# THE EFFECTS OF DOMESTIC AND TRADE POLICY VARIABLES ON THE U.S. BEEF WHOLESALE AND SLAUGHTER MARKETS

by

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# TABLE OF CONTENTS

TABLE OF CONTENTS --Continued

# LIST OF TABLES

LIST OF TABLES--Continued

# LIST OF FIGURES

## ABSTRACT

Trading in beef products has been increasing during the 1980's and its impact on the U.S. beef industry has become an important issue for various interest groups. Particularly, U.S. by-product exports have become a large value item in U.S. beef product exports and contribute greatly to meat packer returns and Japanese beef import quotas have become less stringent. The main objective of this study is to develop a dynamic structural model of the U.S. wholesale carcass and slaughter cattle industry. The model incorporated pertinent domestic variables and foreign trade variables such as imports and exports of beef and veal, live cattle imports, and by-product exports.

The econometric model explicitly includes U.S. carcass demand and supply, U.S. slaughter demand and supply, beef and veal import demand and supply, beef and veal export demand and supply, live cattle import demand and supply, and foreign trade in farm level by-products. The empirical model was estimated within a rational distributed lag framework, using instrumental variables with either the maximum likelihood or ordinary least squares procedure depending upon the nature of the stochastic error terms. The short-run and long-run impacts of the exogenous variables on the dependent variables are calculated using sequential partial derivatives involving the difference equation coefficients and slope parameters. The distributed lag impacts of trade shocks on the U.S. beef prices are calculated using reduced form coefficients specific to selected exogenous and predetermined variables combined with price transmission effects between market levels.

The empirical results show that most of the foreign trade variables were statistically significant and demonstrated theoretically correct signs. The long-run impacts of foreign trade in beef products were generally small but were large enough to suggest that incorporating foreign market arguments in the framework of dynamic analysis is important in a U.S. beef market analysis. However, the use of monthly or quarterly data and disaggregate price and quantity data for the trade variables would be more desirable in order to reduce aggregation bias.

# CHAPTER 1

# INTRODUCTION

For many years economists have studied the institutional structure and economic behavior of agricultural markets in order to develop a better understanding of market demand, supply, and price interrelationships. Statistical models of market demand and supply, based upon historical observations, provide information about future economic phenomena since it is assumed that market participants extend past behavior into the future. However, incorporating past market behavior into economic models can be difficult due to nonmeasurable factors as well as complicated dynamic structures. Alfred Marshall (1890) discussed such difficulties in his influential work, *Principles of Economics*:

> Thus while a list of demand prices represents the changes in the price at which a commodity can be sold consequent on changes in the amount offered for sale, *other things being equal*; yet other things seldom are equal in fact over periods of time sufficiently long for the collection of full and trustworthy statistics. There are always occurring disturbing causes whose effects are commingled with, and can not easily be separated from, the effects of that particular cause which we desire to isolate. This difficulty is aggravated by the fact that in economics the full effects of a cause seldom come at once, but often spread themselves out after it has ceased to exist. (p. 92)

Consequently, in building an economic model economists must consider lagged impacts from exogenous disturbances in order to improve upon predicting economic phenomena.

## Objectives

The purpose of this thesis is to analyze the market structure and dynamic behavior of the U.S. beef wholesale and slaughter markets within the framework of foreign trades.

Trading in beef products has been increasing during the 1980's (refer to Appendix A) and its impact on the U.S. beef industry has become an important issue for various interest groups. For instance, U.S. beef producers have often argued that beef imports tend to reduce their income. Consumers, on the other hand, have contended that beef import quotas tend to increase beef prices. Revenues from beef product exports have also been a concern of the U.S. beef industry. Particularly, U.S. by-product exports have become a large value item in U.S. beef product exports (refer to Appendix A) and contribute greatly to meat packer returns.

It is expected that with continually increasing trade in beef products the U.S. beef industry will depend more upon the foreign market (which largely has been ignored in previous studies). The two most important areas appear to be increasing Japanese beef import quotas (affecting U.S. beef and veal exports to Japan) and exports of by-products since domestic demand is not sufficient and price elasticities are low. Thus, it is hypothesized that beef trade effects should be incorporated in the U.S. beef model to avoid specification error in the structural relations. These relationships include live cattle imports, beef and veal imports and exports, and by-products exports. Specifically, the objectives are:

(1) To develop a dynamic structural demand and supply model of the U.S. wholesale (carcass) and slaughter beef markets by incorporating pertinent domestic variables with Japanese beef and veal trade, live cattle trade with Canada and Mexico, and general trade in U.S. beef by-products.

(2) To estimate the structural supply and demand model within a system's framework and to estimate the respective length-of-run supply and demand elasticity coefficients.

(3) To utilize reduced form coefficients with price transmission equations in order to calculate the distributed lag impacts of various trade variables on U.S. beef prices.

## Procedures

Based upon economic theory, knowledge of the industry, and previous research, appropriate dependent and independent variables are specified within a distributed lag structure. The formulation approximates a flexible rational lag process as given by Jorgensen (1966). The theoretical model explicitly includes U.S. carcass demand and supply, U.S. slaughter demand and supply, beef and veal import demand and supply, beef and veal export demand and supply, live cattle import demand and supply, and foreign trade in farm level by-products (hides and variety meats).

The system of equations are estimated using instrumental variables with either the Maximum Likelihood (ML) or Ordinary Least Squares (OLS) procedure depending upon the nature of the stochastic error terms. Specifically, the equations are estimated by the ML method when autoregressive errors are present and by OLS when white noise errors occur. Instrumental variables are used to handle problems of joint dependency.
The correlation and covariance matrix of the system's error terms are also examined to test the Seemingly Unrelated Regression (SUR) problems in the dynamic structure.

The short-run and long-run impacts of the exogenous variables on the dependent variables are calculated using sequential partial derivatives of the estimated difference equation coefficients and slope parameters. Finally, the distributed lag impacts of trade shocks on prices in the U.S. beef industry are calculated using reduced form coefficients specific to selected exogenous and predetermined variables combined with price transmission effects between market levels.

## Background of Problem

The U.S. beef industry is fairly complex since it is composed of various production and marketing activities. Examples include cow-calf production, production of stockers and feeders, production of fed and nonfed slaughter cattle, cattle slaughtering and meat processing, and the wholesale and retail distribution functions.

The wholesale industry is composed of cattle slaughterers and cattle nonslaughterers (McCoy and Sarhan, 1988). One group of meat packers slaughter fed and nonfed cattle to produce boxed beef; they also produce beef outputs such as carcasses, fores, and hinds. Another group of meat packers may slaughter animals consisting of lean (low grade) carcasses that are further processed into canned meats and sausage items. Cattle nonslaughterers usually include processors and wholesale distributors. The processors may only purchase carcasses for fabrication purposes and/or engage in manufacturing of specialty meats such as sausages, baloney, canned items, etc.

Historically, many studies ignored the impacts of international trade on the U.S. beef industry since foreign trade was not regarded as important as the effects of domestic production and consumption. However, some research incorporated the market effects of trade in beef products and live cattle (Kulshreshtha and Wilson, 1972; Houck, 1974; Freebairn and Rausser, 1975) and the impact of U.S. dairy imports (Novakovic and Thompson, 1977; Salathe et al., 1977). Recently there has been increased interest in the impacts of both beef exports and imports on the U.S. beef market, primarily since beef trade with Japan appears more promising and the fact that exports of by-products have been increasing.

Over the years beef by-products have accounted for an increasing share of trade in beef related products. Hides and skins, variety meats, and tallow and grease are important sources of dollars earned from U.S. livestock by-product exports.[1] In 1988, exports of U.S. hides and skins reached $1,528.8 million which compares to $1,109 million earned from beef and veal exports. The export of variety meats, which include products from the inner organs, head meat, and offals, are also important sources of revenue to the meat packing industry. The U.S. accounts for about one-half of the world's trade in variety meats which include products such as the tongue, liver, heart, and kidney meats. In 1988, the overseas sales of variety meats amounted to $375.1 million.

Modeling the market structure and behavior of U.S. beef retail, wholesale, and farm level demands and supplies encompasses various economic models and econometric methods. Since the U.S. beef market consists of various marketing levels linked by primary and derived demands and supplies (Tomek and Robinson, 1981), specifying all relevant domestic relationships is quite complex. As the U.S. beef industry becomes more involved with foreign trade, trade variables should also be added to the complex setting in order to avoid misspecification of structural and behavioral relationships.

The U.S. beef wholesale and slaughter cattle industry is strongly linked with foreign trading in beef and veal, live cattle, and by-products. Japanese export demand for U.S. high quality beef and veal and U.S. import demand for low quality beef and veal from Australia and New Zealand directly impact U.S. carcass and slaughter prices, demands, and supplies. U.S. import demand for feeder and stocker cattle from Canada and Mexico is

[1]U.S. livestock exports as a percentage of total export value in 1988 are as follows: hides and skins, 35%; red meats, 26%; animal fat, 11%; live animals, 10%; variety meats, 9%; other product, 8% (USDA, *Dairy, Livestock, and Poultry: U.S. Trade and Prospects,* 1989)

also important since imports of live cattle influence regional cattle prices and supplies available for cattle grazing, feeding, and domestic slaughter.

Little attention has been paid to the beef by-product trade even though it has become a large value item in U.S. agricultural trade. U.S. consumption of beef specialty products, i.e., liver, kidney, heart, tongue, tripe, sweetbreads and brains, has been declining primarily due to its inferior good nature (Smith and Goodwin, 1989). Consequently, future export demand and supply of U.S. by-products will play a more important role in affecting the domestic value of by-products and, hence, prices of wholesale beef and live cattle.

In summary, incorporating beef and veal trade, live cattle imports, and by-product exports with traditional domestic market behavior is fundamental to understanding total market behavior of domestic prices, demands, and supplies in the U.S. beef industry.

The remainder of the thesis chapters are organized as follows: Chapter 2 reviews the economic and theoretical background necessary to develop a beef model of factor demands and output supplies. The estimation procedures are also discussed including the econometric methods appropriate for the statistical problems encountered in dynamics. Chapter 3 presents the empirical results of the model, the elasticity estimates, and the results of the policy analysis using reduced form coefficients and price transmission effects. Chapter 4 summarizes the economic model and empirical results and draws some conclusions about the study.

## Review of Previous Studies

Several studies have emphasized the problems of modeling the U.S. and Canadian beef and livestock economies when incorporating beef and veal and live cattle imports. Most econometric models of the beef sector incorporating an open economy have discussed the impacts of beef imports on the domestic livestock market (Arzac and Wilkinson, 1979; Freebairn and Rausser, 1975; Houck, 1974; Langemeier and Thompson, 1967), while only a few studies have focused on the live cattle trade (Freebairn and Rausser, 1975; Kulshreshtha and Wilson, 1972). Even less attention has been paid to the effects of beef and beef by-product exports. In this section, several studies concerning these issues are selected and reviewed.

