wholesale demand and supply responses to exogenous shifts in primary demand such as may result from health and food safety changes. Estimating the various demand and supply responses allows for estimation of revenue effects in each market sector.

Demand and supply linkages in the livestock and meat marketing channel are related through marketing margins (Marsh and Brester 2004). After allowing for product conversion equivalents and by-product values, the price difference per pound of beef between markets constitutes this margin. In essence, the two market-level prices are separated by the costs of time (storage), space (transportation), and form (product conversion) (Tomek and Robinson).

The marketing margin between two vertical markets for a specific commodity is generally defined within the context of fixed input proportions (Tomek and Robinson). For example, in the meat packing industry a decrease (increase) in boxed beef demand price will initiate a decrease (increase) in slaughter demand price such that firms are able to maintain their margins, either on a percentage or constant absolute basis. This is shown in figure 2, where the lower market (slaughter) demand (D_S) shifts in response to the upper market (boxed beef) demand (D_B) shift. The vertical distance between the two market prices remains the same. As shown, the new margin ($M^1 = P_B^1 - P_S^1$) once both markets are in their new equilibriums is equal to the initial margin ($M^0 = P_B^0 - P_S^0$).

Marketing margins are a function of the demand for and supply of marketing services and reflect the nature of costs in the long run. These costs reflect input usage, technological change, economies of scale, efficiencies, etc. Examples of such drivers of marketing margins in the beef sector are economies of scale in meat packing, feeding efficiency in feedlots, and breeding genetics at the farm level. At the packer level, the real farm-wholesale marketing margin is estimated to have decreased by 22.8 cents per pound over the past 20 years (Brester and Marsh 2001). Figure 3 illustrates such a change in the marketing margin. Let a reduction in production costs due to increased economies of scale shift (increase) the derived supply, which, in turn, will cause an outward shift in derived demand. The new marketing margin M^1 in this case is smaller than the original marketing margin, M^0, due to cost savings.

Figure 2. Constant Margins.

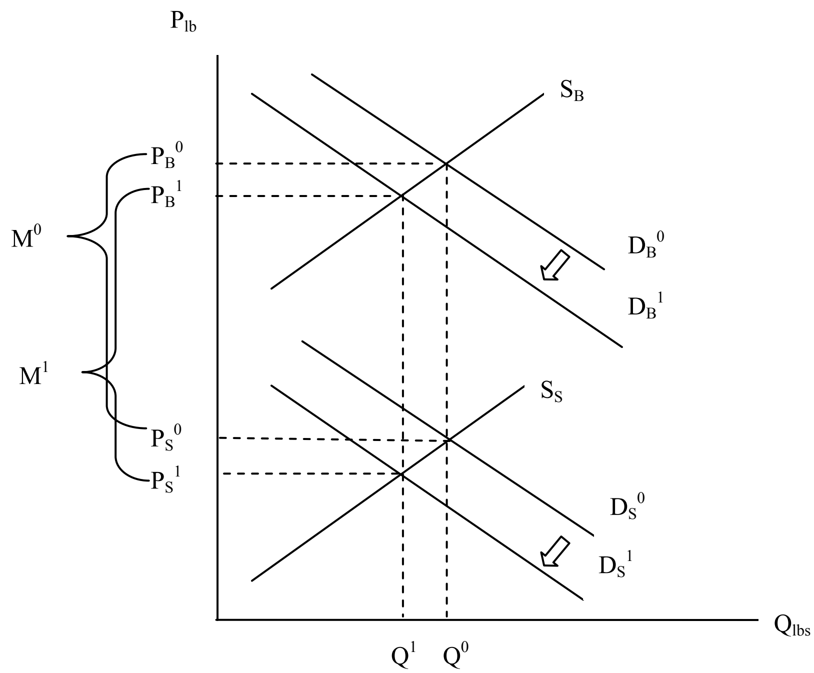
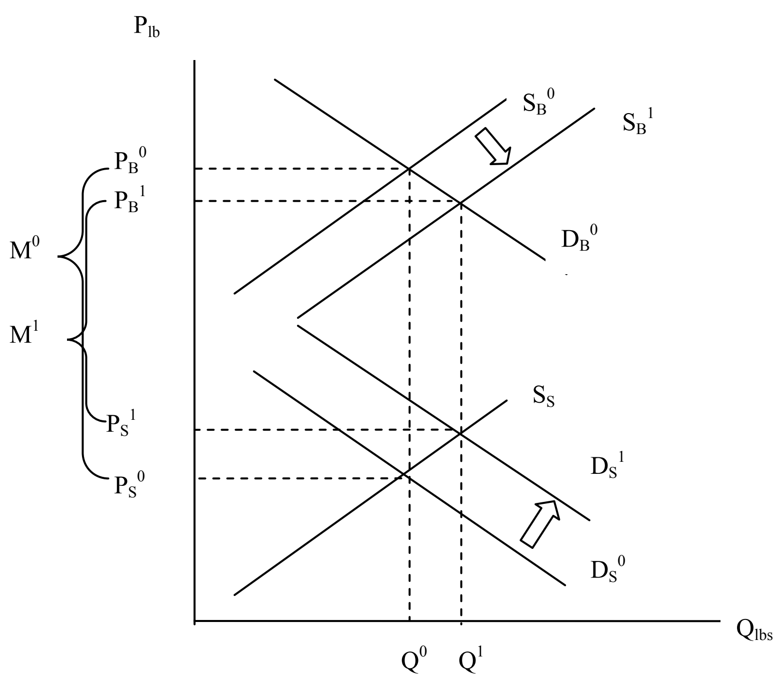


Figure 3. Decreasing Margins.



Model Development: Structural Equations

A systems model is developed to analyze the effects of health information on the beef industry sectors. The model consists of a structural specification of ordinary supply and inverse demand equations at the wholesale (boxed beef), slaughter (fed and nonfed cattle), and feeder cattle levels. Primary (retail) beef demand is assumed to exogenously affect derived wholesale demand. That is, under competitive conditions, exogenous increases (decreases) in primary demand are expected to increase (decrease) derived demands since retail price is the final output price in the livestock - meat marketing channel (Tomek and Robinson; Wohlgenant).

As noted earlier, competition is assumed across the market levels of the beef industry (Brester and Marsh 2002). However, increased concentration in the meat packing industry has fueled speculation about buying and selling market power in the livestock and meat markets. Various studies have shown that increased packer concentration has exerted only minor influence upon meat and livestock prices (Azzam and Anderson; Azzam and Schroeter; Morrison-Paul). Four-firm concentration ratios in the retail grocery, meat packing, and cattle feeding industries are included in the model in order to capture the effects of efficiency gains through economies of scale. However, the effects of firm market power could also be included in the parameter estimates of these variables since these ratios are expected to proxy for both efficiency gains and market power.

Model Specification

The system of inverse demand and supply equations for each market level/sector of the beef industry is specified as follows.

Retail Beef Sector

(3.7) $P_r^d = f(Q_r^d, P_{sub}, E_f, \mu_1)$ (inverse primary demand)

(3.8) $Q_r^s = f(P_r^s, C_L, P_b, \mu_2)$ (derived retail supply)

(3.9) $P_r^d = P_r^s$; $Q_r^d = Q_r^s$ (market clearing)

It is postulated that cholesterol health information is a potential shifter of retail beef demand. As indicated, the BDSG retail beef demand index (Genho; Marsh (2003)) is a proxy measure of retail demand shifts, and potential shifters including cholesterol information are included. The beef demand index in essence replaces the retail beef sector equations (3.7) - (3.9) and its specification is given in equation (3.10) following. The beef demand index accounts for real retail prices and derived retail supplies (formulation of the index is given in chapter 4.) The shifts in primary demand (beef demand index) are expected to impact derived demands facing meat packers, cattle finishers, and cow-calf producers. Resulting changes in prices are expected to affect production of feeder calves, slaughter supplies of fed and nonfed cattle, and supplies of boxed beef.

Retail Beef Demand Index

(3.10) $D_{ri} = f(CH_i, P_{sub}, E_f, S_i, Tr, \mu_1)$ (retail demand shifts)

Boxed Beef Sector

(3.11) $P_b^d = f(Q_b^d, D_{ri}, C_m, B_i, G_4, T_g, \mu_2)$ (inverse demand)

(3.12) $Q_b^s = f(P_b^s, V_{bp}, C_m, P_s, T_m, \mu_3)$ (boxed beef supply)

(3.13) $P_b^d = P_b^s;\quad Q_b^d = Q_b^s$ (market clearing)

Fed Cattle Sector

(3.14) $P_s^d = f(Q_s^d, C_m, P_b, V_{bp}, W_s, B_i, T_m, F_4, \mu_5)$ (inverse demand)

(3.15) $Q_s^s = f(P_s^s, P_c, P_f^d, \mu_6)$ (fed cattle supply)

(3.16) $W_s = f(P_s^d, P_c, C_m, Tr, \mu_7)$ (average live steer and heifer weights)

(3.17) $Q_{sp}^f = W_s * Q_s$ (slaughter production identity)

(3.18) $P_s^d = P_s^s;\quad Q_s^d = Q_s^s$ (market clearing)

Nonfed Cattle Sector

(3.19) $P_{sc}^d = f(Q_{sc}^d, C_m, P_b, V_{bp}, W_c, T_m, F_4, \mu_9)$ (inverse demand)

(3.20) $Q_{sc}^s = f(P_{sc}^s, P_f^d, P_h, \mu_{10})$ (cull cattle supply)

(3.21) $W_c = f(P_{sc}^d, P_c, C_m, Tr, \mu_{11})$ (average live weights of cattle)

(3.22) $Q_{scp} = W_c * Q_{sc}$ (live production identity)

(3.23) $P_{sc}^d = P_{sc}^s;\quad Q_{sc}^d = Q_{sc}^s$ (market clearing)

Feeder Cattle Sector

(3.24) $P_f^d = f(Q_f^d, P_s, P_c, I, Eff_l, \mu_{13})$ (inverse demand)

(3.25) $Q_f^s = f(P_f^s, P_h, \mu_{14})$ (feeder supply)

(3.26) $P_f^d = P_f^s;\quad Q_f^d = Q_f^s$ (market clearing)

Table 1. Variable Definitions.