Blake and Clevenger (1980) pointed out that many beef sector models have neglected the impacts of beef and beef by-product exports on domestic live cattle prices. They argued the supply of beef by-products can be determined only by the number of cattle slaughtered, not by the price of beef by-products since live cattle are slaughtered primarily for beef value and not for by-product value. Based upon this fact, they established the value of beef by-products (the portion of live cattle price attributable to by-products) as a function of the export demand for beef by-products and the domestic demand for beef by-products. They used the ratio of net exports to domestic production for each by-product and estimated each ratio's impact on the portion of live cattle price attributable to by-products for the time period 1958-1977. The portion of the annual average farm price of cattle attributable to beef by-products was regressed on four ratios of annual net exports to domestic production for inedible tallow and grease, edible beef tallow, cattle hides and calf skins, and offal. All regressors showed positive relationships with by-product value except the negative inedible beef tallow impact, which they attributed to the large share of U.S. beef tallow exports in world exports. The ranges of export impacts of inedible tallow, edible tallow, skins and hides, and offal on the price of live cattle per hundred weight were $-3.50 to $-4.71, $0.06 to $1.14, $0.33 to $1.99, and $0.87 to $2.74, respectively. Also, the authors argued that the impacts of beef by-product exports are larger than the impact of beef imports on live cattle prices using Freebairn and Rausser's (1975) results. Finally, they concluded that fewer exports of inedible tallow might increase live cattle prices since their results showed that the negative price impact of inedible tallow exports exceeded the sum of the positive price impacts of the other three by-product exports.

Arzac and Wilkinson (1979) analyzed the U.S. livestock and feed grain markets with a quarterly econometric model and then used dynamic multipliers to examine the effects of changes in beef imports, corn exports, corn yield, consumer income, and other variables. Results showed that changes in nonfed beef imports had small long-run impacts on the retail price of nonfed beef and other various meats. They concluded that corn exports, corn yield, and consumer disposable income were more important in affecting retail and producer prices than nonfed beef imports. Also, they found that nonfed beef production demonstrated an inverse relationship with beef imports in the long-run.

Freebairn and Rausser (1975) analyzed the impacts of alternative levels of beef imports on retail and farm level prices and beef industry growth. Choice beef and other beef were separated into higher and lower quality beef, respectively, with the assumption of insignificant beef exports. The econometric model consisted of consumer demand, marketing margin, meat production, inventory, net trade, and stock change equations based on 1956-1971 annual data. A set of solved reduced form equations was used to analyze the time path impacts of beef imports on the livestock industry. An equation for imports of feeder calves from Canada and Mexico as a function of U.S. price of feeder calves was also estimated.

Overall, they argued that an increase in imports would increase the supply of lower quality beef, which is expected to decrease retail meat prices and livestock prices and to increase the inventory level of beef cows. From their estimated long-run effects of a 100 million pound increase in beef imports, all meat prices declined, particularly hamburger meat prices, and domestic production levels were reduced for all livestock except for other beef. Using dynamic multipliers they estimated that a 100 million pound increase in beef imports would decrease retail choice beef price by .87 cents, hamburger price by 1.52 cents, pork price by .13 cents, and chicken price by .21 cents. They also estimated the impact of a 200 million pound increase in beef imports on live cattle prices and reported that the price of choice beef would fall by .99 cents, hamburger meat by 1.1 cents, and slaughter steers by 56 cents, cull cows by 94 cents, feeder calves by 69 cents per hundred weight, and that the inventory of beef cows would increase .11 million head. They concluded that an increase in beef imports reduced retail prices of all meats, particularly for lower quality beef products, by more than price reductions for slaughter steers, cull cows, and feeder calves.

Houck (1974) estimated the short-run impact of beef imports from Australia and other countries on U.S. retail beef prices with separate data for table cuts and processed meats. He argued that the separation of consumption data into table beef and processed beef was crucial to estimate the beef import impact on the U.S. beef sector. The results showed that imports of processed meat generally reduced domestic retail meat prices, particularly for hamburger and other processed items. Overall, increases in beef imports decreased all meat prices, i.e., 35-50 percent for processed meat and 11-13 percent for table cut beef with an 18-24 percent weighted average reduction. All estimated cross effects were aggregated and the results showed in the short run that the U.S. CPI index (Meat, Fish and Poultry portion) would be higher by 11-12 percent without beef imports while the total U.S. CPI index would be higher by 3 percent.

Kulshreshta and Wilson (1972) formed an annual model of the Canadian beef sector incorporating cattle exports to the U.S. The model was a system of simultaneous equations using two-stages least squares for the period 1949-1969. In their model, the endogenously determined Canadian feeder cattle export demand affected the domestic cattle inventory which recursively influenced domestic beef cattle slaughtered, average dressed carcass weight, and subsequently the demand and supply of finished beef. The export demand for live cattle was estimated as a function of the Canadian beef cattle price, the price difference between Canadian and U.S. feeder cattle markets, U.S. per capita supply of beef, and a dummy variable for the 1952-1956 period of foot and mouth disease.

The price differential showed a positive relationship with the export demand for live cattle showing an elasticity of .0336. The Canadian farm price of beef cattle was negatively related to the export demand with an elasticity of -.8071. Beef cattle inventory was negatively related to the volume of cattle exports. Predicted changes in the Canadian beef cattle sector were estimated based upon projections of exogenous disturbances. Kulshreshta and Wilson (1972) concluded that the domestic demand for beef and farm prices of beef would increase while exports of live cattle would decline by 1975, and that the expansion of beef production largely depended upon price and production levels of feed grains. However, the analyses did not take into account time lag impacts of export demand and the econometric model was limited in tracing export impacts on prices at the various levels of the Canadian beef sector.

Farris (1971) studied factors affecting U.S. cattle hide exports for the 1956-1969 period. The empirical model consisted of two structural equations, export demand and export supply, with an equilibrium identity. It was hypothesized that export demand for U.S.

cattle hides was determined by price of U.S. cattle hides, production of cattle hides abroad, and time trend. In the supply equation, export supply of U.S. cattle hides was specified as a function of the price of U.S. cattle hides, U.S. production of cattle hides, purchasing power in the U.S., and a time trend. Foreign hide production and U.S. hide price inversely affected the export demand for U.S. hides. In the supply equation, exports of U.S. hides were negatively related to U.S purchasing power and were positively related to U.S. cattle slaughter and U.S. hide price. The price elasticity of foreign demand for U.S. hides was about -.8. Farris explained that the significantly positive coefficient of the trend variable in both demand and supply equations showed the growing foreign market for U.S. cattle hides; however, these coefficients possessed a great deal of inseparable information. He concluded that the U.S. cattle hide price did not drop sharply during the period of rapidly increasing U.S. beef production due to strongly expanding foreign markets for cattle hides, and that future U.S. cattle hide price would depend largely on foreign demand.

Langemeier and Thompson (1967) constructed an econometric model of the U.S. beef sector allowing for simultaneity between supplies and demands. Beef supply was separated into the fed, domestic nonfed, and import components and the beef demand was disaggregated into fed and nonfed components. The structural models consisted of eight behavioral equations: number of fed beef slaughtered, weight per head of fed beef slaughtered, supply of nonfed beef from domestic sources, imports of beef, per capita demand for fed beef, per capita demand for nonfed beef, a fed beef margin, and a nonfed beef margin. The structural equations were estimated for the 1947-1963 period using two-stage least squares to address the simultaneity problem and ordinary least squares was used to estimated the reduced form.

Langemeier and Thompson (1967) hypothesized that beef imports were determined by the U.S. price of nonfed beef and wage rates in the meat packing industry, the empirical results showing that beef imports were positively correlated with both of these variables. They argued that exporters of beef observe U.S. prices of nonfed beef as well as costs of labor. Elasticities of demand and supply were calculated; the demand elasticities of fed beef, nonfed beef, and all beef were -.98, -1.24, and -1.06, respectively, while supply elasticities of .232, -.552, and 3.428 were obtained for fed beef, nonfed beef, and beef imports, respectively. The authors concluded that the effect of beef imports on the price of fed beef was opposite to the effect of the supply of fed beef, and that the depression in fed beef prices from 1962 to 1964 primarily was a result of increases in fed beef supplies and a lack of commensurate growth in consumer purchasing power.

# CHAPTER 2

# MODEL DEVELOPMENT AND ESTIMATION PROCEDURES

## Theoretical Considerations

### Derivation of Consumer Demand

Consumer demand theory begins with a utility function that defines consumer preferences. The utility function is U(x), where $\mathbf{x} \in R^{n}{}_{+}$, is an n dimensional column vector in commodity space, defined as a nonnegative orthant of an Euclidean n-space, a closed, convex set. For a well behaved utility function, U(x) is twice differentiable with continuous second order partial derivatives, is a monotone function strictly increasing in x ( $\partial U(\mathbf{x}) / \partial \mathbf{x} > \mathbf{0}$ ), and is strictly quasiconcave (Varian, 1984). These conditions for the utility function guarantee a unique interior solution to the constrained utility maximization problem. Given the well behaved utility function, the maximization problem can be expressed as the following:

$$Max \{ U(\mathbf{x}) \ : \ \mathbf{x} \in R_{+}^{n}, \ \mathbf{p}' \mathbf{x} \leq M \}$$

where $\mathbf{p} \in R^{n}{}_{+}$, is an n dimensional price column vector and M is total consumer expenditures.

The Lagrangian for this maximization problem can be constructed as follows :

$$L \ (\mathbf{x}, \lambda) = U(\mathbf{x}) + \lambda \ ( M - \mathbf{p}' \mathbf{x} )$$

Kuhn-Tucker conditions for the Lagrangian are the necessary and sufficient conditions for utility maximization if the quasiconcavity condition holds. Kuhn-Tucker conditions are:

$$\frac{\partial L}{\partial \boldsymbol{x}} = \frac{\partial U}{\partial \boldsymbol{x}} - \lambda\, \boldsymbol{x} \le 0, \quad \boldsymbol{x} \ge 0, \quad \frac{\partial U}{\partial \boldsymbol{x}} \cdot \boldsymbol{x} = 0$$

$$\frac{\partial L}{\partial \lambda} = M - \boldsymbol{p}'\, \boldsymbol{x} \ge 0, \quad \lambda \ge 0, \quad \frac{\partial L}{\partial \lambda} \cdot \lambda = 0$$

For $\mathbf{x} > \mathbf{0}$, the Lagrange multiplier $\lambda$ must be positive. The sufficient second-order conditions guarantee a nonsingular Hessian matrix so that, by the implicit function theorem, there is a unique solution of $\mathbf{x}$ at the optimum levels of $\mathbf{x}$.

$$\frac{\partial L}{\partial \boldsymbol{x}} = M - \boldsymbol{p}'\, \boldsymbol{x} = 0$$

$$\frac{\partial L}{\partial \lambda} = \frac{\partial U}{\partial \boldsymbol{x}} - \lambda\, \boldsymbol{p} = 0$$

Simultaneously solving the above equations for $\mathbf{x}$ as a function of $\mathbf{p}$ and M, the Marshallian market demand equations are derived as follows:

$$\boldsymbol{x}^* = \boldsymbol{x}^* \,(\, \boldsymbol{p},\ M\,)$$

$\mathbf{x}^*$ has properties of nonnegative value, zero degree homogeneity in all prices and income, satisfying the Engel aggregation condition, and the symmetric negative semidefinite Slutsky matrix.