Q_b^d, Q_b^s	Quantities demanded and supplied of boxed beef, bil. lbs.
P_b^d, P_b^s	Respective demand and supply prices of boxed beef, real $/cwt.
Q_s^d, Q_s^s	Respective demand and supply quantities of fed slaughter steers and heifers, million head.
P_s^d, P_s^s	Demand and supply prices of slaughter steers, real $/cwt.
Q_{sc}^d, Q_{sc}^s	Demand and supply quantities of nonfed slaughter cattle (cows), million head.
P_{sc}^d, P_{sc}^s	Demand and supply prices of slaughter cows, boning utility, Sioux Falls, real $/cwt
Q_f^d, Q_f^s	Demand and supply quantities of feeder calves, (calf crop less heifer replacements), million head.
P_f^d, P_f^s	Demand and supply prices of feeder calves, medium no. 1, 600-650 lbs., Oklahoma City, real $/cwt.
Q_{sp}	Slaughter production, calculated by multiplying average live weights and # head
Q_{scp}	Slaughter cow production, # head * average live weights of non-fed cattle.
D_{ri}	Retail beef demand index, 1970 = 100.
CH_i	Health (cholesterol) information index, 1970 = 100.
P_{sub}	Weighted real retail prices of poultry and pork, cents/lb.
E_f	Real per capita food consumption expenditures, dollars.
C_m	Index of food marketing costs, 1967 = 100.
B_i	U.S. net imports of beef, bil. lbs.
G_4, F_4	Respective grocery and meat packer concentration ratios, percent of total marketings by four largest firms.
T_g, T_m	Respective grocery and meat packing technology measures, index of output per employee hour.
V_{bp}	Beef by-product value, hides and offal, real cents/lb.
W_s ,W_c	Average live weights of steers and heifers, and slaughter cows, lbs.
P_c	Corn price, no. 2 yellow, Central Illinois, real $/bu.
I	Real U.S. prime interest rate.
P_h	Hay price, mixed grass-alfalfa, U.S. average, real $/ton.
Eff_l	Feedlot efficiency, proxied by fed cattle marketings from feedlots $\geq$ 32 thousand head as a percentage of total fed cattle marketings from feedlots of 1,000 head or greater capacity.
C_L	Real food labor cost per unit, $.
Tr	Trend, 1970-2001.
Si	Food safety information variable.

Table 1 gives the variable definitions. The error terms μ_1 through μ_{14} are assumed to be white noise but may be contemporaneously correlated. Equation (3.7) represents real retail beef demand price (P_r^d) as a function of per capita retail beef quantity demanded (Q_r^d), the weighted real price of substitutes (P_{sub}), and real per capita food consumption expenditures (E_f). Equation (3.8) represents per capita retail (derived) supply (Q_r^s) as a function of real retail supply price (P_r^s), real food labor costs (C_L), and real boxed beef price (P_b). Equation (3.9) specifies the market clearing conditions for retail beef market supply and demand.

Equation (3.10) identifies the factors expected to determine the U.S. retail beef demand index (D_{ri}). A major objective is to investigate the effects of cholesterol/health information on the beef sector. This information is given by a health index variable (CH_i), an index built with the variable constructed by Kim and Chern (1997). Beef as a retail food product competes with other meat products, most notably poultry and pork. Thus, weighted real retail poultry and pork prices are included (P_{sub}) to capture expected substitution effects on beef demand. Poultry and pork prices are weighted in one variable due to their multi-collinearity effects. Beef demand is also a function of consumer food budget constraints, thus, the variable real per capita food expenditures (E_f) is included. Recent literature has indicated that food safety information should also be a statistically significant shifter of retail meat demand, although perhaps in considerably less magnitude than health information (Piggott and Marsh 2002). Hence an index based on food safety information (S_i) should be included in beef demand as well. A trend variable is included to capture missing information such as advertising.

Equation (3.11) represents the inverse demand for boxed beef (P_b^d) facing beef packers/processors. It is a function of quantity demanded of boxed beef (Q_b^d) -- an increase (decrease) in quantity demanded of boxed beef supply results in a decrease (increase) in the demand price for boxed beef. The retail beef demand index (D_{ri}) is included to proxy the effects of primary demand shifts on the derived demand for wholesale/boxed beef. A positive correlation is expected. Costs of time, space, and form affect retailer demands for wholesale beef inputs. Thus, marketing cost (C_m) is included as a shifter of derived demand (Tomek and Robinson). As marketing costs increase, derived wholesale demand is expected to decrease. To capture meat trade effects on wholesale prices, net beef imports (imports less exports) are also specified (B_i) in the equation. An autonomous increase in net beef imports is expected to have negative effects on boxed beef price. Measures of market concentration in the retail grocery industry (G_4) and technological change in the retail grocery sector (T_g) are included to capture potential effects of increased economies of scale and efficiency.

Boxed beef supply (Q_b^s) of meat packers/processors, given by equation (3.12), depends primarily upon output prices and input costs. The price of boxed beef (P_b^s) is expected to positively affect boxed beef supply. Similarly, by-product (hide, offal, tallow) values (V_{bp}) of a beef animal are an important part of meat packer revenues and often pay packer slaughter costs and profits. An increase (decrease) in joint product values should result in an increase (decrease) in wholesale beef supply. Slaughter steer price (P_s) is a major input cost in meat packing and processing and is expected to inversely affect wholesale beef production. Marketing costs (C_m) affects meat packer profitability. An increase (decrease) in marketing costs is expected to decrease (increase) wholesale beef production. Technology (T_m) and efficiency are important factors in affecting supplies in the meat packing/ processing sectors. Efficiency increases are expected to increase supplies of boxed beef due to reduced unit costs. Equation (4) specifies the market clearing conditions for the boxed beef market supply and demand.

Equation (3.14) represents the derived inverse demand for U.S. slaughter steers and heifers (fed cattle). Demand price (P_s^d) is a function of quantity demanded of slaughter steers and heifers (Q_s^d) by beef packers, average slaughter steer and heifer weights (W_s), boxed beef price (P_b), the value of slaughter by-products (V_{bp}), food marketing costs (C_m), net beef imports (B_i), technology (T_m), and efficiency in the form of economies of scale (F_4). The derived demand for slaughter cattle depends upon the primary demand for meat (Wohlgenant). Thus, specification of boxed beef price in this equation captures the effects of shifts in retail beef demand, through the price transmission from boxed beef, on beef packer buying decisions. Marketing costs capture the effects of input costs on packer fed cattle demand. Net imports of beef are included to capture the trade effects of wholesale meat on livestock prices. Increased net imports of beef are expected to reduce the demand price for domestic slaughter steers and heifers. Average live weight of steers and heifers is included to capture the relationship between current status of feedlot marketings and demand price of fed cattle. The red meat production technology variable is included to capture effects of any efficiency or productivity gains. A measure of packer concentration is included to capture unit cost advantages through economies of scale. However, market power effects could be manifest in this variable as well.

Equation (3.15) represents the supply of slaughter steers and heifers (Q_s^s). Slaughter cattle supply is a function of output (slaughter) price (P_s^s), and input costs consisting of feed corn price (P_c) and feeder cattle price (P_f).

Equation (3.16) represents the average live weights (W_s) of slaughter steers and heifers. Average slaughter weight for steers and heifers (commercial) has increased almost 20 percent from 1970 to 2001, i.e., from 1,042 to 1,245 pounds. Weights are expected to be determined by steer slaughter price (P_s^d), corn price (P_c), marketing costs (C_m), and a trend (Tr) in genetic productivity. Increases in slaughter and corn prices are expected to increase and decrease live weights, respectively. Average slaughter weights and cattle slaughter numbers determine live weight slaughter production as defined in equation (3.17). Their separate specification in the model captures supply effects which differ according to length of run. For example, commodity analysts usually focus on slaughter weights for evaluating changes in short run beef production because they are more easily adjusted to price incentives. Changes in cattle slaughter can also occur in the short term. However, cattle slaughter usually adjusts over a longer time period as it reflects calf crop numbers and feedlot placements. Equation (3.18) specifies the market clearing conditions for the slaughter steer and heifer market.

Equation (3.19) represents the derived inverse demand for nonfed cattle, primarily consisting of slaughter cows. (Few grass-fed steers and heifers are slaughtered in the U.S.) Demand price (P_{sc}^d) for slaughter cows is a function of the quantity of slaughter cows demanded (Q_{sc}^d) by beef packers, slaughter cow weights (W_c), boxed beef price (P_b), the value of slaughter by-products (V_{bp}), food marketing costs (C_m), and net beef imports (B_i).

Equation (3.20) represents the supply of non-fed slaughter cattle (Q_{sc}^s). Supply is hypothesized to be a function of output (slaughter cow) price (P_{sc}^s) and the input price of hay (P_h). Feeder cattle price (P_f) is also included to account for opportunity costs of selling breeding herd offspring. A priori, increases (decreases) in feeder calf prices are expected to decrease (increase) slaughter cow supplies as producers adjust culling of older breeding cows to expected profitability of selling calves.

Equation (3.21) represents the average live weight of slaughter cows. Average cow weight (W_c) is determined by slaughter cow price (P_{sc}^d), feed corn price (P_c), marketing costs (C_m), and trend (Tr) as a proxy for genetic improvements. Live weight slaughter cow production is given as an identity in equation (3.22). Equation (3.23) specifies the market clearing identities for the slaughter cattle market supply and demand.

Equation (3.24) represents the derived inverse demand for feeder cattle (P_f^d), primarily by feedlots. Feeder cattle price depends on feeder quantities (placements) demanded (Q_f^d), output price of slaughter cattle (P_s), and input costs consisting of feed corn (P_c) and interest rate (I). Marsh (2001) has shown that opportunity costs of feedlot financing and retained ownership (represented by the interest rate) affect feeder cattle prices. Feedlot technology in animal finishing affects finishing cost of production and, therefore, is also specified (Eff_l). The technology variable is proxied by fed cattle marketings from large feedlots (32 thousand head or more) as a percent of all feedlot marketings of 1,000 head or more. This percentage has grown from ten percent in 1970 to 46.7 percent in 2001. Growth in large feedlots is attributed to scale economies, management organization, and mechanized systems (Duncan, et al; Kuchler and McClelland.)

Equation (3.25) represents the supply of feeder calves (Q_f^s) by cow-calf producers. Feeder calf supply is proxied by the U.S. calf crop which represents the pool of animals available for feedlot placement. Feeder cattle supply is a function of the price of feeder cattle (P_f^s) and cost of hay roughage (P_h). Feeder price, a direct input price for feedlots purchasing calves, is the output price to cow-calf producers. The price of hay influences the cost of breeding herd maintenance, but may also reflect forage/grazing conditions. Equation (3.26) specifies the market clearing conditions for feeder calf market supply and demand.

Dynamics

The theoretical model should contain dynamics since current supply conditions are likely affected by previous years' economic expectations and market rigidities or constraints. For example, the dynamics of calf crop inventory decisions normally include information from previous years, expectations about future output and input prices, and biological production constraints in producing calves. Expectations concerning prices may be modeled as distributed lags (Rucker, Burt, and LaFrance; Marsh 2003). Consequently, the dynamics of boxed beef supply, slaughter steer and heifer supply, slaughter cow supply, and feeder calf supplies are modeled as auto-regressive distributed lags or rational distributed lags (ARDL) (Greene.)

According to the maintained hypothesis of an ARDL, supply (Q_t) may depend, in part, upon expectations of future prices:

(3.27) $Q_t = \psi[E(P)]$

where E(P) is expected price. Price expectations are generally formed by information on current and past prices. (Futures contract prices could serve as expected output prices but in the case of calf inventory production, the production cycle from heifer retention and breeding to weanling calf sales can involve two to three years. In addition, an ARDL model allows estimation of length-of-run multipliers.) The following equation allows for different weights (w) on each lagged price. Conceptually, there are an infinite number of lag terms with an inferred polynomial shape:

(3.28) $E(P) = w_0P_t + w_1P_{t-1} + w_2P_{t-2} + \ldots..$

Thus, supply levels are specified as:

(3.29) $Q_t = \beta(w_0P_t + w_1P_{t-1} + w_2P_{t-2} + \ldots..)$,

where β is a long run parameter of the effect of market price on supply.

This infinite weight distribution can be represented as a rational lag (Greene):

(3.30) $Q_t = [\beta(L)/\lambda(L)]P_t$,

where the term in brackets represents a rational generating function that comprises the infinite lag structure in equation 3.29. The rational lag numerator is:

(3.31) $\beta(L) = \beta_0 + \beta_1L + \beta_2L^2 + \ldots\ldots + \beta_qL^q$,

where $L^qP_t = P_{t-q}$ is a lag operator that gives a polynomial numerator of order q. The rational lag denominator is:

(3.32) $\lambda(L) = 1 - \lambda_1L - \lambda_2L^2 - \ldots\ldots. - \lambda_rL^r$,

where $L^rQ_t = Q_{t-r}$ is a lag operator that gives a polynomial denominator of order r.

Multiplying both sides of equation (3.30) by λ(L) gives the equation in the form:

(3.33) $\lambda(L)Q_t = \beta(L) P_t$.

Letting the polynomial lag operators be r = 2 and q = 1 and adding a white noise error term gives:

(3.34) $(1 - \lambda_1L - \lambda_2L^2)Q_t = (\beta_0 + \beta_1L)P_t + \mu_t$

Written out in its distributed lag form:

(3.35) $Q_t - \lambda_1Q_{t-1} - \lambda_2Q_{t-2} = \beta_0P_t + \beta_1P_{t-1} + \mu_t$

Equation 3.35 can be reorganized into the estimable equation:

(3.36) $Q_t = \beta_0 P_t + \beta_1 P_{t-1} + \lambda_1 Q_{t-1} + \lambda_2 Q_{t-2} + \mu_t$

This second order difference equation is also referred to as the ARDL(2,1) model.

The ARDL structural model allows derivation of economic multipliers over varying time lengths. The short run or impact multiplier from a one unit shock in price in equation (3.36) is:

(3.37) $\partial Q_t / \partial P_{t-j} = \beta_0 \qquad j = 0$

The long-run or equilibrium multiplier for a one unit shock in price would be

(3.38) $\partial Q_t / \partial P_{t-j} = (\beta_0 + \beta_1)/(1 - \lambda_1 - \lambda_2) \qquad \text{for } j \to \infty$.

The equilibrium multiplier derives from the long run equation:

(3.39) $Q_t^*(1 - \lambda_1 - \lambda_2) = (\beta_0 + \beta_1)P_t^*$

or

(3.40) $Q_t^* = [(\beta_0 + \beta_1)/(1 - \lambda_1 - \lambda_2)]P_t^*$,

where * indicates equilibrium levels of Q and P, usually their sample means in empirical work. The rational lag model also allows for estimation of intermediate run impacts (interim multipliers), however, the partial derivative solutions for second- order difference equations are more complex.

Comparative Statics

The system of market demands and supplies and length-of-run multipliers permits the derivation of comparative statics. Comparative statics measure direct and indirect effects on equilibrium prices and quantities from perturbations in exogenous information. Thus, an exogenous shock to primary retail beef demand due to health, food expenditures, or substitute price factors is expected to affect beef prices and quantities in the vertical marketing system. For example, consider a change in cholesterol information and its effect on feeder cattle price. Cholesterol information initially affects retail beef demand (measured by the demand index) with a subsequent shift in inverse boxed beef demand. In turn, the derived demand linkages result in changes in slaughter cattle price and feeder cattle price. Equation (3.41) defines the ceteris paribus effect of a shock in cholesterol information on feeder price. The function is a multiplicative relationship of price transmissions involving derivatives through the chain rule:

3.41) $\partial P_f / \partial CH_i = \partial D_{ri} / \partial CH_i \bullet \partial P_b / \partial D_{ri} \bullet \partial P_s / \partial P_b \bullet \partial P_f / \partial P_s$

where $\partial P_f / \partial CH_i$ is the effect on feeder calf price of a shift in the cholesterol index. The term $\partial D_{ri} / \partial CH_i$ is the change in the beef demand index due to a change in the cholesterol index, the term $\partial P_b / \partial D_{ri}$ is the response of boxed beef price to a shift in the beef demand index, the term $\partial P_s / \partial P_b$ is the response of slaughter steer price to boxed price, and the term $\partial P_f / \partial P_s$ is the effect of a shift in fed steer price on feeder calf price. To properly evaluate the comparative statics in a system of equations, reduced form multipliers or total elasticities are required. These permit direct evaluation of exogenous shocks on prices and quantities after allowing for endogenous feedback in demand and supply.

The above model linking exogenous shocks of primary demand throughout the vertical marketing chain is potentially useful for evaluating other issues beyond the scope of this study. They include food safety problems such as Foot and Mouth Disease (FMD) or Bovine Spongiform Encephalopathy (BSE, or mad cow disease).

Reduced Form

The comparative statics discussed above can be evaluated through reduced multipliers or total elasticities. The structural system specified above involves joint dependency of prices and quantities. Thus, evaluation of exogenous shocks necessitates solving the structural model in its reduced form. If the structural model involves dynamics, solving the reduced form first involves deriving the long-run structural equations and then solving the system for the endogenous variables. If the dynamics involve rational lag functions with lagged dependent variables, the long run equations are obtained by dividing the intercept and slope coefficients of the exogenous variables by 1.0 minus the coefficients of the lagged dependent variables.

For example, consider the feeder cattle sector. The feeder inverse demand is static and the supply equation is a rational lag structure. The nondiagonal covariance matrix of errors calls for the SUR estimator to obtain the short run coefficients. The model structure is:

(3.42)
$$\begin{aligned} P^f{}_t &= \beta_{12} Q^f{}_t + \varphi_{11} P^s{}_t + \varphi_{12} P^c{}_t + \varphi_{13} I_t + \varphi_{14} Eff^l{}_t + \mu_{1t} \\ Q^f{}_t &= \varphi_{25} P^f{}_{t-1} + \varphi_{26} P^h{}_{t-1} + \varphi_{27} Q^f{}_{t-1} + \varphi_{28} Q^f{}_{t-2} + \mu_{2t} \end{aligned}$$

For inverse demand let Q^f_t be the only endogenous regressor. Because of the feeder supply function dynamics, the model is rearranged to calculate long run coefficients:

(3.43) $$(1 - \varphi_{27} - \varphi_{28}) Q^f{}_t = \varphi_{25} P^f{}_{t-1} + \varphi_{26} P^h{}_{t-1} + \mu_{2t}$$

Let $(1 - \varphi_{27} - \varphi_{28}) = \gamma$ be the long run coefficient (or denominator of the rational generating function) for feeder quantity. Dividing the dynamic equation by γ and solving the equations for the endogenous variables yields:

$$(3.44)\quad \begin{aligned} P^f - \beta_{12}Q^f &= \varphi_{11}P^s + \varphi_{12}P^c + \varphi_{13}I + \varphi_{14}Eff^l + \mu_1 \\ Q^f - (\varphi_{25}/\gamma)P^f &= (\varphi_{26}/\gamma)P^h + \mu_2 \end{aligned}$$

The subscripts are omitted since the equations are in long run form. Putting these functions in matrix form gives the solved reduced form for prices and quantities of the feeder demand and supply equations. This process was conducted for all equations in the system. The resulting matrices of left-hand-side endogenous variable coefficients and right-hand-side exogenous variable coefficients (noted as β and Γ, respectively) are used to calculate equilibrium multipliers. Assume a simultaneous equations system (G equations) in the general form of:

(3.45) $\beta Y_t + \Gamma Z_t = \mu_t, \qquad t = 1,2, \ldots, T$

where Y_t is the Gx1 vector of jointly endogenous variables; Z_t is the Kx1 vector of exogenous variables; μ_t is the Gx1 vector of white noise disturbances but may be contemporaneously correlated; β is the GxG matrix of coefficients of the endogenous variables; and Γ is the GxK matrix of coefficients of the exogenous variables. Assuming β is full rank, solving for the Y_t vector yields:

(3.46) $Y_t = (-\beta^{-1}\Gamma)Z_t + \beta^{-1}\mu_t$

or

(3.47) $Y_t = \Pi Z_t + V_t$,

The Π matrix is $-\beta^{-1}\Gamma$, or the GxK matrix of reduced form coefficients or equilibrium (long run) multipliers. The reduced form errors, V_t, are a nonlinear function of the structural disturbances, or $\beta^{-1}\mu_t$. The Π matrix of equilibrium multipliers allows estimation of the effects of shifts in primary demand (beef demand index) on all market level prices and quantities in the system. Although this study focuses on shocks to primary demand due to health (cholesterol) information, exogenous shocks from any market level may be evaluated in the system.

CHAPTER 4

DATA AND ESTIMATION ISSUES

Data

Annual time-series data for the years 1970 through 2001 are used to estimate the beef demand index equation and the structural demand and supply model. All variables in dollar value terms are deflated by the Consumer Price Index (CPI, 1982-84 = 100).

All quantity and price data in the model are obtained from the USDA Red Meats Yearbook and the USDA Livestock Dairy, Poultry and Situation Outlooks reports. The marketing cost data were obtained from the USDA Agricultural Outlook series and Elitzak (1999). Hay prices were compiled from USDA Agricultural Statistics. The CPI, interest rate, and consumer expenditures (food expenditures) data were collected from the Economic Report of the President.