Derivation of Firm's Factor Demand and Output Supply

Assume a production function, f(**y**), where $\mathbf{y} \in R^n_+$, is an input vector of the nonnegative orthant of Euclidean n-space. A well behaved production function is assumed by imposing f(**y**) to be twice continuously differentiable, an increasing function with respect to **y**, and concave so the Hessian matrix of f(**y**) is negative definite. Furthermore, assume there is a profit maximizing firm with the production function f(y), given output price p, and factor costs of column vector **w**, where $\mathbf{w} \in R^n_+$. Then revenue (R) and costs (C) of production can be respectively expressed as:

$$R = p \cdot f(\mathbf{y}), \qquad C = \mathbf{w}\,\mathbf{y}$$

Therefore, the long run profit maximization problem of the firm can be written as follows:

$$Max\,\{\,\Pi(\mathbf{y}) = p\,f(\mathbf{y}) - \mathbf{w}\,\mathbf{y} \,:\, \mathbf{y} \in R^n_+\,\}$$

Kuhn-Tucker conditions are the necessary and sufficient conditions for a profit maximization problem assuming concavity:

$$\frac{\partial\Pi(\mathbf{y})}{\partial\mathbf{y}} = p \cdot \frac{\partial f(\mathbf{y})}{\partial\mathbf{y}} - \mathbf{w} \le 0, \quad \mathbf{y} \ge 0, \quad \frac{\partial\Pi(\mathbf{y})}{\partial\mathbf{y}} \cdot \mathbf{y} = 0$$

For y > **0** the first order conditions are as follows:

$$p \cdot \frac{\partial f(\mathbf{y})}{\partial\mathbf{y}} = p \cdot MP(\mathbf{y}) = \mathbf{w}$$

which says the value of marginal product must equal the factor cost of production. A solution to the firm's profit maximization problem exists if the Hessian matrix is negative definite at the optimum solution. Thus, the equation for the input y is given as:

$$y^* = y^* ( p, w )$$

which are the firm's factor demands that express optimal choices as functions of output price (p) and factor costs (w). These functions are homogeneous of degree zero.

The output supply function of the firm can be derived by substituting the factor demand functions into the production function:

$$q^* = f[ y^*(p,w) ] = q^*(p, w)$$

This set of equations shows output supplies of the profit maximizing firm to also be a function of output price and input prices. $q^*$ has properties of zero degree homogeneity in all prices and symmetric substitution effects.

Marketing Margins

A marketing margin for a product can be defined as the difference between the price paid by consumers and the price received by producers, or as the price of a collection of marketing services as determined by the demand for and the supply of such services (Tomek and Robinson, 1981). Marketing margins are influenced by marketing input prices, degrees of marketing efficiency, the merchandising mix, and technological changes (pp.160, Dahl and Hammond, 1977). The importance of marketing margins is that their changes impact retail, middlemen, and farm prices by shifting supply and demand schedules. Tomek and Robinson (pp.130-140, 1981) argue the incidence of margin changes depend upon whether there is an introduction of new services (for a new product) or whether costs change for existing services. In the former case, if consumers accept the new product, a new primary demand may exist at a higher level and derived demand may be changed according to the cost of the new service. However, in the latter case, an increase in the marketing margin usually increases retail price and decreases producer price. Figure 1 shows these relationships. An increase in the cost of existing market services implies downward shifts of derived demand at the slaughter level (DD to DD') and upward shifts of derived supply (DS to DS') at the retail level which results in increasing retail beef prices ($P^{bf}_0$ to $P^{bf}_1$) and decreasing slaughter prices ($P^{sl}_0$ to $P^{sl}_1$). $M_2$ represents the increased marketing margin from $M_1$.

Two-Country Beef Trade Model

In the beef model, it is assumed that the United States exports beef and veal to Japan, exports by-products to the rest of the world, imports beef and veal from Australia and New Zealand, and imports live cattle from Canada and Mexico.

Figure 2 illustrates the fundamentals of the trade model in this study. Countries A and B represent the exporting and importing countries, respectively. The domestic demand and supply for the exporting and importing countries are labeled $D_A$, $S_A$, $D_B$, and $S_B$, respectively. The center diagram represents the world market for particular beef product. The incentive to trade is represented by the horizontal difference between domestic demand and supply for the countries. As can be seen, for instance, the U.S. desires to export beef and veal by AB while Japan desires to import beef and veal by RS given world price $P_W$. In the diagram of world market, the difference between U.S. beef and veal demand and supply is graphed as the U.S. export supply (XS: $XS=S_A-D_A$) while the

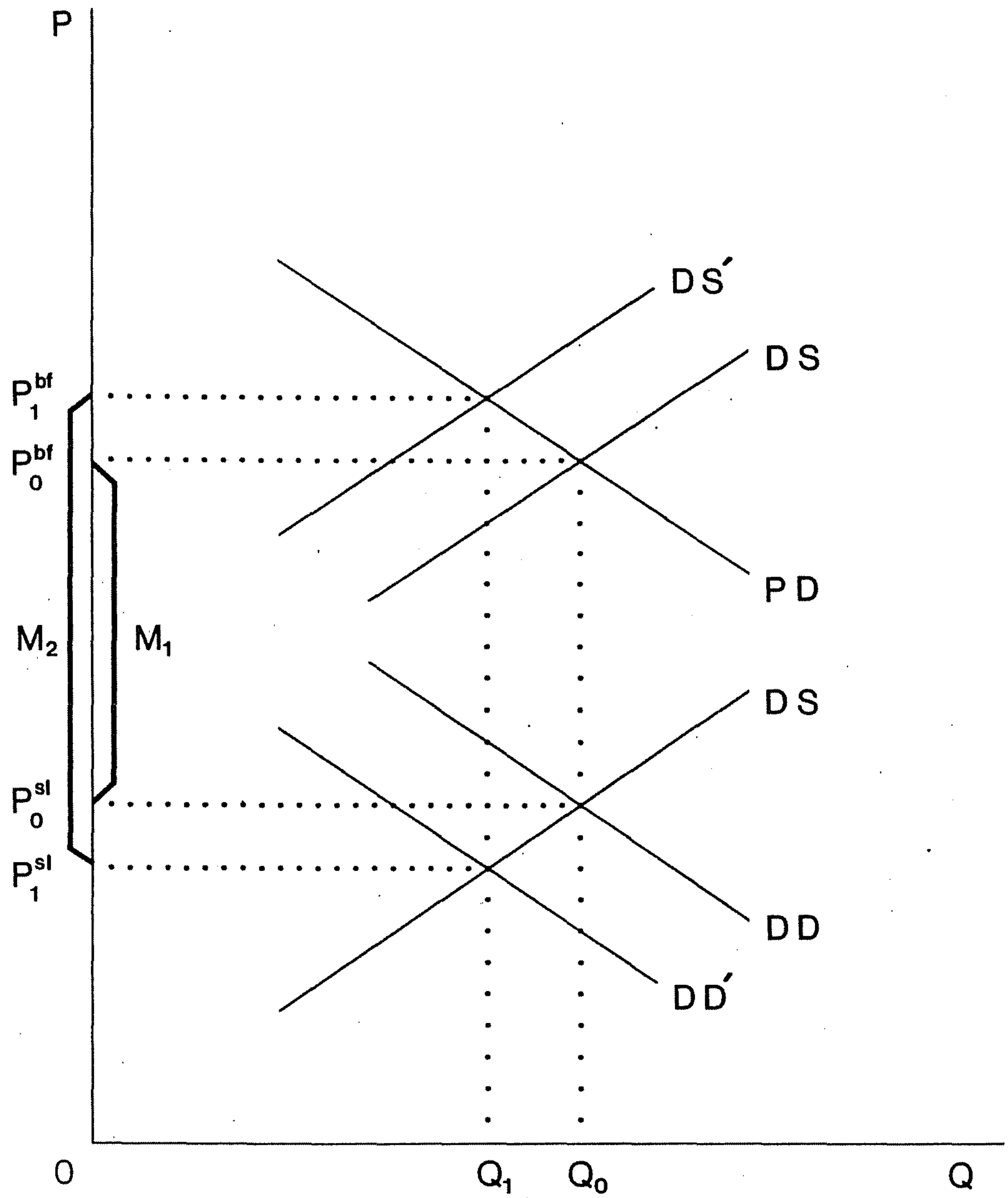


Figure 1. Impacts of change in marketing margin on beef prices

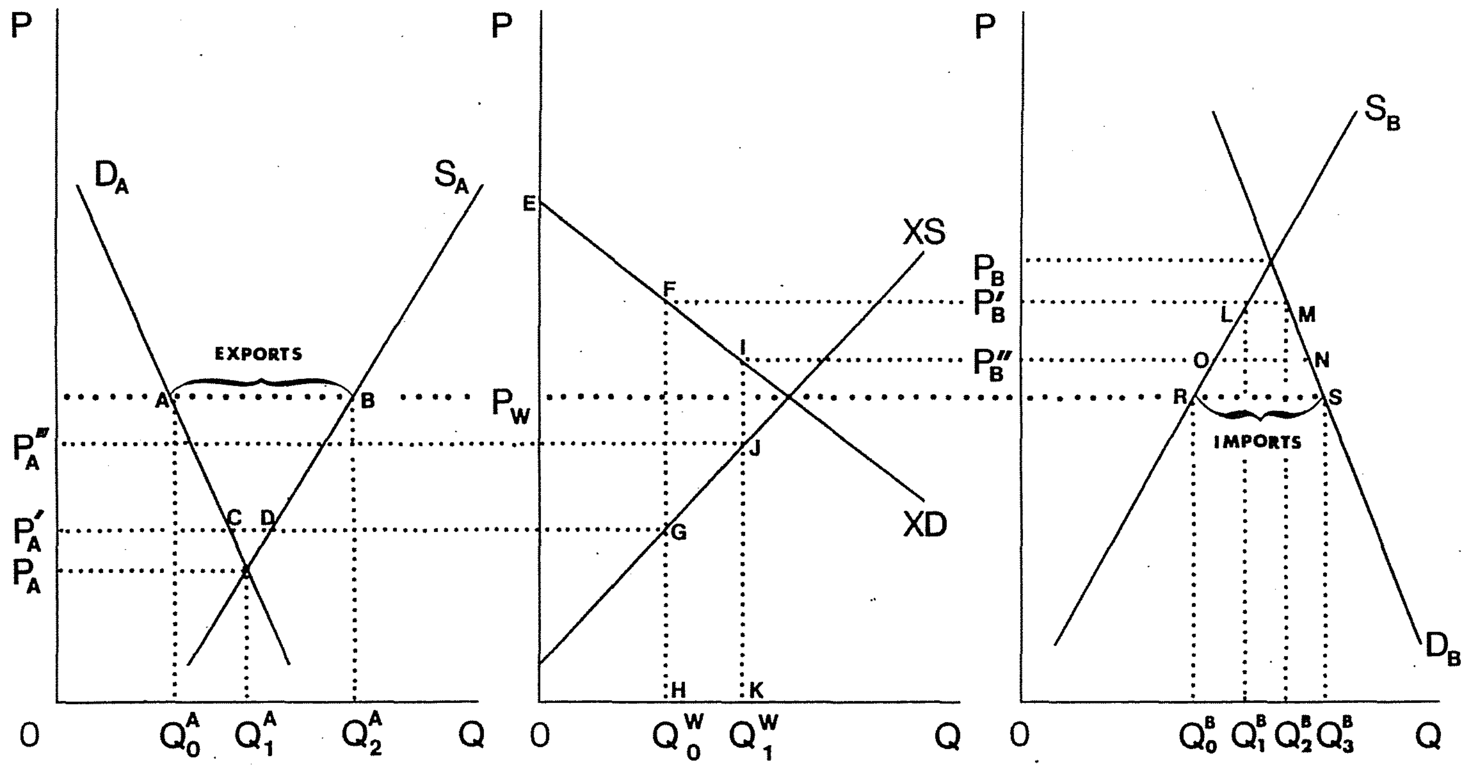


Figure 2. Two-country beef trade model

difference between Japanese beef and veal demand and supply is graphed as the Japanese export demand (XD: $XD=D_B-S_B$). The interaction of demand and supply in both countries determines the world prices of beef and veal and the quantities traded. The world market demand and supply are affected by factors that influence domestic demand and supply such as income, substitute prices, quotas, foreign exchange, policy, etc. With an increase in income of importing countries, the domestic demand curve ($D_B$) shifts upward so that the excess demand is expanded and, consequently, the export demand increases. Price difference ($P_B-P_W$ or $P_B-P_A$) is also a factor affecting export demand since a larger price gap increases the size of excess demand in the importing country, which again increases export demand in the world market.

Exchange rates, quotas, and tariffs are typical factors influencing exports and imports. If the currency of the importing country were depreciated, imports would become more expensive (domestic price increases from $P''_B$ to $P'_B$) so that excess demand would be reduced from ON to LM. Thus, the quantity of export demand would be reduced from $Q^W_1$ to $Q^W_0$. In Figure 2 LM represents the Japanese beef import quota at the disequilibrium price $P'_B$. Given the amount of quota LM, the XD curve becomes kinked since it is inelastic at that quota level (LM) and the new export demand curve is EFGH. If the quotas are increased (LM to ON), given world market price, export quantity demanded would increase ($Q^W_0$ to $Q^W_1$) and the kinked XD curve would shift to EIJK, which implies a movement along the XS curve (G to J). Consequently, an increase in the Japanese beef import quota increases the quantity of export demanded so that domestic beef price of the exporting country increased from $P'_A$ to $P''_A$.

Figure 2 also relates the impacts of U.S. beef and veal and live cattle imports on the U.S. beef prices. This relationship can be found by shifting XD or XS in the center diagram and tracing price changes in the right-hand diagram. For example, an increase in imports of beef and veal or live cattle would depress U.S. beef prices. An increase in U.S. by-product exports shifts XS downward so that world market price ($P_W$) would decline if the U.S. share of the world market is considerably large. Consequently, U.S. exporters may increase domestic supply instead of exporting so that domestic beef prices would decline. However, in the short run, domestic supply decreases as XS increases since more quantities are sold to the world market.

## Model Specifications

The U.S. beef industry is a relatively complex structure with its different market levels, various marketing institutions, and the types of products and services offered. The conceptual framework of the thesis model is presented in Figure 3. This figure shows factors affecting primary demand and supply, factors affecting derived demand and supply, and the relationships involving foreign trade of cattle and beef products. The supplies and demands at the market levels are interdependent, linked by the appropriate marketing margins. The wholesale and slaughter levels of the U.S. beef industry, the concern of this study, reflect much of the beef and veal, by-product, and live cattle trading. The effects of the retail beef and feeder cattle markets are included in the diagram since these levels constitute the respective components of primary demand and primary supply. Overall, the figure demonstrates that marketing group behavior is related to output prices, input prices, and other factors specific to each level. Inclusion of both output and input prices in the fgure implies the influence of marketing margins and, thus, emphasizes market level interdependency (George and King, 1971, pp. 32-33)

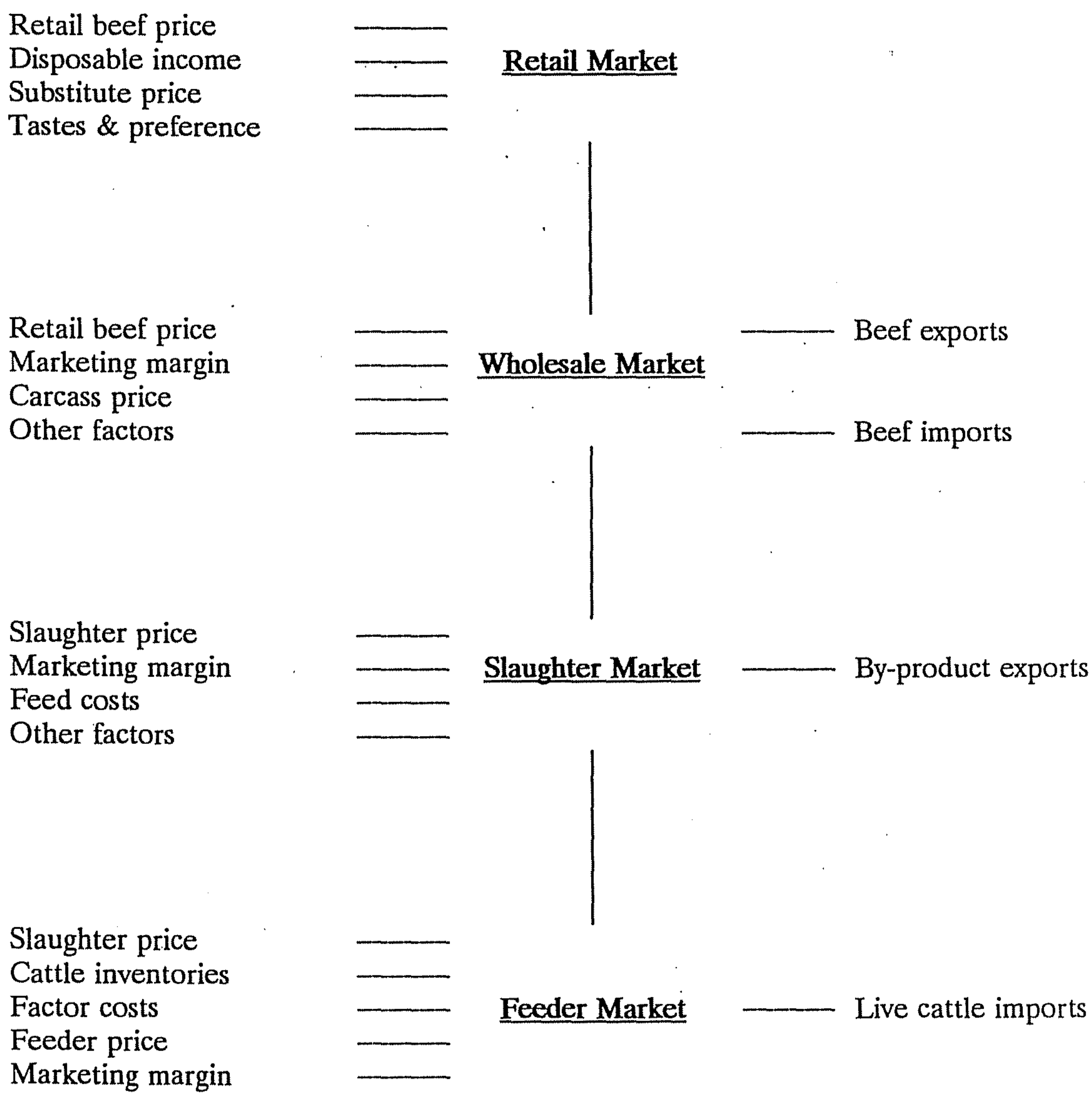


Figure 3. Flow chart of conceptual beef model

Domestic Carcass Demand and Supply

The following equations represent the derived demand and derived supply of beef arcasses:

$$Q_d^{car} = f_1 ( P^{car},\ P^{bf} ; Y_d,\ P^{ck},\ P^{pk} ) \qquad \text{(demand)}$$

$$Q_s^{car} = f_2 ( Q_d^{sl},\ M ) \qquad \text{(supply)}$$

$$Q_d^{car*} = Q_s^{car*} \qquad \text{(market clearing)}$$

where,

$Q_d^{car}$ : Quantity demanded of carcasses, carcass weight, mil.lb.

$Q_s^{car}$ : Quantity supplied of carcasses, carcass weight, mil.lb.

$P^{car}$ : Steer beef carcass price, choice grade, 600-700 lb., $/cwt, Chicago.

$P^{bf}$ : Price of retail beef, choice grade, cents/lbs, U.S. average.

$Y_d$ : U.S. per capita disposable income, dollars.

$P^{ck}$ : Wholesale broiler price, ready to cook, 9 city weighted average, cents/lb.

$P^{pk}$ : Wholesale pork price, cents/lb., U.S. average.

$Q_d^{sl}$ : Quantity demanded of slaughter cattle, number of cattle and calves slaughtered, 1,000 h.

$M$ : Farm-retail marketing margin for beef, cents/lb.

The quantity demanded of carcasses (by retailers) is a function of the carcass input price, retail beef output price, per capita disposable income, and prices of substitutes. The derived demand for carcasses should also depend upon a marketing margin variable defined as the difference between the price of retail beef and the price of carcasses. However, a margin variable in derived demand may be omitted when the price of the lower market ($P^{car}$) and price of the higher market ($P^{bf}$) are jointly included (George and King, 1971).

Since retail demand is not modeled in the system, the demand for carcasses should necessarily include arguments underlying primary demand such as per capita disposable income and prices of substitutes, i.e., pork and chicken. A priori quantity demanded of carcasses should have a negative own price effect, positive output price effect, and positive income and substitution effects for normal goods.

The domestic carcass supply equation indicates carcasses supplied by meat packers are determined by quantities of cattle that are slaughtered and a marketing margin. Specifically, the domestic carcass supply function is recursively determined from the domestic slaughter demand model which, in turn, depends upon factor prices and output prices at the slaughter level. The marketing margin is defined as the difference between retail and slaughter level prices (costs over time, space, and form) and is specified to be a shifter of derived carcass supply. *Ceteris paribus,* an increase in the margin shifts the derived supply schedule upward causing a higher price at the wholesale level of the market (Tomek and Robinson, 1981).

Beef and Veal Import Demand and Supply

The following equations represent U.S. import demand and supply of beef and veal:

$QM_d^{bv} = f_3 ( P^{car}, Y_d, P^{ck}, P^{pk} )$ (import demand)

$QM_s^{bv} = f_4 ( P^{car}, P_w^{car}, TRG_{us}, EXR, W_f )$ (import supply)

$QM_d^{bv*} = QM_s^{bv*}$ (market clearing)

where,

$QM_d^{bv}$ : U.S. import demand of beef and veal, carcass weight, mil.lb.

$QM_s^{bv}$ : U.S. import supply of beef and veal, carcass weight, mil.lb.

$P^{car}$ : Steer beef carcass price, choice grade, 600-700 lb., \$/cwt, Chicago

$Y_d$ : U.S. per capita disposable income, dollars.

$P^{ck}$ : Wholesale broiler price, ready to cook, 9 city weighted average, cents/lb.

$P^{pk}$ : Wholesale pork price, cents/lb., U.S. average.

$P_w^{car}$ : Weighted average price of Australian and New Zealand beef carcasses, \$/cwt.

$TRG_{us}$ : U.S. trigger level of beef and veal imports.

EXR : Weighted average of Australian and New zealand exchange rates in terms of dollars.

$W_f$ : Average hourly earnings per production worker in food manufacturing industry, dollars.

Beef imported into the U.S. is generally lower quality meat, i.e., hamburger and processed meat, than the domestic table cuts of Select and Choice grades. These imports usually occur at the packer-processing level of the market. Total U.S. demand for beef and veal consists of the horizontal summation of domestic demand and import demand. Accordingly, import demand for low quality beef would be considered a function of U.S. carcass prices, disposable income, and prices of substitutes.

Total U.S. beef demand, however, is not an aggregate demand of homogeneous commodities. In other words, domestic demand includes consumption of domestically produced processed and table cut beef while import demand is the demand for hamburger and other processed beef. Research separating U.S. beef demand into table cut beef and processed meats is quite limited since separate price data for the two classes of beef meat are not consistently available. Hunt (1972)[1] isolated price and income elasticities of

[1]These results are summarized and discussed in Houck (1974).

demand for table cut beef and processed beef. Based upon three stage least squares estimation, the price elasticity of table cut beef was -2.03 and that of processed meat was -1.35. Income elasticities were .92 and .20, respectively. Even though processed meat price data is a necessary argument in the beef and veal import demand function, carcass price data including both table beef and processed beef are used, requiring careful interpretation of the results. A priori an increase in U.S. carcass price increases domestic excess demand for lower quality beef so that the import demand for beef and veal would be expected to increase.