Feedlot efficiency is calculated as the ratio of fed cattle marketed from feedlots of greater than 32,000 head capacity to the total number of fed cattle marketed (feedlots of greater than 1,000 head capacity). It is assumed that the ratio reflects feedlot economies of scale and efficiency, which would affect the demand price of feeder calves (Marsh 2001). The feedlot data is obtained from the Livestock Marketing Information Center (LMIC). Technology in the red meats product industries and technology in the retail grocery industry reflect unit cost changes due to resource configuration, management and organization, new products, etc. (Brester and Marsh 2001; Marsh and Brester 2004). The technology changes are measured as productivity changes, i.e., indexes of output per employee hour in each of the industries. These data were obtained from the Monthly Labor Review published by the Bureau of Labor Statistics (BLS).

The four firm concentration ratio for the beef packing industry is obtained from Nelson 1985 and USDA – GIPSA. Data for the four firm concentration ratio in the retail grocery sector are obtained from Kaufman, Newton, and Handy (1993) and Cotterill (1999).

The retail beef demand index was originally calculated by the 1998 Beef Demand Study Group (BDSG) using 1980 = 100.0 as the base year. It was later updated by Marsh (2003) using an earlier base year of 1970 = 100.0. Construction of the index is based on percentage differences between observed retail beef prices and estimated retail beef prices with demand held constant. Allowing for quantity or supply changes, the differences in these two prices conceptually represent shifts in retail beef demand. Applying the differences to the base year generates the annual BDSG beef demand index. A sample calculation (Genho, pp. 4-6) is computed with a base year of 1970 = 100. USDA per capita beef consumption (Q) for 1970 and 1971 is 84.6 lbs. and 83.9 lbs., respectively. Deflated choice retail beef prices (P) for these years are \$2.57/lb. and \$2.62/lb., respectively. The calculations are:

(4.0.a)
$$\frac{Q_t - Q_{t-1}}{Q_{t-1}} = \%\Delta Q$$
, or
$$\frac{83.9 - 84.6}{84.6} = -0.008.$$

(4.0.b)
$$\frac{\%\Delta Q}{E_d} = \%\Delta P\Big/_{D=D^0}, or$$
$$\frac{-0.008}{-0.67} = 0.012.$$

(4.0.c)
$$P_{t-1} + \%\Delta P/_{D=D^0} * P_{t-1} = P/_{D=D^0}, or$$
$$2.57 + 0.012(2.57) = \$2.60 / lb.$$

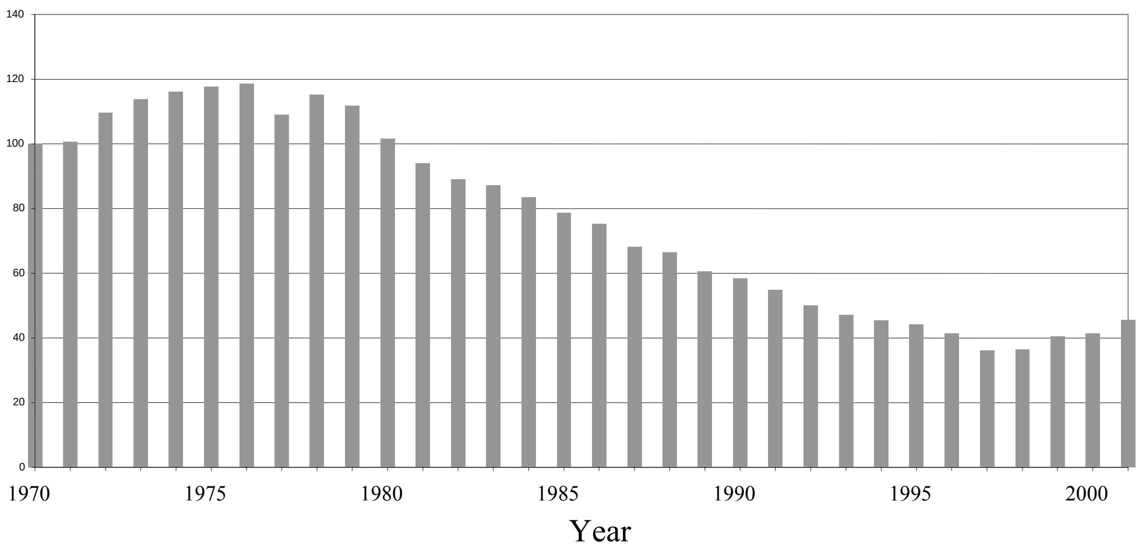
(4.0.d)
$$\frac{P_t - P/_{D=D^0}}{P/_{D=D^0}} = D', or$$
$$\frac{\$2.62 - \$2.60}{\$2.60} = 0.008.$$

where t = 1971, $t\text{-}1$ = 1970

Equation (4.0.a) gives the percentage change in per capita beef consumption from 1970 to 1971 (%ΔQ,) or -0.008 (-0.80%.) Equation (4.0.b) gives the percentage change in retail price from 1970 to 1971 by holding demand constant ($\%\Delta P/_{D=D^0}$), or 0.012 (1.2%.) The demand elasticity (E_d) is -0.67 for this calculation, and supply is changed by -0.80% as estimated in equation (4.0.a). Equation (4.0.c) produces the 1971 constant demand price ($2.60/lb.) Equation (4.0.d) represents the difference (D′) between the actual 1971 retail price ($2.62/lb.) and its constant demand price ($2.60/lb.) expressed as a percent of the latter, or 0.008 (0.80%.) The 0.80% basically represents the 1970 to 1971 shift in retail beef demand. Adding D′ to the 1970 = 100 base year forms the 1971 beef demand index value of 100.8. The procedure is repeated for every year from 1970 through 2001. The demand index is based on a constant elasticity of demand of -0.67 as reported by Genho, therefore, alternative retail demand elasticities could give different results.[2]

Figure 4 shows the results of the BDSG index calculations using 1970 as the base year. Note that the retail beef demand index increases until 1976 and then shifts downward from 1976 through 1997. Since 1998 the index has been increasing.

Figure 4. Retail Beef Demand Index (1970 = 100), 1970-2001.



The cholesterol health variable employed as an explanatory variable in the beef demand index equation was constructed and updated by Chern. Specifically, the variable is based on geometrically declining health information incorporated in lag structure effects. As previously given, figure 1 shows the pattern of this variable.

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[2] Marsh (2003) addresses this possibility by re-calculating the index using alternate demand elasticity estimates as calculated by Huang (-0.62), Wohlgenant (-0.78), and Moschini and Meilke (-1.05). He notes that use of the different constant demand elasticity estimates did not change the pattern of each beef demand index series from the original. He also points out that, assuming the retail demand elasticity of -0.67 used in the index formula could be a conservative estimate, the coefficients measuring the effects of retail demand on livestock prices and quantities are lower bound estimates.

Food safety information and its impacts on meat markets has received attention in previous studies (Flake and Patterson; Lusk and Schroeder; Piggott and Marsh; McKenzie and Thomsen). Studies using a single food safety index find that the effects of food safety information on meat demand are modest and largely dominated by a separate variable of health information effects. The Piggott and Marsh results indicate food safety indices (both indices concerning beef safety and indices concerning pork and poultry safety) provide statistically significant estimates of effects on meat demand. The estimated demand response to food safety information is, however, small in comparison to estimates of health information effects on beef demand. McKenzie and Thomsen find boneless beef prices in the retail market to be responsive to food safety information in the short run, however, prices in the boxed beef and live cattle markets show little or no response to meat recall events.

Food safety information, specified in the theoretical model (S_i), is an index variable built on information available in the popular press. Piggott and Marsh (2002) constructed three separate food safety information indexes for beef, pork, and poultry. These indexes were used to estimate consumer response to bundles of contaminant information reported individually for each kind of meat, allowing estimation of own-commodity and cross-commodity responses. The indexes are constructed using the academic version of Lexis-Nexis.com, specifically searching for articles[3] in the top fifty English language newspapers from 1982 through 1999. Attempts to update the Piggott and Marsh (2002) beef food safety information index for the current study were

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[3] Search keywords as follows: "food safety or contamination or product recall or outbreak or salmonella or listeria or E.coli or trichinae or staphylococcus or foodborne" for each kind of meat.

unsuccessful, as the Lexis-Nexis database only extends back to 1980 for the majority of its newspaper sources. Attempts to update the index by forecasting values for years 1970 to 1981 contained in the sample of the current study yielded unsatisfactory results.

Statistical Problems and Testing

The time-series data and systems structural beef model conceptually may entail numerous statistical problems. Econometrically, these problems include non-stationarity and cointegration, joint dependency or simultaneity, autoregressive(AR) or nonspherical error terms, and contemporaneously correlated errors. Overall, these issues can create statistical problems ranging from spurious regression to poor sample distribution properties of the estimated parameters (Greene; Pindyck and Rubinfeld).

Stationarity and Cointegration

Time series data such as prices and quantities usually demonstrate trends that are prone to exhibiting non-stationary behavior. That is, the underlying stochastic process of a variable may follow a random walk (mean and variance are not time invariant) or random walk with a drift (Pindyck and Rubinfeld). The presence of unit roots (non-stationarity) in model variables negates the ability to estimate equations with fixed coefficients in data-level form. Since a random walk variable exhibits an infinite variance, Ordinary Least Squares (OLS) regression results produce inconsistent parameter estimates. Without consistency in the estimator, normal significance tests are unreliable and may identify economic relationships where none actually exist, i.e., spurious regression.

The Augmented Dickey-Fuller (ADF) unit root test is a common procedure used for testing data stationarity (Pindyck and Rubinfeld). This test is a version of Dickey and Fuller's conventional unit root test that allows for serial correlation in the error terms. Given a random variable Y_t in its autoregressive form:

(4.1) $Y_t = \alpha + \beta t + \rho Y_{t-1} + \varepsilon_t$,

where ε_t is an error term with zero mean and constant variance but may exhibit serial correlation, and t is a trend variable.

The ADF test includes lagged changes in Y_t on the right hand side and begins with the unrestricted OLS regression:

(4.2) $$Y_t - Y_{t-1} = \alpha + \beta t + (\rho-1)Y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta Y_{t-j},$$

followed by estimating the restricted regression:

(4.3) $$Y_t - Y_{t-1} = \alpha + \sum_{j=1}^{p} \lambda_j \Delta Y_{t-j}$$

The standard F ratio is calculated to test the null hypothesis of nonstationarity ($\beta = 0$ and $\rho = 1$) using F distributions calculated by Dickey and Fuller.[4]

If the ADF test fails to reject the null hypothesis of a unit root for one or more variables in the equation, each random walk series may be differenced before attempting estimation. This preserves the statistical properties of OLS, but information about long-run relationships between the variables may be lost. Thus, the next question becomes whether the unit root variables are cointegrated. If the unit root variables are

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[4] F is calculated as: $F = (N-K)(ESS_R - ESS_{UR})/q(ESS_{UR})$ where ESS_R and ESS_{UR} are the sums of squared residuals in the restricted and unrestricted regressions, respectively. N is the number of observations, K is the number of estimated parameters in the unrestricted regression, and q is the number of parameter restrictions.

cointegrated, OLS can be used in the equation in data-level form without biasing the statistical inference of the estimated parameters (Gujarati; Johnston and DiNardo). Alternatively, error correction models are recommended for cointegrated equations (Greene).