The supply of beef and veal imports is expected to be determined by U.S. carcass price, world market carcass price, exchange rates, wage rates in the meat packing industry, and the quota trigger level given of the U.S. meat import law of 1972. The supply of beef and veal imports is expected to have a positive relationship with U.S. carcass price and a negative relationship with Australian and New Zealand carcass prices. Under the U.S. meat import law, the trigger level of beef and veal imports serves as a constraint to import supplies; ceteris paribus, an increase in the trigger level would increase import supplies. Exchange rates are also specified in the theoretical model since their values influence the amount of revenue foreign exporters earn from trade. Wage rates in the meat packing industry is also a factor affecting import supply. Langemeier and Thompson (1967) argued that exporters of beef carefully observe labor costs in the meat packing industry. For example, import supplies of beef increase when wage rates increase because meat packers reduce domestic production and buy relatively cheaper beef from foreign countries.

Beef and Veal Export Demand and Supply

In this model, export demand and supply relationships for beef and veal pertain primarily to Japan and the United States. Historically, Japan has been the largest importer of U.S. table cut beef and future trade is expected to continue growing. The Japanese market offers attractive conditions for U.S. exporters such as higher prices, payment in hard currency, and stable export demand; it is also the only market for which U.S. sales are not dependent on export subsidies under the Export Enhancement Program (Alston, et al., 1989).

From a theoretical standpoint, exports of beef and veal from the U.S. to Japan is given as the horizontal difference between U.S. domestic supply deducting domestic demand and all other foreign demand; imports of U.S. beef and veal by Japan is given as the horizontal difference between Japanese domestic demand deducting domestic supply and all other import supplies. Consequently, the intersection of Japanese excess demand and U.S. excess supply determines prices and quantities in beef trading, assuming other trade factors unchanged. The following equations represent export demand and supply for U.S. produced beef and veal:

$$QX_d^{bv} = f_4\,(\,P_{diff},\ Y_{jap},\ EXR,\ Quota\,) \qquad \text{(export demand)}$$

$$QX_s^{bv} = f_5\,(\,P_{us}^{car},\ Quota\,) \qquad \text{(export supply)}$$

$$QX_d^{bv*} = QX_s^{bv*} \qquad \text{(market clearing)}$$

where,

$QX_d^{bv}$ : Export demand of U.S. beef and veal by Japan, carcass weight, mil.lb.

$QX_s^{bv}$ : Export supply of U.S. beef and veal to Japan, carcass weight, mil.lb.

| | |
|---|---|
| $P_{us}^{car}$ | : U.S. steer beef carcass price, choice grade, 600-700 lb., $/cwt, Chicago. |
| $P_{jap}^{car}$ | : Japanese wholesale beef (carcass) price, Yen per Kg. |
| $P_{diff}$ | : Difference between Japanese and U.S. carcass prices ($P_{jap}^{car}$-$P_{us}^{car}$), adjusted by exchange rate and weight units (Kg to lb.) |
| Quota | : Japanese beef import quota, metric tons. |
| EXR | : Exchange rate, Yen per dollars. |
| $Y_{jap}$ | : Japanese national income, billion Yen per year. |

The specification of the price difference variable (Japanese carcass price - U.S. carcass price) in the model has implications of a trade margin. As the price difference increases (net of trade costs), Japanese distributors of imported beef would increase their demand for U.S. table cut beef since it is relatively cheaper. Furthermore, an increase in Japanese carcass price, U.S. price constant, would increase the Japanese beef import quota since one of its major purposes is to stabilize domestic wholesale beef prices. Based on these factors, the carcass price difference between Japan and the U.S. is expected to demonstrate a positive impact on the export demand of U.S. beef and veal.

In measuring the price elasticity of export demand for U.S. beef and veal, the price difference concept is thought to be meaningful. For example, Houthakker and Magee (1969) estimated price elasticities for both imports and exports using ratios of import prices to importer's domestic wholesale prices, and those of export prices of one country to that of another. They concluded the sign should be negative in both the import and export equations.

Japanese income is specified in the function as a demand shifter. A priori a positive income effect is hypothesized since table cut beef in Japan is considered to be a normal good. Many studies have indicated that the income elasticity of demand for beef in Japan is elastic since beef is preferred to pork and chicken.[2] However, the Japanese income elasticity of demand for U.S. beef and veal exports may not be elastic since moderate increases in beef imports have resulted from strong political groups supported by Japanese beef producers (Coyle, 1986). Another possible reason for expecting a relatively low Japanese income elasticity is that U.S. beef is considered a lower quality product than Japanese beef of the Wagyu cattle breed and dairy steers.[3]

Exchange rates, quotas, and tariffs are typical trade factors affecting imports and exports. A priori an increase in the exchange rate (Yen per dollar) would decrease Japanese demand for U.S. beef and veal since Japanese traders would pay more domestic currency to import the same quantities. In order to examine exchange rate influences, it is essential to understand Japanese importer and U.S. exporter vested interests in their currencies. The Japanese importer considers Yen prices of imported beef and veal weighed against the Yen prices of other goods and services within Japan. The U.S. exporters are concerned about export prices in terms of dollars received. If the value of the Yen were depreciated, raising the exchange rate of Yen per dollar, Japanese beef imports would become more expensive unless there was a drop in the dollar price of U.S. beef and veal. U.S. beef and veal exporters, on the other hand, would tend to meet a lower dollar price on beef sales to Japan unless the Yen price were raised by the same

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[2]Dyck (1988) reviewed 13 previous studies on the Japanese income elasticity for beef and found that an income elasticity between 1 and 2 is generally observed. Also, using his statistical results, he argued that beef is an income-elastic food in Japan, with the significant estimates ranging from .87 to 2.62.

[3]Wagyu is the Japanese original beef cattle and its meat is high quality. Several previous studies on the Japanese beef grade are discussed in Mori et al. (1987, p. 2). For example, Faminow (1987) found the grade of fed beef imported from U.S. may correspond to that of Japanese fed dairy beef, 3rd grade, and that the wholesale price of Wagyu beef, 2nd grade, is approximately 40 to 50 percent higher than that of fed dairy beef. Coyle(1983) equated the qualities of U.S. Choice beef and Wagyu beef.

percentage devaluation. Therefore, it is hypothesized that Japanese export demand for U.S. beef and veal should demonstrate a negative relationship with the exchange rate.

Beef and veal trade between the U.S. and Japan also depends heavily on the Japanese beef import quota. This quota is set by the Japanese government, as it considers such factors as levels of domestic production, wholesale prices, etc. Governments often prefer quotas to tariffs in regulating imports since quotas can improve the balance of payments by limiting import quantities and they also grant governments greater administrative flexibility and power in dealing with domestic firms (Lindert, 1986, p. 167). Anderson (1983) argued that Japan uses beef import quotas instead of tariffs in order to acquire specific supplies from specific countries. Alston et al. (1989) also argued that the Japanese government has manipulated both beef and wheat quotas favorably for the United States. These results suggest that the quota is critical to beef and veal trade between the U.S. and Japan. Overall, it is expected that export demand for U.S. beef would increase as the Japanese beef import quota increases.

The export supply equation indicates that U.S. exports of beef and veal to Japan are determined by the U.S. carcass price and Japanese beef import quota. The U.S. price is a direct factor that determines excess supply; a priori, an increase in U.S. carcass price may decrease the Japanese desire to import U.S. beef and veal (given Japanese carcass price is not raised), consequently, decreasing U.S. export supply to Japan. Overall, it is assumed that U.S. beef and veal export supplies are negatively correlated with domestic carcass price.

It is assumed that the U.S. export supply to Japan is also affected by major institutional constraints. Thus, U.S. beef and veal export supply would depend heavily upon the Japanese beef import quota since it is a direct constraint on penetrating the Japanese market and satisfying consumer demand. A priori an increase in the quota would increase U.S. beef and veal export supply, particularly since Japanese imports constitute a large share of U.S. foreign trade in beef and veal and there exists preferential quota treatment of U.S. produced beef (Alston et al., 1989).

## Domestic Slaughter Demand and Supply

The following equations represent domestic slaughter demand and supply for live cattle:

$$Q_d^{sl} = g_1 ( P^{sl},\ P^{car},\ W_f,\ BPVF,\ BPVC ) \qquad \text{(demand)}$$

$$Q_s^{sl} = g_2 ( P^{sl},\ P^{fd},\ P^{crn} ) \qquad \text{(supply)}$$

$$Q_d^{sl*} = Q_s^{sl*} \qquad \text{(market clearing)}$$

where,

$Q_d^{sl}$ : Quantity demanded of slaughter cattle, number of cattle and calves slaughtered, 1,000 head.

$Q_s^{sl}$ : Quantity supplied of slaughter cattle, number of cattle and calves slaughtered, 1,000 head.

$P^{sl}$ : Choice slaughter steer price, 900-1,100 lb., \$/cwt, Omaha.

$P^{car}$ : Steer beef carcass price, choice grade, 600-700 lb., \$/cwt, Chicago.

$W_f$ : Average hourly earnings per production worker in food manufacturing industry, dollars.

BPVF : Farm by-product allowance, portion of gross farm value attributed to edible and inedible by-products, cents/lb.

BPVC : Carcass by-product allowance, portion of gross carcass value attributed to fat, bone, and trim, cents/lb.

$P^{fd}$ : Feeder steer prices, medium #1 frame, 600-700 lb., \$/cwt., Kansas City.

$P^{crn}$ : Price of #2 yellow corn, \$/bushel, Omaha.

Meat packers purchase fed and nonfed slaughter cattle and produce outputs such as carcasses, boxed beef, and by-products such as hides, offals, and tallows, etc. Therefore, output prices and input prices are important variables in derived slaughter demand. As profit maximizers, meat packing firms would demand more slaughter cattle when output prices rise and/or when factor prices decrease.

Wage rate in the food manufacturing industry was specified in the model as a cost factor that shifts the derived demand by meat packers. Wages are usually included in the marketing margin; thus, an increase in packer wages shifts the derived supply back at the carcass level and shifts the derived demand downward at the slaughter level. As a result, the price of carcass rises and the price of slaughter cattle falls with a decrease in equilibrium quantities marketed. Thus, a negative relationship between wage rate and quantity demanded of slaughter is hypothesized.

Because meat packers produce joint products, the prices of farm and carcass by-products should also impact slaughter demand. By-products are critical to meat packers since the revenue they generate covers slaughter costs and profit margins (Ward, 1980). A priori by-product values are expected to be positively related to the demand for slaughter cattle.

The domestic slaughter supply equation is composed of the price of slaughter cattle, the price of feeder cattle, and the price of corn. Cattle slaughtered by U.S. meat packers are primarily supplied by feedlot operators, grass fed operators, and cow-calf operators (i.e., cull cows). A priori feedlot operators and grass fed producers will supply more slaughter cattle when the price of slaughter cattle rises and/or the price of feeder or stocker cattle falls. Feedlot suppliers also respond to changes in feed costs (ie, corn price) by adjusting their marketing patterns (Brester and Marsh, 1983). For example, if there were an increase in the price of corn, fed cattle marketings would increase within year t since it would be more costly to carry cattle over to heavier weights in year t+1.

Live Cattle Import Demand and Supply

The following equations represent import demand and supply for live cattle:

$QM_d^{fd} = g_3 ( P^{fd}, INV, RNG )$ (import demand)

$QM_s^{fd} = g_4 ( P^{fd}, P_w^{fd}, INV_w )$ (import supply)

$QM_d^{fd*} = QM_s^{fd*}$ (market clearing)

where,

$QM_d^{fd}$ : U.S. import demand of stocker and feeder cattle from Canada and Mexico, 1,000 head.

$QM_s^{fd}$ : U.S. import supply of stocker and feeder cattle from Canada and Mexico, 1,000 head.

$P^{fd}$ : Feeder steer prices, medium #1 frame, 600-700lb., $/cwt., Kansas City.

INV : U.S. inventory of cattle on farms, January 1., 1,000 head.

RNG : U.S. range conditions for the states of the southwest, percentage.

$P_w^{fd}$ : Feeder steer prices in Canada and Mexico.

$INV_w$ : Inventory of cattle in Canada and Mexico, 1,000 head.

Feeder cattle price is specified in the demand equation since it is a direct cost factor in purchasing feeders and stockers from Canada and Mexico. A trade margin which is the price difference between the importer and exporter could also explain import demand (Houthakker and Magee, 1969; Kulshreshtha and Wilson, 1972); however, the simple specification of U.S. feeder price is meaningful since its change would indicate whether more or less cattle from these countries should be imported. A priori, an increase in U.S. feeder price would encourage more imports since cattle buyers could purchase relatively cheaper feeders and stockers, given they meet basic quality specifications. Alternatively, an increase in U.S. feeder cattle price directly increases domestic excess demand so that U.S. import demand for live cattle increases.

The January 1 inventory of cattle on farms is included in the model to serve as a stock variable. A priori the previous year's stock of cattle will affect future import demand of feeder and stocker cattle. For example, if there were an increase in inventories, there would be an expected decline in live cattle imports.

Factors such as pasture and weather conditions can affect the quantity of U.S. stocker and feeder cattle imports. Other variables constant, an improvement in pasture conditions would increase the demand for live cattle imports as stocker operators desire to utilize improved available pasture. For cattle feeders, improved weather conditions could mean an increase in feed supplies and, thus, lower feed prices.

Live cattle import supplies from Canada and Mexico are hypothesized to be determined by the U.S. price of feeder cattle, Canadian and Mexican prices of feeder cattle, and cattle inventory in Canada and Mexico. The import supply of feeder cattle from Canada and Mexico should be positively correlated with the U.S. price, Canadian and Mexican cattle inventory, and negatively associated with the feeder cattle price in Canada and Mexico.

Foreign Trade in By-Products (Hides, Skins, and Variety Meats)

U.S. beef by-products at the farm level basically include hides, skins, and offals. Foreign trade in farm-level by-products is important for several reasons. First, some beef specialty products are not highly preferred by U.S. consumers, as characterized by relatively low income and price elasticities of demand. Second, hides and offals are joint products in the meat packing industry so that their price elasticity of supply may be very low. Third, sales of by-products are critical sources of revenue for meat packers; however, domestic demand alone is not sufficient to sustain these needed revenues.

Since farm level by-products include several items, it is ideal to specify their separate quantities in the theoretical model to avoid aggregation bias. Likewise, prices of the separate items should be incorporated in the model. The theoretical model is composed of four foreign trade structural equations: hide and skin export demand and supply, and variety meat export demand and supply. These equations are presented as follows:

$$QX_d^{hd} = f\,(\,QP_w^{hd},\ P_{us}^{hd},\ P_w^{hd},\ Y_w,\ EXR\,) \qquad \text{(export demand)}$$

$$QX_s^{hd} = f\,(\,QP_{us}^{hd},\ P_{us}^{hd},\ P_w^{hd},\ EXR,\ Quota\,) \qquad \text{(export supply)}$$

$$QX_d^{vm} = f\,(\,QP_w^{vm},\ P_{us}^{vm},\ P_w^{vm},\ Y_w,\ EXR\,) \qquad \text{(export demand)}$$

$$QX_s^{vm} = f\,(\,QP_{us}^{vm},\ P_{us}^{vm},\ P_w^{vm},\ EXR,\ Quota\,) \qquad \text{(export supply)}$$

$$QX_d^{hd*} = QX_s^{hd*} \qquad \text{(market clearing)}$$

$$QX_d^{vm*} = QX_s^{vm*} \qquad \text{(market clearing)}$$

where,

$QX_d^{hd}$ : Export demand for U.S. hides and skins, 1,000 pieces.

$QX_s^{hd}$ : Export supply of U.S. hides and skins, 1,000 pieces.

$QX_d^{vm}$ : Export demand for U.S. variety meats, 1,000 metric tons.

$QX_s^{vm}$ : Export supply of U.S. variety meats, 1,000 metric tons.

$QP_{us}^{hd}$ : U.S. production of hides and skins, metric tons.

$QP_w^{hd}$ : World production of hides and skins, metric tons.

$QP_{us}^{vm}$ : U.S. production of variety meats, 1,000 metric tons.

$QP_w^{vm}$ : World production of variety meats, 1,000 metric tons.

$P_{us}^{hd}$ : U.S. price of hides and skins, \$/piece.

$P_w^{hd}$ : Prices of hides and skins in importing countries, \$/piece.

$P_{us}^{vm}$ : U.S. price of variety meats, \$/lb.

$P_w^{vm}$ : Prices of variety meats in importing countries, \$/lb.

$Y_w$ : Importing countries' national income.

$EXR_w$ : Importing countries' exchange rates.[4]

$Quota_w$ : Importing countries' quota.

The export demand equations for hides, skins, and variety meats are determined by production in the rest of the world, U.S. prices, prices of by-products in major importing countries (such as Korea and Japan), income of importing countries, and exchange rates. The change in world production would be negatively related to export demand. U.S. prices and importing countries' prices represent the concept of a trade margin in the model. The lower are U.S. prices and the higher are importing countries' prices, the more export demand would be expected to increase. Exchange rates are expected to display a negative sign on export demand while a positive sign for the income variable would be expected assuming the commodities are normal goods.

The export supply equations for hides, skins, and variety meats are hypothesized to be a function of U.S. production, U.S. prices, prices in major importing countries (such as Japan and E.C.), exchange rates, and import quotas. Export supply should have a positive relationship with U.S. production, prices in importing countries, and import quotas. U.S. prices and exchange rates are expected to be negatively associated with export supply.[5]

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[4]Currencies of importing countries per dollar (Won/\$, Yen/\$, etc.)

[5]Application of well known trade models such as the Armington model (Chapter 11, Embargoes, Surplus Disposal, and U.S. Agriculture, USDA, 1989) may be more appropriate for by-product export demand and supply since several types of products and several different regions are involved. However, introduction of such models makes the issues of this study more complex.

One of the major problems in estimating the theoretical model above is the availability of appropriate data. For example, price data for separate items of farm level by-products are not available so that a total farm by-product price must be used, which may introduce some aggregation bias. Furthermore, the theoretical equations include foreign variables for which data are not available. Therefore, the equations of the theoretical model must be modified (see following) for estimation purposes. These modifications are a combinations of the Farris (1971) and Blake and Clevenger (1980) by-product models.

The purpose of the structural demand and supply specifications above is to provide the basis for determining the value of farm by-products. Such a relationship can be given in a reduced form equation, shown as follows:

$$BPVF = g_4\ (\ QP_{bp},\ \ Y_d,\ \ P^{hl},\ \ QX^{hd},\ \ Qx^{vm}\ )$$

where,

- BPVF : Farm by-product allowance from choice yield grade #3 steers, portion of gross farm value attributed to edible and inedible by-products, cents/lb.
- $QP_{bp}$ : U.S. production of by-products at farm level, mil.lb.[6]
- $Y_d$ : U.S. per capita disposable income, dollars.
- $P^{hl}$ : U.S. producer price index for hides, skins, leathers, and related products, 1982=100.
- $QX^{hd}$ : U.S. exports of hides and skins to the rest of the world, 1,000 pieces.
- $QX^{vm}$ : U.S. exports of variety meats to the rest of the world, metric ton.

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[6] $QP_{bp}$ is a proxy variable for annual pounds of farm level by-products produced in the U.S. This figure is calculated from the following formula: annual BPVF production = annual average live weight - annual average dressed weight. Overall the estimate does not represent exact pounds of farm level by-product production but is a broader figure by including hide, head meat (tongue, brain), innards, feet, rumen, intestines, heart, liver, spleen, kidney, etc. However, hides and offals are the major items of this figure and still useful for analysis.

Farm level by-product value represents the aggregate price of by-products composed primarily of hides, skins, and offals. The explanatory variables consist largely of two groups[7,8]: variables in the domestic market which are $QP_{bp}$, $Y_d$, and $P^{hl}$, and variables in the foreign market which are $QX^{hd}$ and $QX^{vm}$.

The domestic price of farm level by-products is assumed to be negatively affected by quantity of by-products produced. Smith and Goodwin (1989) argue that U.S. beef specialty products such as liver, kidney, heart, tongue, tripe, sweetbreads and brains are inferior goods; thus, the income effects would be negative. However, the income effect for hides and skins is somewhat ambiguous. For example, high quality hides and skins that are imported or domestically produced may be normal goods while exports of U.S. hides

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[7]These arguments actually are based upon the following by-product domestic market equations:

$Q_d^{hd} = f(P^{hd}, Y_d, P^{hl})$ (export demand)
$Q_s^{hd} = f(P^{hd}, Q_s^{sl})$ (export supply)
$Q_d^{vm} = f(P^{vm}, Y_d, P^{hl})$ (export demand)
$Q_s^{vm} = f(P^{vm}, Q_s^{sl})$ (export supply)
$Q_d^{hd*} = Q_s^{hd*}, Q_d^{vm*} = Q_s^{vm*}$ (market clearing)

where
$P^{hd}$ : U.S. price of hides and skins
$P^{vm}$ :U.S. price of variety meats
$Q_s^{sl}$: Domestic supply of slaughter cattle

[8]Blake and Clevenger (1980) argued that by-product value can be determined only by demand factors since by-product supply is not a function of own price, i.e., by-products are produced in fixed productions to slaughter cattle and carcasses. Their reasoning is correct in the case of non-market goods or if the price of by-products is quite small relative to the major product price. However, producers may be concerned about total revenues since the cost function is for a composite unit of by-products and carcasses. Producers will be indifferent between, for example, sales of by-products for \$1 and carcasses for \$10 or sales of by-products for \$10 and carcasses for \$1. Therefore, demand conditions may determine price, given competition (Stigler, 1987, p. 165). However, this does not mean that the by-product supply is not a function of own price. Evidently, the revenue from by-products is an important source to cover losses from carcass production in the U.S. meat packing industry (Brester and Marsh, 1983).

and skins may be inferior goods if they are of lower quality. Overall, the theoretical income effect on farm level by-products is not clear due to these possibilities but would be left to the empirical results.

The producer price index for hides, skins, leather and related products was included in the model to capture the impact of output price. A single output price for by-products is not ideal since various commodities are produced from farm-level by-products. For example, the analysis might be improved if the price of variety meat was available. However, even with limited data, the output price of hides and leathers is meaningful since hide value constitutes a large share of by-product value. Economic theory indicates that an increase in output price would result in expanding of a firm's supply and hence factor demands for inputs.