Equation cointegration can be tested by running the ADF test on the estimated OLS residuals involving variables that are integrated of order d, $d \neq 0$. If the null hypothesis of unit root residuals is rejected, then cointegration is present among the data series and there is no need to difference the random walk variables for OLS estimation. In the case of cointegration, equations may be estimated in either data level form or as an error-correction model (Gujarati).

Johnston and DiNardo indicate that the presence of simultaneity in model equations generally negates consideration of cointegration problems in the estimation procedure. Therefore, conventional simultaneous equations estimation techniques can be utilized in the presence of unit root variables.

Simultaneity

Price-quantity relationships in the livestock-meat markets may be subject to joint dependency. If simultaneity or joint dependency is present in a model with a diagonal covariance matrix of errors, OLS will be an inconsistent estimator of the population parameters and an Instrumental Variable (IV) estimator such as Two-Stage Least Squares (2SLS) or Limited Information Maximum Likelihood should be used (Pindyck and Rubinfeld).

Simultaneous equations bias can be tested for using the Wu-Hausman specification test. Consider the feeder supply equation:

(4.4) $Q^f{}_t = \alpha_2 P^f{}_t + \alpha_3 P^h{}_t + \varepsilon_t$,

with previously defined variables. The null hypothesis of no simultaneity indicates that the covariance of P^f_t and ε_t is zero (i.e., they are statistically uncorrelated). If the null hypothesis is rejected, they are statistically correlated and instrumental variables estimation is necessary. Assuming the model consists only of feeder supply and demand equations, the reduced form for feeder price, P^f_t, is given as:

(4.5) $P^f{}_t = \varphi_2 P^h{}_t + \varphi_3 P^c{}_t + \varphi_4 I + \varphi_5 Eff + v_t$,

with variables defined prior. The OLS estimation yields:

(4.6) $P^f{}_t = \hat{\varphi}_2 P^h{}_t + \hat{\varphi}_3 P^c{}_t + \hat{\varphi}_4 I + \hat{\varphi}_5 Eff + \hat{v}_t$

so that

(4.7) $P^f{}_t = \hat{P}^f{}_t + \hat{v}_t$.

This equation is substituted into the supply equation (4.4) so that the residuals from equation (4.7) are included in the estimation:

(4.8) $Q^f{}_t = \alpha_2 \hat{P}^f{}_t + \alpha_3 \hat{P}^h{}_t + \delta \hat{v}_t + \varepsilon_t$

Rewriting equation (4.8) and substituting $\hat{P}^f{}_t = P^f{}_t - \hat{v}_t$ will allow a simpler way of testing for simultaneity:

(4.9) $Q^f{}_t = \alpha_2 P^f{}_t + \alpha_3 P^h{}_t + (\delta - \alpha_2)\hat{v}_t + \varepsilon_t$.

Under the null hypothesis (no simultaneous equations bias,) the coefficient expression on $\hat{v}_t$ will not be significantly different from zero. The Wu-Hausman test applied to the current beef model indicated right-hand side market prices and quantities for all four sectors, average live weights of steers and heifers, and the average live weights of cows were all endogenous. Thus, OLS is not an appropriate estimator for the system.

<u>Error Term Properties</u>

Error terms in a normal linear regression are assumed to be spherical (Pindyck and Rubinfeld). That is, errors are drawn from a normally distributed population with zero expected value, independently distributed (not autocorrelated) and with a constant variance. However, serially correlated errors often exist in estimation of time series regressions either due to correlated measurement errors or due to high correlation in the cumulative effects of omitted variables (Pindyck and Rubinfeld).

Serial correlation affects the efficiency of the OLS estimators, thus must be corrected (when present) to avoid incorrect statistical inferences due to biased standard errors of the coefficient estimates. Common tests for serial correlation are the Durbin-Watson test (static models) and Durbin-h test (models with lagged dependent variables.)

Systems of time series regressions such as used in this thesis are also subject to contemporaneously correlated errors (nondiagonal covariance error matrix). Closely related stochastic processes in supply and demand market interactions in the system (i.e., weather effects) may very well exhibit a non-diagonal covariance matrix of errors. Misspecifications common to the demand and supply equations could also result in cross-correlated errors (Johnson and DiNardo).

Econometric Method

With the presence of simultaneity and contemporaneously correlated errors in the model, estimation of the model with OLS would produce biased, inconsistent and inefficient results. The Two Stage Least Squares (2SLS) estimator corrects for simultaneity and restores consistency in the parameter estimates. However, 2SLS is a limited information estimator which fails to correct for a non-diagonal error matrix. Therefore, a full-information (systems) estimator is required to restore both asymptotic efficiency and consistency in this model. In the case of the beef model, Iterative Three Stage Least Squares (I3SLS) in the Eviews 3.1 software regression program was utilized.

CHAPTER 5

EMPIRICAL RESULTS

The OLS regression results for the retail beef demand index are given in table 2. The I3SLS regression results for the boxed beef, fed cattle, non-fed cattle, and feeder cattle system of supply and inverse demand equations are given in tables 3-6. The demand index equation was not integrated within the system since a correlation matrix indicated its error term was not highly correlated with the system demand and supply errors.

The adjusted R^2 terms and standard errors of regressions are reported in the tables for each equation below. However, such statistics require cautious interpretation in the case of equations estimated as a system. Due to the transformation of the system equations' product moment matrices by the estimated inverse of the error covariance matrix of 2SLS residuals, these statistics are primarily descriptive (Greene).

The residuals of all equations were tested for first-order autoregressive behavior [AR(1)] using the Durbin-Watson test in static relations and Durbin-h test in equations with lagged dependent variables. AR(1) disturbances could not be rejected in every system equation with the exception of non-fed slaughter cattle demand. The (ρ) coefficient estimates were significant at the $\alpha = 0.05$ level except in the boxed beef demand, boxed beef supply, and average live weights (slaughter cattle) equations. The boxed beef supply's AR(1) term was significant at the $\alpha = 0.10$ level.

Equation error terms across markets were hypothesized to be contemporaneously correlated due to close interactions across the beef industry sectors. The residual correlation matrix revealed a non-diagonal covariance matrix of errors, with a range of pairwise correlations occurring. For example, the error correlation coefficient between feeder calf supply and slaughter cattle price was 0.31, and correlation between errors in feeder calf price and slaughter cattle supply equations was 0.70. Within market levels, error correlation between the boxed beef supply and price equations was 0.20, between slaughter cattle supply and price the error correlation was 0.21, non-fed slaughter cattle supply and price indicated an error correlation of 0.33, and the error correlation between feeder supply and price was 0.14.

The autoregressive errors (within) equations and their contemporaneous correlation (across equations) are jointly estimated with the structural parameters by nonlinear Iterative Generalized Least Squares (IGLS) within the Iterative Three Stage Least Squares (E-views 3.1) estimator.

Regression Results - Retail Beef Demand

Table 2. OLS Regression Results of Retail Beef Demand Index, 1970-2000.

Retail Beef Demand Index:

$$D_{ri} = \underset{(0.525)}{15.112} - \underset{(-3.252)}{0.11}\, CH_i + \underset{(4.325)}{0.46}\, P_{sub} + \underset{(1.065)}{0.022}\, E_f - \underset{(-0.861)}{0.532}\, Tr$$

Dep. variable = 77.8407
Adjusted R-squared = 0.958 S.E. = 5.965

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = .05$ significance level for 27 degrees of freedom is 2.052, and at $\alpha = 0.10$ the t-value is 1.703. Dep. variable is the mean of the dependent variable. S.E. is the standard error of the regression.

The cholesterol information index (CH_i) and weighted retail price of substitutes (P_{sub}) are separately significant at the $\alpha = .05$ level. Coefficient signs for all variables in the estimation are consistent with theory: an increase in cholesterol information is associated with a decrease in the retail beef demand index (-0.11), while increases in prices of competitive meats and per capita food expenditures (E_f) result in upward shifts in the beef demand index (0.46 and 0.022, respectively). However, the food expenditures coefficient was not statistically significant. One alternative to the food group expenditures variable is to specify total consumption expenditures (real per capita). This variable was also insignificant in a separate regression. Its coefficient was -0.152, with a t-value of -0.193.

Regression Results - Boxed Beef Price and Supply

In the boxed beef price and supply equations, most estimated coefficients are significant at the $\alpha = .05$ level. The retail beef demand index (coefficient of 1.672) is statistically significant in the boxed beef price (P_b) equation. Coefficient signs of other statistically significant variables are consistent with theory. Grocery technology (T_g) is statistically insignificant and carries a counter-intuitive sign on its coefficient. The grocery industry concentration (G_4) coefficient (2.092) is statistically significant, indicating a positive effect of concentration on the boxed beef price. Competitive theory would indicate that gains in economies of scale and efficiency should be at least partially transferred as a higher willingness to pay for inputs (boxed beef). This result may be reflected in the grocery concentration coefficient.

Table 3. I3SLS Regression Results of Inverse Boxed Beef Demand and Supply, 1970-2001.

Boxed Beef Price:

$$P_b = 185.088 - 8.338\, Q_b + 1.672\, D_{ri} - 0.372\, C_m - 7.164\, B_i$$
(6.638) (-16.208) (21.684) (-10.674) (-3.898)

$$+ 2.092\, G_4 - 0.188\, T_g$$
(6.964) (-0.897)

Dep. variable = 102.28 Adjusted R-squared = 0.987
S.E. = 3.418

Boxed Beef Supply:

$$Q_b = 23.701 + 0.355\, P_b + 0.306\, V_{bp} + 0.007\, C_m - 0.733\, P_s$$
(7.065) (6.356) (5.835) (1.203) (-8.603)

$$+ 0.027\, T_m$$
(0.823)

Dep. variable = 23.61 Adjusted R-squared = 0.841
S.E. = 0.614

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = .05$ significance level is 1.96 and at $\alpha = .10$ the critical value is 1.645[5]. Dep. variable is the mean of the dependent variable. S.E. is the standard error of the regression.