In order to consider the foreign trade effects on domestic by-product price, U.S. exports of hides, skins and exports of variety meats were thought to be important variables. In the very short term, the U.S. domestic price of by-products could rise as the U.S. export supply of by-products increases, i.e., more by-products are sold to the world market, decreasing the domestic supply. However, if the share of U.S. supply in the world by-product market is sufficiently large, the increase of U.S. exports may depress world price of by-products,[9] given enough time for the world market to adjust. The U.S. by-

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[9]The U.S. exports take about one-half of the world's trade in variety meats (USDA, *Dairy, Livestock, and Poultry: U.S. Trade and Prospects*, 1989). The United Stated is the largest cattle hide production country with 24 percent of total world production and exports approximately 55 percent of its production each year (USDA, *Dairy, Livestock, and Poultry: U.S. Trade and Prospects,* 1989). Therefore, it is plausible to expect that the increase of U.S. exports of by-products(hides, skins, and variety meats) depress the world market price. How fast the world market price drops according to the increase of U.S. exports depends largely upon U.S. world market share, price elasticity, and market situation specific to that year. Similar reasoning can be found in Blake and Clevenger (1980).

product price could fall due to the increase of domestic supply as world market price falls. For annual data, a negative relationship is expected between domestic by-product price and U.S. exports of hides, skins and variety meats.

## Estimation Procedures

### Distributed Lag Analysis

It is hypothesized that a rational distributed lag framework would be appropriate in capturing the dynamics inherent in demand, supply, and trade behavior of the beef wholesale and slaughter markets. These lags exist because of partial adjustments from institutional constraints, biological factors, and expectations of market participants. Jorgenson's (1966) rational distributed lag model can be employed to approximate an infinite distributed lag structure. It is a more general form than Koyck's (1954) geometric lag model, Nerlove's (1956) partial adjustment model and Cagan's (1956) adaptive expectations model.

The general form of a flexible dynamic model as shown by Harvey (1981) can be expressed as:

$$Y_t = \frac{\alpha(L)}{\lambda(L)} X_t + \frac{\gamma(L)}{\phi(L)} \vartheta_t \qquad (2.1)$$

where $\upsilon_t$ is Gaussian white noise. The parameter expressions are given as:

$$\alpha(L) = \alpha_o + \alpha_1 L + \alpha_2 L^2 + \cdots + \alpha_m L^m$$

$$\lambda(L) = 1 + \lambda_1 L + \lambda_2 L^2 + \cdots + \lambda_n L^n$$

$$\gamma(L) = 1 + \gamma_1 L + \gamma_2 L^2 + \cdots + \gamma_p L^p$$

$$\phi(L) = 1 + \phi_1 L + \phi_2 L^2 + \cdots + \phi_q L^q$$

The general form of Jorgenson's rational distributed lag model is very similar to equation (2.1) shown as:

$$Y_t = R(L)\, X_t = \frac{\alpha(L)}{\lambda(L)}\, X_t + e_t \tag{2.2}$$

where $e_t$ is a disturbance term, R(L) is a rational generating function represented by the ratio of two polynomials lag operators $\alpha$(L) and $\lambda$(L) of degrees m and n, respectively. The lag operator L is given as $L^k X_t = X_{t-k}$. According to Jorgenson this distributed lag can approximate any arbitrary lag structure with sufficiently high values of m and n.

Multiplying both sides of equation (2.2) by the normalized $\lambda$(L) yields the autoregressive form

$$\lambda(L)\, Y_t = \alpha(L)\, X_t + \lambda(L)\, e_t$$

such that

$$(1 + \lambda_1 L + \cdots + \lambda_n L^n)\, Y_t = (\alpha_o + \alpha_1 L + \cdots + \alpha_m L^m)\, X_t + e_t^*$$

where $e^*_t = \lambda(L)\, e_t$ and is autocorrelated. The empirical form of the rational distributed lag is expressed as:

$$Y_t = \alpha_o X_t + \alpha_1 X_{t-1} + \cdots + \alpha_m X_{t-m} - \lambda_1 Y_{t-1} - \lambda_2 Y_{t-2} - \cdots - \lambda_n Y_{t-n} + e^*_t$$

The stability of the function is important when considering the behavior of distributed lag impacts. Generally, the function is stable when $\Sigma\, \lambda_j < 1.0$, where $\lambda_j$ represents the coefficients of the lagged dependent variables. In this case, the long run marginal effects will asymptotically converge to zero.

The characteristic roots of, for example, a second order difference equation are important in determining the time path of the distributed lag process. If there exists one real root, the result is a Pascal distributed lag, i.e., $\lambda^2_1 + 4\lambda_2 = 0$. If $\lambda^2_1 + 4\lambda_2 > 0$, two real roots exist and the result is a peak effect in period t+i and a dampening factor thereafter. If $\lambda^2_1 + 4\lambda_2 < 0$, the roots are complex and the function oscillates over time approaching an equilibrium state.

The long run elasticity responses can be calculated using the estimated slope and difference equation coefficients of the distributed lag model. For example, given a function as follows:

$$Y_t = \beta_1 X_t + \beta_2 X_{t-1} + \lambda_1 Y_{t-1} + \lambda_2 Y_{t-2} + U_t$$

the long run partial derivative is the summation of the coefficients specific to the lagged independent variable divided by $1 - \Sigma\lambda_j$. Therefore, the long run elasticity computed at the mean values of the variables is given as:

$$\frac{\partial Y^*}{\partial X^*} \cdot \frac{\overline{X}}{\overline{Y}} = \frac{\beta_1 + \beta_2}{1-(\lambda_1 + \lambda_2)} \cdot \frac{\overline{X}}{\overline{Y}}$$

Determining the proper lag order of the rational lag model relies little on economic theory. Rather, the data play a strong role in the lag structure as revealed by relevant statistical tests. Griliches (1967) indicated that, in practice, one would not be interested in polynomial orders higher than two or three. Higher order polynomials result in distributions very similar to the Pascal distribution, and the shape of the distribution is very sensitive to parameter values.

In this study, the choice of the empirical lag structure was based upon the joint criteria of adjusted $R^2$'s, the standard errors of estimate, and the asymptotic t-ratios. The initial lags were set as first order difference equations with first order lags on the independent variables, and the equations were then separately tested (using the mentioned criteria) by augmenting and truncating the lag structure.

Development of Estimation Procedures

Several violations of the classical linear regression model are inherent in the beef model. First, some behavioral equations include endogenous explanatory variables such as price of retail beef, price of carcass, price of slaughter cattle, and price of feeder cattle. Economic theory suggests that meat and live cattle prices are jointly determined within the demand and supply relationships. In the case of jointly endogenous models, application of OLS regression yields inconsistent parameter estimates as demonstrated through the formula:

$$Plim\hat{\beta}_i = \beta_i + Plim(\frac{1}{N}H^T H)^{-1} \; Plim(\frac{1}{n}H^T \varepsilon_i) \neq \beta_i, \; i=1,2,\ldots,n$$

where H is a matrix of explanatory variables and it is assumed Plim $(N^{-1}H'H)^{-1} = \Sigma_{HH}$ and is nonsingular and Plim $(N^{-1}H^{T}\varepsilon) \neq 0$. For any i the OLS estimator is inconsistent. In other words, only one non-zero element in the vector in Plim $(N^{-1}H^{T}\varepsilon)$ can make all the estimators of $\beta_i$ inconsistent. The reason is that the decomposition between the variation of explanatory variables and variation of the unknown factors is not valid when correlation exists between the independent variables and error term (Kmenta, 1971, p. 303).

Instrumental variables is a commonly employed technique to yield consistent estimates in jointly endogenous models. In this model the instruments used were the predicted values obtained from reduced equations whereby each right-hand-side endogenous variable was regressed on all exogenous and predetermined variables in the system.

Second, in many structural equations, serial correlation problems are expected due to the use of time series data. Consequently, the application of OLS to equations with autocorrelated disturbances still yields unbiased estimates but they are no longer minimum variance among all linearly unbiased estimators, thus, invalidating inference procedures based on the OLS formula that assume $\Sigma = \sigma^2 I$. Positive autocorrelation implies an underestimation of standard errors of coefficients (by the conventional OLS formula) and overestimation of t statistics and significance levels. The Generalized Least Squares (GLS) estimator is known to be Best Linear Unbiased Estimator (BLUE) and produces a more efficient estimator than OLS by minimizing a generalized residual sum of squares. However, a problem in GLS estimation is that $\rho$, an autoregressive parameter in the variance-covariance matrix of the disturbance vector($\Psi$), is unknown. Estimated Generalized Least Squares (EGLS) estimates $\Psi$ from the data and replaces the unknown $\Psi$ in the GLS procedure. The EGLS estimator is known to have desirable asymptotic properties (consistency and efficiency) if the estimator of $\Psi$ is consistent, even though it is not linear or unbiased. Several different techniques have been developed to produce EGLS (Judge et al., 1985, chapter 9).

The Cochrane-Orcutt (1949) iterative least squares procedure uses OLS on the transformed variables with new estimates of $\rho$ until successive estimates of $\rho$ are arbitrarily close. While the Cochrane-Orcutt procedure typically ignores the first observation, Beach-MacKinnon (1978) developed a maximum likelihood procedure that incorporates the first observation and is computationally efficient. Both the Cochrane-Orcutt iterative least squares and Beach-MacKinnon iterative procedures are used for estimating AR(1) and AR(2) error processes and the more favorable procedure is accepted in terms of standard errors of the estimate and t ratios. Pagan's least squares procedure (Judge et al., 1985, p. 257) is used for estimating an autoregressive error process of higher order than two.

The third problem in distributed lag estimation involves the presence of lagged dependent variables with autocorrelated errors. In this case, the lagged dependent variable is stochastic and is not independent of the disturbance process since the dependent variable is correlated with the contemporaneous disturbance term. With these problems, OLS yields inconsistent estimators of all parameters (Johnston, 1984, p. 363). Instrumental variables for the lagged dependent variables provide a consistent but inefficient estimator since it does not correct for correlated errors; however, the Maximum Likelihood (ML) method provides an asymptotically efficient estimator in such cases (Kennedy, 1985, pp. 118-119). Instrumental variables with the ML method is used for this problem, with the instrumental variables estimator providing a consistent estimator as a starting point in the iterative ML technique (Johnston, 1984, p. 366).

The fourth violation of the classical linear regression model is multicollinearity. Because market level prices in the beef industry generally move together, the presence of these price variables in the same structural equation introduces high interdependency within the regressions. Multicollinearity can be tested using condition numbers advocated by Belsley et al. (1980). In the presence of multicollinearity, the OLS estimator remains BLUE (with unaffected $R^2$) but the OLS coefficients are very sensitive to small variations in the data, and the sampling variances of the OLS coefficients increase sharply as collinearity among explanatory variables increases. Consequently, signs of the coefficients can be reversed from theoretical expectations and the estimated t ratios are smaller than true t values. There is usually no sure way to eliminate the problem since it is a property of the time series relationships in the data set.

Often recursive structures are involved in a system of equations. With a diagonal covariance error matrix between the equations, OLS yields consistent estimates in the lower order recursive equations if there are no lagged endogenous variables among regressors (Johnston, 1985, pp. 467-469). However, if the covariance structure of the error terms is not diagonal, OLS estimators are biased and inconsistent because the endogenous explanatory variables in the lower order equations are now contemporaneously correlated with their error terms. In this study, recursive structures exist between domestic slaughter demand and domestic carcass supply, and between foreign by-product trade and domestic slaughter demand.