The negative signs of coefficients for boxed beef quantity (-8.338), marketing costs (-0.372), and net beef imports (-7.164) are also theoretically consistent. Increased supplies reduce price which is consistent with downward-sloping demand functions. Increases in net beef imports (hence supplies) reduce boxed beef price. Marketing costs are an input in the retail grocery business and negatively affect boxed beef prices.

[5] Degrees of freedom for a system are determined as: MT-K, where M = number of equations, T = the sample size, and K = the number of parameters specified. Degrees of freedom in this system estimation are 247: 10 equations * 30 years - 50 unduplicated parameters -1 observation for the AR term and -2 observations for the t-2 lag in the feeder supply equation (following).

The supply of boxed beef is a statistically significant function of boxed beef price (0.355), beef by-product value (0.306), and slaughter cattle price (-0.733). Boxed beef price and beef by-product value, as joint output values for packers, positively affect boxed beef supply. Slaughter cattle price is the major input cost to meat packers. Increases in cattle price theoretically reduce wholesale beef output. Marketing costs (C_m) and technology (T_m) in the meat packing industry were not statistically significant.

Regression Results - Slaughter Cattle Price and Supply

Inverse slaughter cattle demand and supply are estimated with the relevant quantities measured in number of head (table 4). Average live weight of slaughter cattle is also included in the specification as changes in demand price at feedlots are associated with changes in slaughter weights.

Most coefficient estimates in the inverse slaughter cattle demand and supply equations are statistically significant at the $\alpha = 0.05$ level, with the exception of meat packer technology (T_m), meat packer concentration (F_4), and feed corn price (P_c). The coefficient for net beef imports (B_i) is significant at the $\alpha = 0.10$ level for the price equation.

Quantity of cattle slaughtered (Q_s) is a significant variable in affecting slaughter cattle price (-3.646), which is consistent with theory. Net beef imports (-2.868) displays an effect similar to that of slaughter quantity. Increased quantities of beef will reduce price regardless of the source. Marketing costs (-0.167) and average live weights of slaughter cattle (-0.041) are also negatively related to slaughter cattle price. The expected positive impact of by-product value (0.901) is statistically significant while meat packing technology (0.198) and four-firm concentration ratio (0.146) are not statistically significant.

Boxed beef price was specified as an output price in inverse slaughter demand. However, confounding issues between endogenous boxed price and other regressors in this structural equation necessitated using the retail beef demand index (0.689) as an instrument for boxed beef price. Results indicate boxed beef price is significant and positive, which is consistent with theory. This effect indicates meat packers are guided by retail-related information (through boxed beef price) in terms of price bids on slaughter cattle. Thus, consumer sovereignty plays an important role in the meat packing industry. That is, the significant effects of the boxed beef price reveal that the effects of autonomous shifts in health (cholesterol) and other retail demand information on the meat packing sector are registered through market prices.

Slaughter cattle supply responds positively to slaughter price (0.08) and to slaughter supply from the previous time period, t-1 (0.829). Feed corn price (-0.12) and feeder calf price (-0.095) as input costs both negatively affect slaughter supply, however, corn price is not statistically significant. The negative results are consistent with the theoretical expectations of the impacts of variable input prices in meat packer profit functions.

Estimation results for the average live weights of slaughter cattle (W_c) are consistent with supply theory as well. Slaughter cattle prices (0.844) have significant positive impacts on average live weights and marketing costs (-0.897) reduce average live weights as feedlots try to market output more quickly in response to rising costs.

The trend variable (Tr), a proxy for information regarding un-measured variables such as genetics, is significant and positive (7.576).

Table 4. I3SLS Regression Results of Inverse Slaughter Cattle Demand and Supply, 1970-2001.

Slaughter Cattle Price:

$$P_s = \underset{(4.867)}{174.194} - \underset{(-9.114)}{3.646}\, Q_s - \underset{(-2.285)}{0.167}\, C_m + \underset{(5.356)}{0.689}\, D_{ri} + \underset{(7.868)}{0.901}\, V_{bp} - \underset{(-2.011)}{0.041} W_s$$

$$- \underset{(-1.822)}{2.868}\, B_i + \underset{(1.406)}{0.198}\, T_m + \underset{(1.219)}{0.146}\, F_4$$

Dep. Variable = 62.86 Adjusted R-squared = 0.981
S.E. = 2.435

Slaughter Cattle Supply:

$$Q_s = \underset{(3.084)}{6.662} + \underset{(2.197)}{0.08}\, P_s - \underset{(-0.479)}{0.12}\, P_c - \underset{(-4.08)}{0.095}\, P_f + \underset{(10.969)}{0.829}\, Q_{s-1}$$

Dep. Variable = 28.29 Adjusted R-squared = 0.536
S.E. = 0.889

Average Live Weights ~ Steers and Heifers:

$$W_s = \underset{(24.382)}{1231.121} + \underset{(2.769)}{0.844}\, P_s + \underset{(0.605)}{1.61}\, P_c - \underset{(-7.662)}{0.897}\, C_m + \underset{(11.629)}{7.576}\, Trend$$

Dep. Variable = 1123.494 Adjusted R-squared = 0.960
S.E. = 14.211

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = .05$ significance level is 1.96 and at $\alpha = .10$ the critical value is 1.645. Lags are denoted by -1 in the variable subscripts. Dep. variable is the mean of the dependent variable. Trend is the trend variable and S.E. is the standard error of the regression

Regression Results - Non-fed Cattle Price and Supply (Table 5)

The coefficient estimates in the inverse non-fed cattle slaughter equation are statistically significant at the $\alpha = .05$ level, and are consistent with the theory of inverse derived demands. Coefficients in the non-fed cattle supply equation are significant and also carry the theoretically correct signs. Boxed beef price (instrumented by the retail demand index) is significant and positively impacts the non-fed cattle price (0.699). Thus, prices paid by meat packers for slaughter cows (P_{sc}) are sensitive to consumer demand. By-product values (V_{bp}) were statistically significant (positive effect) while beef packer concentration (F_4) effects on price were significant and positive. The positive concentration coefficient (as with the fed slaughter price equation) may be reflecting efficiency effects. Average live weights of non-fed slaughter cattle (Wc) are not statistically significant in the non-fed cattle price equation.

Non-fed slaughter cattle supply (Q_{sc}) is positively correlated with both slaughter price (0.149) and hay price (0.032) which is consistent with theoretical reasoning. Increased hay price increases herd maintenance costs, but hay prices may indirectly reflect supply conditions of hay and forage due to weather. A rise in feeder calf price (P_f) reduces non-fed slaughter cattle quantity (-0.140) as producers retain healthier slaughter cows for further feeder calf production.

Two of the regressors in the equation for average live weights of cull cattle (Wc) were statistically significant: non-fed slaughter cattle price (1.754) and the trend variable (6.523). Improved cattle genetics may again play a role in the effects picked up by the trend variable. If so, it may indicate that improved genetics allow breeding cattle to lead a productive life without losing as much body condition by the time they are culled.

Table 5. I3SLS Regression Results of Inverse Nonfed Cattle Demand and Supply, 1970-2001.

Nonfed Slaughter Cattle Price:

$$P_{sc} = \underset{(-2.17)}{-67.709} - \underset{(-6.493)}{3.864}\, Q_{sc} + \underset{(1.35)}{0.103}\, C_m + \underset{(5.762)}{0.699}\, D_{ri} + \underset{(4.442)}{0.868}\, V_{bp} + \underset{(0.956)}{0.028}\, W_c$$

$$- \underset{(-.0951)}{0.159}\, T_m + \underset{(3.724)}{0.483}\, F_4$$

Dep, Variable = 40.468 Adjusted R-squared = 0.964
S.E. = 2.709

Nonfed Cattle Supply:

$$Q_{sc} = \underset{(4.956)}{5.066} + \underset{(3.552)}{0.149}\, P_{sc} - \underset{(-4.766)}{0.140}\, P_f + \underset{(3.47)}{0.032}\, P_h$$

Dep. Variable = 5.63 Adjusted R-squared = 0.964
S.E. = 0.651

Average Live Weights ~ Cull Cattle:

$$W_c = \underset{(4.23)}{705.405} + \underset{(5.781)}{1.754}\, P_{sc} - \underset{(-0.845)}{3.281}\, P_c - \underset{(-0.496)}{0.203}\, C_m + \underset{(3.658)}{6.523}\, Trend$$

Dep. Variable = 812.613 Adjusted R-squared = 0.922
S.E. = 12.266

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = .05$ significance level is 1.96 and at $\alpha = .10$ the critical value is 1.645. Dep. variable is the mean of the dependent variable. Trend is the trend variable and S.E. is the standard error of the regression.

Regression Results - Feeder Calf Price and Supply (Table 6)

All coefficients in the feeder calf inverse demand and supply equations are statistically significant at the $\alpha = .05$ level. Signs of all coefficient estimates are consistent with a priori reasoning of derived demand and primary supply behavior. The effects of the retail beef demand index (or primary demand shifts) in the feeder calf price equation are transmitted through slaughter steer price, a critical output price that affects feedlot profitability and derived demand for feeder placements.

Table 6. I3SLS Regression Results of Inverse Feeder Demand and Supply.

Feeder Price:

$$P_f = -5.658 - 1.03\, Q_f + 1.866\, P_s - 5.481\, P_c - 0.53\, I + 69.074\, Eff_l$$
$$(-0.354) \quad (-2.761) \quad (20.66) \quad (-4.695) \quad (-3.174) \quad (5.47)$$

Dep. Variable = 68.838   Adjusted R-squared = 0.928
S.E. = 4.893

Feeder Supply:

$$Q_f = 0.424 + 0.043\, P_{f\text{-}1} - 0.037\, P_{h\text{-}1} + 1.367\, Q_{f\text{-}1} - 0.390\, Q_{f\text{-}2}$$
$$(0.296) \quad (7.641) \quad (-2.97) \quad (16.096) \quad (-4.007)$$

Dep. Variable = 42.500   Adjusted R-squared = 0.967
S.E. = 0.685.

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = .05$ significance level is 1.96 and at $\alpha = .10$ the critical value is 1.645. Lags are denoted by -1 and -2 in the variable subscripts. Dep. variable is the mean of the dependent variable and S.E. is the standard error of the regression.

For inverse demand, quantities have the expected negative impact on feeder price (-1.03). Slaughter cattle price and feed corn price both are highly significant, with slaughter price positively impacting feeder price (1.866) and corn price negatively affecting feeder price (-5.481). These variables are critical factors in determining the profitability of feedlots, thus, impacting prices paid for feeder replacements. Interest, or finance cost, is statistically significant and negative (-0.53) in feeder price determination. Feedlot efficiency (Eff_l) is a significant factor in determining the feeder price (69.074).

Table 7. Structural System Elasticities.

Right- side Variables	Left- side Dependent Variables									
	P_b	Q_b	P_s	Q_s	P_{sc}	Q_{sc}	P_f	Q_f	W_s	W_c
P_b		1.538								
Q_b	-1.925									
P_s		-1.952		0.92			1.704		0.047	
Q_s			-1.641							
P_{sc}						1.293				0.087
Q_{sc}					-0.664					
P_f				-1.353		-2.199		1.296		
Q_f							-0.636			
W_s			-0.733							
W_c					0.562					
D_{ri}	1.256		0.842		1.327					
C_m	-1.147	0.093	-0.838		0.802				-0.252	-0.079
B_i	-0.093		-0.063							
G_4	1.295									
T_g	-0.187									
V_{bp}		0.21	0.232		0.347					
T_m		0.106	0.291		-0.363					
F_4			0.128		0.656					
P_c				0.009			-0.219		0.003	-0.01
P_h						0.7		0.891		
I							-0.063			
Eff_I							0.276			

The Auto-Regressive Distributed Lag (ARDL) structure of the feeder supply equation resulted in statistically significant coefficients on the first- and second-order lags of feeder quantity (1.367 and -0.390, respectively). Estimations also resulted in significant first order lags on feeder price (0.043) and hay price (-0.037). The negative effect of the lagged hay price in feeder calf supply supports the estimated positive effects of current hay price in non-fed slaughter cow supply. As feed costs rise, producers have incentive to reduce herd size by culling less productive breeding cattle, which reduces the following year's feeder calf supply.

The structural system elasticities are reported in table 7. The elasticity coefficients are long-run estimates.

Reduced Form Multipliers

To evaluate the comparative static effects of exogenous shifts on beef prices and quantities, the I3SLS system is solved for the reduced form. Thus, consistent with thesis objectives, the effects of health information on the various beef sectors can be analyzed. To obtain the reduced form, the structural system is converted to its long run equations and parameters due to rational lag (ARDL) dynamics of the supply functions. The resulting reduced form coefficients are the equilibrium or long-run multipliers. These total elasticities reflect direct and indirect effects in the model (table 8). The dependent variable (D_{ri}) of the OLS beef demand index equation recursively enters boxed beef inverse demand with no feedback because its estimated residuals exhibited low correlation with the derived slaughter demand residuals. Thus, as noted earlier, the beef demand index equation was estimated separately, and its elasticities are reported in table 8.

The health information elasticity for retail beef demand (-0.322) is somewhat smaller than the -0.583 reported by Kinnucan, et al. (1997). This more inelastic response was expected because the current model allows for supply response feedback. Note that the cross-price elasticity of the retail beef demand index with respect to substitute prices (0.767) is significantly larger (less inelastic) than estimated health information elasticity (table 9). A one percent decrease in weighted substitute prices reduces retail demand by more than twice that caused by a one percent increase in health information.

Food expenditure elasticity of the retail demand index is estimated as 0.464, but was not statistically significant.

Table 8. Reduced Form Multipliers and Total Elasticities.

-	Exogenous Variables											
Endog. Var.	Dri	Cm	Bi	G4	Tg	Vbp	Tm	F4	Pc	Ph	I	Effl
P_B	1.159	-0.248	-4.878	0.528	-0.048	0.319	0.155	0.156	-1.409	1.216	-0.393	51.215
	0.871	*-0.766*	*-0.065*	*0.327*	*-0.047*	*0.051*	*0.140*	*0.084*	*-0.038*	*0.826*	*-0.031*	*0.144*
Q_B	0.062	-0.015	-0.274	0.188	-0.017	-0.038	-0.019	-0.019	0.169	-0.146	0.047	-6.142
	0.200	*-0.198*	*-0.016*	*0.503*	*-0.073*	*-0.026*	*-0.073*	*-0.044*	*0.020*	*-0.429*	*0.016*	*-0.075*
P_S	0.477	-0.091	-1.988			0.624	0.137	0.101	-0.912	0.788	-0.255	33.177
	0.584	*-0.454*	*0.043*			*0.161*	*0.201*	*0.089*	*-0.040*	*0.871*	*-0.033*	*0.152*
Q_S	0.005	-0.010	-0.223			0.070	0.015	0.011	0.241	-0.224	0.072	-9.411
	0.145	*-0.113*	*-0.011*			*0.040*	*0.050*	*0.022*	*0.023*	*-0.549*	*0.023*	*-0.096*
P_{SC}	0.497	0.019	-0.640			0.627	-0.034	0.270	-1.285	0.423	-0.174	22.609
	0.943	*0.147*	*-0.022*			*0.251*	*-0.077*	*0.367*	*-0.087*	*0.725*	*-0.039*	*0.161*
Q_{SC}	0.059	0.021	0.158			0.070	-0.033	0.059	0.293	-0.104	0.043	-5.567
	0.647	*0.937*	*0.031*			*0.164*	*-0.435*	*0.464*	*0.116*	*-1.040*	*0.050*	*-0.231*
P_F	0.306	-0.058	-1.276			0.401	0.088	0.065	-2.471	1.070	-0.346	45.051
	0.342	*-0.266*	*-0.025*			*0.094*	*0.118*	*0.052*	*-0.099*	*1.079*	*-0.041*	*0.188*
Q_F	0.568	-0.108	-2.364			0.742	0.163	0.120	-4.578	0.389	-0.641	83.470
	1.026	*-0.798*	*-0.076*			*0.283*	*0.354*	*0.156*	*-0.294*	*0.636*	*-0.123*	*0.565*
W_S	0.403	-0.973	-1.677			0.527	0.116	0.085	0.840	0.665	-0.215	27.988
	0.028	*-0.273*	*-0.002*			*0.008*	*0.010*	*0.004*	*0.002*	*0.041*	*-0.002*	*0.007*
W_C	0.871	-0.170	-1.123			1.100	-0.059	0.473	-5.534	0.741	-0.304	39.650
	0.082	*-0.066*	*-0.002*			*0.022*	*-0.007*	*0.032*	*-0.019*	*0.063*	*-0.003*	*0.014*

***** Elasticities are reported in italics below the equilibrium multipliers. They are calculated at the mean values of the variables.

In principle, the interactions of inverse demands and supplies in the structural system and the direct and indirect effects inherent in the reduced form preclude a priori reasoning regarding the relative size (and sometimes coefficient signs) of the total elasticities. However, because the reduced form allows for multiple interactions in the vertical marketing channel, it would be expected that most of the equilibrium multipliers expressed in percentage terms would be inelastic. Such is the case for the current beef model.

The equilibrium multipliers of the beef demand index, specific to the various beef sectors, are the key links to evaluating the effects of health information. Boxed beef, slaughter cattle, non-fed slaughter cattle, and feeder calf prices have estimated beef demand index elasticities of 0.871, 0.584, 0.943, and 0.342, respectively. Marsh (2003) estimated elasticities with respect to the retail demand index as 0.487 for slaughter price and 0.122 for feeder price.

Table 9. Elasticities of the Retail Beef Demand Index.

Retail Beef Demand Index:

$$D_{ri} = 19.372 - 0.11\, CH_i + 0.46\, P_{sub} + 0.022\, E_f \qquad \text{(OLS)}$$

(-0.322) *(0.767)* *(0.464)* (elasticities at mean values)

*Italics denote health information, cross-price, and food expenditure elasticity estimates for the retail beef demand index.

Based on the comparative statics, the health information elasticity of the retail demand index (-0.322 in table 9) translates into health information elasticities with respect to the other beef sectors. For the supply sectors, the health information elasticities are -0.33 for feeder calves, -0.208 in the non-fed slaughter cattle market, -0.047 in the slaughter cattle market, and -0.064 at the derived boxed beef supply market level (table 10). Health information elasticity of (derived) demand is relatively less inelastic at -0.28, -0.188, -0.304 and -0.11 for boxed beef, slaughter cattle, non-fed slaughter cattle, and feeder calves, respectively.

Table 10. Health Information Elasticities of Inverse Demands and Supplies.

	Boxed Beef	Fed Slaughter	Non-fed Slaughter	Feeders
Inverse Demand	-0.28	-0.188	-0.304	-0.11
Supply	-0.064	-0.047	-0.208	-0.33

Effects of Conditional Variance in Exogenous Variables (Table 11)

Total elasticities can be used to calculate the relative importance of shifts in exogenous variables in the sample period. For example, how important are the shifts in cholesterol information vis-à-vis feed costs, efficiency, or by product values? This information can be estimated using the conditional variance inherent in the exogenous variables. Conditional Variance (CV) is defined as a variable's standard deviation divided by its sample mean. Multiplying each variable's CV by its respective reduced form elasticity reveals its market behavior effect on prices and quantities relative to that of other exogenous variables. For example, boxed beef price's long run elasticity with respect to the retail demand index is 0.871 (table 8), and the health information elasticity estimate for the retail demand index is -0.322 (table 9). Their chain derivative product gives a -0.28% change in boxed beef price due to a 1% increase in cholesterol information. The -0.28 is multiplied by the conditional variance of the cholesterol information index variable (103.347 / 228.468 = 0.452 CV) to give a 0.127% effect on boxed beef price of the conditional variance inherent in the cholesterol information index. These estimates allow comparison of market behavior impacts among variables in the model. For example, the conditional variance of the cholesterol information index may account for an upward or downward swing of 0.127 percent in boxed beef price (around its mean). The conditional variance of the retail beef demand index shifts may account for more than twice as large (0.331%) a fluctuation in boxed beef price. The conditional variances of by-product value and hay price produce a percentage fluctuation in boxed beef price of 0.014 and 0.192%, respectively.

Table 11. Percent Effects of Conditional Variance in Exogenous Variables.

	Exogenous Variables							
Endogenous Variable	CH Index	Dri	Ef	Bi	Vbp	Pc	Ph	Interest
	(0.45)	(0.38)	(0.04)	(0.43)	(0.27)	(0.48)	(0.23)	(0.36)
P Boxed Beef	-0.127	0.331	0.016	-0.028	0.014	-0.018	0.192	-0.012
Q Boxed Beef	-0.029	0.076	0.004	-0.007	-0.007	0.010	-0.100	0.006
P Slaughter Steers	-0.085	0.222	0.011	0.019	0.045	-0.019	0.202	-0.012
Q Slaughter Steers	-0.021	0.055	0.003	-0.005	0.011	0.011	-0.128	0.008
P Slaughter Cows	-0.137	0.359	0.018	-0.009	0.070	-0.042	0.169	-0.014
Q Slaughter Cows	-0.094	0.246	0.012	0.014	0.045	0.056	-0.242	0.019
P Feeders	-0.050	0.130	0.006	-0.011	0.026	-0.048	0.251	-0.015
Q Feeders	-0.149	0.390	0.019	-0.033	0.078	-0.143	0.148	-0.045
Avg Live Wt Steers	-0.004	0.010	0.001	-0.001	0.002	0.001	0.010	-0.001
Avg Live Wt Cows	-0.012	0.031	0.002	-0.001	0.006	-0.009	0.015	-0.001

Exogenous variables’ CV values are reported in parentheses below their names.

Trend Effects on Total Revenue

Producers and marketers are often interested in revenue effects from perturbations in important market variables. Trends in exogenous variables within a sample period provide analysis of long term market price and quantity response to exogenous shifts over time. The effects on total revenue for each level of the vertical marketing chain are calculated for exogenous variable trends over the sample period. The equilibrium multipliers of the exogenous variables of interest are multiplied by the trend percent change from 1970-2001. The results are used to calculate total revenue changes in terms of the percent of average total revenue over the sample period. These results are given in table 12.

Table 12. Total Revenue Impacts (in Billion $ and Percent).

	Market Level				
Exogenous Variables	Boxed Beef	Slaughter Cattle	Non-fed Slaughter Cattle	Feeder Calves	TOTAL
(trend % change)	$24.148	$19.982	$2.285	$18.285	
RetailDemandIndex	-0.625	-0.221	-0.030	-0.304	-1.179
(-70.82%)	*-2.6*	*-1.1*	*-1.3*	*-1.7*	*-1.8*
Cholesterol Index	-0.381	-0.133	-0.018	-0.194	-0.727
(131.71%)	*-1.6*	*-0.7*	*-0.8*	*-1.1*	*-1.1*
FoodExpenditures	0.051	0.017	0.003	0.028	0.098
(10.74%)	*0.2*	*0.1*	*0.1*	*0.2*	*0.2*
Net Beef Imports	-0.037	-0.021	0.000	-0.035	-0.093
(-61.61%)	*-0.2*	*-0.1*	*0.0*	*-0.2*	*-0.1*
By-Product Value	-0.006	-0.043	-0.010	-0.070	-0.124
(-33.5%)	*0.0*	*-0.2*	*-0.5*	*-0.4*	*-0.3*
Corn Price	-0.013	-0.009	0.000	-0.188	-0.209
(-69.69%)	*-0.1*	*0.0*	*0.0*	*-1.0*	*-0.3*
Hay Price	0.047	0.033	-0.005	0.201	0.276
(-19.14%)	*0.2*	*0.2*	*-0.2*	*1.1*	*0.4*
Interest	-0.003	-0.002	0.000	-0.027	-0.033
(-29.2%)	*0.0*	*0.0*	*0.0*	*-0.1*	*-0.1*

The upper numbers in each row of table 12 are annual changes in total revenue by sector (billions of dollars), while the numbers in italics are percent changes relative to average total revenue. The real average total revenue (billions of dollars) for each sector (1970-2001) is: boxed beef = $24.148; fed slaughter cattle = $19.982; non-fed slaughter cattle = $2.285; and feeders = $18.285 (top of table 12).

Table 12 presents real revenue impacts in the vertical beef marketing channel from the trend in health (cholesterol) information. The health information index increased by 131.71% over the sample period, resulting in an estimated 1.1 percent decline ($727 million) in total beef marketing revenue. Farm-level producers absorbed $212 million of that decrease (feeder calf and non-fed slaughter cattle markets). This translates into a 1.1% reduction from average total revenue in the feeder calf market and a 0.8% reduction from average total revenue in the cull slaughter cattle market. The fed slaughter cattle market, or the beef feedlot industry, experienced a 0.7% reduction in total revenue due to the cholesterol information index, which amounted to a $133 million reduction in relation to average total revenue over the sample period.

The distribution of revenue declines indicate the boxed beef market experienced the greatest impact from retail demand shifts because this market is adjacent to the retail beef demand sector in the vertical marketing chain. Health information, through retail demand shifts, impacted the boxed beef market with a 1.6% or $381 million reduction in total revenue relative to its average total revenue. Overall, the revenue impact estimates based on cholesterol-related shifts inherent in retail beef demand indicate that revenue effects are not exclusively borne by farm-level producers, but are distributed among the four market levels. The revenue-loss distribution in this case is not entirely uniform--farm-level producers appeared to absorb significantly more total revenue reduction than those in the fed cattle market, but the boxed beef market experienced almost twice as much revenue impact as the farm-level market.

Overall the estimated trend effects on revenue from the cholesterol information index ($727 million loss) were larger than trend effects on revenue from factors such as feed corn price, net beef imports, and beef by-product values. These variables displayed trend effects on reducing total revenues across industry sectors of $209 million, $93 million, and $124 million, respectively. The cholesterol revenue effects in relation to revenue effects of other market factors emphasize the importance, over the long term, of changing primary beef demand on the economic well being of market level beef producers.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Beef producers are concerned about the negative consequences of public information relating red meat consumption and cholesterol to heart disease. Therefore, the primary objective of this study was to estimate the effects of health (cholesterol) information on a system of beef inverse demand (price) and supply equations, and revenue effects per beef marketing sector. Previous literature which estimated the effects of health (cholesterol) information on beef inverse demand was reviewed; although this study's format allows investigation of cholesterol information as a shifter of retail beef demand. Supply equations as well as inverse demand were estimated for all sectors (feeder, slaughter, and wholesale) of the beef marketing chain. Identifying the factors that resulted in downward shifts in retail demand (particularly health) from 1976-1997 and the distribution of these impacts among the beef industry sectors could have potential policy implications in terms of strategies to deal with health perceptions.

Shifts in retail beef demand were proxied by the retail beef demand index. Estimation of factors, particularly health, that affect this retail demand index is a significant addition to the literature concerning shifts in retail beef demand. The retail demand index has recently been used to estimate impacts of demand shifts on derived wholesale and farm level inverse demands and primary and derived supply markets. Health (cholesterol) information, weighted price of substitutes (pork and poultry), food expenditures, and trend were the exogenous variables hypothesized to determine the demand index. The demand index elasticity with respect to health information and substitute prices was estimated as -0.322 and 0.767, respectively. Per capita food expenditure and per capita income were not statistically significant variables in affecting the retail demand index.

A system of inverse demand and supply equations was estimated for the boxed beef, slaughter cattle, non-fed slaughter cattle, and feeder levels of the beef marketing chain. The retail demand index was specified in the boxed beef inverse demand to capture effects of primary demand shifts in this adjacent market. Inclusion of supply equations allows the system to estimate supply responses to the effects of primary demand shifts as they reverberate through the chain. Thus, this study allows estimation of specific beef sector responses to shifting retail beef demand.

Inverse demand and supply equations for all four sectors were estimated jointly in a full-information systems estimator, Iterative Three-Stage Least Squares. Estimation results showed the retail demand index to be statistically significant in the boxed beef demand equation. The significant coefficients of boxed beef price and slaughter steer price in the slaughter and feeder price equations, respectively, served as the transmission route for the retail index's effects on the slaughter and feeder cattle markets at the farm level. Given the significant effect of cholesterol information on the retail demand index, the model allows for the comparative statics of cholesterol information effects throughout the beef marketing chain.

The system was solved as a reduced form and long-run impact multipliers and total elasticities were calculated. Long-run elasticities were used to calculate conditional variance effects and total revenue effects of sample trends in exogenous variables for each of the four beef industry sectors. The total revenue impacts of the downward sample period trend in the retail demand index amount to 2.6%, 1.1%, 1.3%, and 1.7% annual reductions (as a percent of the sample mean) in the boxed beef, slaughter cattle, non-fed slaughter cattle, and feeder industries, respectively. That amounts to a reduction in total revenue across all industry sectors of $1.179 billion, or 1.8%.

Cholesterol information, as a driver of retail demand's downward trend, was associated with annual total revenue reductions of 1.6%, 0.7%, 0.8%, and 1.1% in the boxed beef, slaughter cattle, non-fed slaughter cattle, and feeder industries. In other words, health (cholesterol) information precipitated a total revenue loss annually of $727 million, or 1.1%, to the U.S. beef industry as a whole.

Statistically significant parameter estimates of the econometric model suggest that health (cholesterol) information is indeed a significant shifter of retail beef demand and, subsequently, of prices and quantities throughout the beef marketing channel. These results support the growing list of literature suggesting that consumers do respond to information in consumption decisions, which has implications for livestock producer and meat processor returns. It would be interesting to include advertising information in the retail beef demand index equation. (Kinnucan, et al.; Brester 1995). Food safety information is also missing in the model estimation because of limited years in which it could be constructed; this variable would be useful data in future estimation.

The effects of shifts (decline) in retail beef demand were distributed among all four sectors of the beef marketing chain. The boxed beef (packing and processing) industry is estimated to have absorbed almost twice as much reduction in total revenues ($625 million) as the farm level, which was the second most significantly impacted sector ($334 million in the feeder market and the non-fed slaughter cattle markets). The beef feedlot industry appears to have been affected the least ($221 million reduction annually) by revenue effects of the retail demand shifts over the sample period.

Limitations and Implications

The econometric results of the model are based on the assumption of representative sample size and minimal specification errors. The relatively small sample size (n = 32) utilized, however, would imply that careful interpretation of the estimated results is advisable. Expanding the sample over several more years (particularly including more recent years where the demand index has continued to increase) would potentially improve statistical analysis and allow more precise economic conclusions.

Utilization of the full-information system estimator has several benefits, perhaps chief among them the correction of simultaneity and contemporaneous correlation in errors. However, a down side of the systems estimator is that any specification error in one equation could harm the quality of estimation across the entire system.

Ultimately, important policy implications regarding beef demand and health information may be gleaned from this thesis project. Beef revenue simulations suggest that economic impacts of health information and shifts in retail demand are not trivial. Hence, less contentious avenues for promoting retail beef demand (the current national Beef Check-Off program is a source of recurring debate and controversy over its effectiveness) may lie in the direction of identifying the positive health benefits of some certain level or variety of beef consumption. Given current diet trends such as high-protein, low-carbohydrate programs, such emphasis on positive health benefits may be possible. The crux of the issue, however, is that new information supporting such an argument would be much more effective in impacting consumer behavior if it is released through the channels of an authentic health study. Releasing such information directly into popular media from beef industry groups may be perceived as merely advertising, which appears to be less effective.

The model developed in this thesis, by interacting demand level and supply level shocks through price - quantity endogeneity and error term relationships, may also be useful in the future for simulation of related issues. These include food safety scares (such as BSE or e. coli), agri-bioterrorism, or other issues potentially impacting retail beef demand and supplies of livestock and meat.

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