In a study of this nature it is always possible that the system of equations possesses contemporaneous correlation of error terms. Zellner's Seemingly Unrelated Regression (SUR) method, which is based upon a consistent estimate of the covariance matrix, yields estimators that are consistent and asymptotically as efficient as the GLS estimator based on the true covariance matrix. However, these desirable properties no longer hold if there exists correlation between explanatory variables and error terms. The 3SLS estimator is known to be consistent and asymptotically more efficient than the 2SLS estimator for this problem. In this study, the seriousness of the SUR problem is tested by examining the correlation and covariance matrices of the equation error terms.

Overall, the instrumental variables technique and ML method are jointly employed in the beef model, which can be thought of as a modified 2SLS handling simultaneously the problems of jointly endogenous equations, nonspherical disturbances, and lagged dependent variables. If serial correlation does not exist with any of the other problems (joint dependency or lagged dependent variables), then the usual OLS estimator is used. In the empirical results, these problems are discussed equation by equation and the various statistical techniques employed are identified.

# CHAPTER 3

# EMPIRICAL RESULTS

This chapter provides the empirical results of the structural equations presented in Chapter 2. Tables 1-12 present the statistical results of the regression equations and the short-run, immediate-run (two periods), and long-run elasticities of demand and supply. Annual time series data from 1964 to 1988 were used to estimate the structural equations, and all price variables were deflated by the Consumer Price Index (1982-1984=100).

## Domestic Carcass Demand and Supply

The final carcass demand equation was estimated with a distributed lag structure on the independent variables and a second order autoregressive error process. The ML estimation method, along with instrumental variables, was used because of joint dependency and autocorrelation problems. The statistical results and estimated elastcities are presented in Tables 1 and 2. The highest order lag on the explanatory variables was one year (t-1) on the price of carcass, the price of retail beef, and wholesale broiler price while per capita disposable income and wholesale pork price showed only contemporaneous effects. All estimated coefficients had signs as theoretically expected and were significantly different from zero at the 1 percent significance level, except for broiler price which was significant at the 20 percent significance level.

The negative coefficient on carcass price implies that a higher factor price results in decreasing retailer carcass demand while the positive coefficient on retail beef price indicates a higher output price increases retailer carcass demand. On a yearly basis, a one dollar per hundredweight increase in carcass price decreases carcass demand by 323.9 million pounds in the current year and increases it by 89.3 million pounds in the following year, showing a net increase 234.6 million pound. For an increase in retail price by one dollar, carcass demand increases by 173.8 million pounds through a two year period. The short run demand elasticities are -1.68 and 1.55 and the long run elasticities are -2.14 and 1.99, respectively, for the two sets of prices. The long run represents a period of time when retailers can make complete adjustments to institutional, technical, and economic constraints in the market.

The positive signs on the coefficients of the substitutes, i.e., wholesale broiler price, agree with a priori expectations. These variables represent the arguments of primary demand that reflect the impacts at the retail market level. The price elasticity of pork (.14) is higher than the price elasticity of broiler (.08) while the short run income elasticity of carcass demand is .221. This implies that a 10 percent increase in per capita disposable income results in a contemporaneous increase of carcass demand by 2.2 percent.

The final carcass supply equation was a first order difference equation with a white noise error term. A recursive relationship with the slaughter demand equation was specified and instrumental variables was employed since the covariance of error terms between carcass supply and slaughter demand was nonzero, although the first order correlation coefficient was small (.2459). The statistical results and calculated elasticities are presented in Tables 1 and 2.

The independent variables were first order lags on the quantity of slaughter demanded, and marketing margin with a lagged dependent variable. All signs of the estimated coefficients are theoretically correct and are significant at 95 percent probability level.

Table 1. Statistical results for the domestic carcass demand and supply equations[a]

| Equation | Intercept | Explanatory Variables[b] | | | | | | | | Statistics[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $HP^{car}_{t}$ | $HP^{car}_{t-1}$ | $HP^{bf}_{t}$ | $HP^{bf}_{t-1}$ | $Y_{d,t}$ | $P^{ck}_{t}$ | $P^{ck}_{t-1}$ | $P^{pk}_{t}$ | $R^2$ | $S_y$ | D-W |
| $Q_d^{car}$ | 13763 | -323.88 | 89.288 | 135.65 | 38.102 | .3134 | 29.067 | 37.130 | 22.357 | .9512 | 329.86 | 2.501 |
| | | (-12.538) | (-4.174) | (10.437) | (3.516) | (8.264) | (1.577) | (4.276) | (3.276) | | | |
| | | $Q^{car}_{t-1}$ | $HQ^{sl}_{d,t}$ | $HQ^{sl}_{d,t-1}$ | $M_t$ | $M_{t-1}$ | | | | $R^2$ | $S_y$ | Dh |
| $Q_s^{car}$ | 1467.4 | .8888 | .3342 | -.2894 | 62.411 | -68.693 | | | | .8726 | 666.26 | -.386 |
| | | (6.404) | (6.556) | (4.563) | (2.776) | (2.764) | | | | | | |

[a] The t-ratios are given in parentheses under each coefficient.

[b] The letter 'H' before a variable indicates that it is an instrument.

[c] Regression test statistics are defined as: $R^2$= adjusted R-squared, $S_y$=standard error of the estimate, D-W=Durbin-Watson statistic, and Dh=Durbin's h statistic.

Table 2. Estimates of the short, immediate, and long run demand and supply elasticities for the domestic carcass demand and supply model

| Equation | | Explanatory Variables | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| (Demand) | | $P^{car}$ | $P^{bf}$ | $Y_d$ | $P^{ck}$ | $P^{pk}$ |
| $Q_d^{car}$ | S-R | -1.6769 | 1.5501 | .2214 | .0840 | .1372 |
| | I-R | -2.1392 | 1.9855 | .2214 | .1914 | .1372 |
| | L-R | -2.1392 | 1.9855 | .2214 | .1914 | .1372 |
| (Supply) | | $Q_d^{sl}$ | M | | | |
| $Q_s^{car}$ | S-R | .5899 | .2257 | | | |
| | I-R | .6034 | .1779 | | | |
| | L-R | .7113 | -.2043 | | | |

1) S-R: Short-Run, I-R: Intermediate-Run(2 periods), L-R: Long-Run.

2) The elasticities are calculated at the mean values of the variables and are given as:

$$\frac{\partial Q_t}{\partial X_{t-j}} \cdot \frac{\bar{X}}{\bar{Q}} \quad \text{where} \quad , \; j = 0, 1, 2, \cdots, n$$

The coefficient of the first order difference equation was .89, indicating that a 10 million pound increase in carcass demand in the current year is followed by an 8.9 million pound increase in carcass demand in the subsequent year. The first order difference equation is stable which means that the adjustment process of carcass demand approaches an equilibrium state given permanent shocks in the exogenous variables.[11]

Inclusion of slaughter demand in the equation incorporates information about factor demand and output supply at the slaughter level into the carcass supply function. The positive relationship between carcass supply and slaughter demand implies that as meat packers demand more slaughter cattle, more carcasses are supplied to the retail level. The coefficients show that a 10,000 head increase in the number of cattle slaughtered in the current year increases carcass supply in the current year by 3.3 million pounds. The elasticities of carcass supply with respect to slaughter demand in the short run, immediate run, and long run are .59, .60, and .71, respectively.

The negative sign of the marketing margin is consistent with the maintained hypothesis, i.e., an increase in the marketing margin reduces the derived supply of carcasses. The short run and long run margin elasticities are .226 and -.204, respectively, indicating that a 10 percent increase in marketing margin will increase carcass supply by 2.26 percent in the short run but will decrease carcass supply by 2.04 percent in the long run.

## Beef and Veal Import Demand and Supply

The beef and veal import demand equation incorporated lagged dependent variables, endogenous variables as regressors, and an autocorrelated error term. The ML estimation

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[11]The function is stable when $\Sigma \lambda_j < 1$, where $\lambda_j$ represents the coefficients of the lagged dependent variables. The long-run marginal effects asymptotically vanish to zero in a stable function.

procedure and instrumental variables for the lagged dependent variables ($HQM^{bv}_{t-1}$, $HQM^{bv}_{t-2}$) and endogenous right-hand-side variables ($HP^{car}_{t}$, $HP^{car}_{t-1}$) were employed. Tables 3 and 4 give the estimation results and elasticities.

The final specification of beef and veal import demand was a second order difference equation with a fourth order serially correlated error process. The high order autoregressive term is a possible indication of misspecification in the beef and veal imports such as institutional and political impacts in trade negotiations. First order lags resulted on carcass price and pork price while contemporaneous values were specific to income and broiler price. All signs were consistent with a priori expectations and were significantly different from zero at the 5 percent significance level, except that broiler price displayed a wrong sign and statistical insignificance.

The summation of the difference equation coefficients indicates the function is stable; also, the characteristic roots of the second order difference equation are real.[12] Therefore, the long run impacts of the exogenous variables on beef and veal imports asymptotically converge to zero with a relatively quick dampening factor given by $\lambda_2$=.26.

The first order lag on carcass price (along with the difference equation coefficients) indicates that carcass prices affect beef and veal imports both contemporaneously and in a distributed lag framework. It was hypothesized that U.S. carcass prices are positively related to the import of beef and veal. The estimated coefficient of contemporaneous carcass price is .980, implying that a $10 per hundredweight increase in carcass price

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[12]These roots are critical in determining the time path of the distributed lag process. If $\lambda^2_1 + 4\lambda_2 = 0$, where $\lambda_j$ represents the coefficients on the lagged dependent variables, there exists one real root indicating a Pascal distributed lag process. If $\lambda^2_1 + 4\lambda_2 > 0$, two real roots exist which implies a peak effect at period t+i and a dampening distributed lag process thereafter. If $\lambda^2_1 + 4\lambda_2 < 0$, the roots are complex and the function is oscillating.

Table 3. Statistical results for the beef and veal import demand and supply equation[a]

| Equation | Intercept | Explanatory Variables[b] | | | | | | | | Statistics[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $HQM^{bv}_{t-1}$ | $HQM^{bv}_{t-2}$ | $HP_t^{car}$ | $HP^{car}_{t-1}$ | $Y_{d,t}$ | $P^{ck}_t$ | $P^{pk}_t$ | $P^{pk}_{t-1}$ | $R^2$ | $S_y$ | Dh |
| $QM_d^{bv}$ | 722.17 | .6935 | .2634 | .9795 | -12.427 | .0267 | -.6498 | -1.7832 | 4.707 | .9808 | 54.678 | -.9209 |
| | | (14.874) | (5.821) | (2.223) | (-23.021) | (16.087) | (-.369) | (-2.497) | (12.341) | | | |

| Equation | Intercept | $HQM^{bv}_{t-1}$ | $HP^{car}_t$ | $W_{f,t}$ | T | $R^2$ | $S_y$ | Dh |
|---|---|---|---|---|---|---|---|---|
| $QM_s^{bv}$ | -8005.9 | -.1944 | 5.5548 | 518.89 | 69.560 | .8391 | 141.56 | .9261 |
| | | (-1.541) | (1.707) | (3.208) | (4.5666) | | | |

[a] The t-ratios are given in parentheses under each coefficient.

[b] The letter 'H' before a variable indicates that it is an instrument.

[c] Regression test statistics are defined as: $R^2$= adjusted R-squared, $S_y$=standard error of the estimate, D-W=Durbin-Watson statistic, and Dh=Durbin's h statistic.

Table 4. Estimates of the short, immediate, and long run demand and supply elasticities for the beef and veal import demand and supply model

| Equation | | Explanatory Variables | | | |
|---|---|---|---|---|---|
| (demand) | | $P^{car}$ | $Y_d$ | $P^{ck}$ | $P^{pk}$ |
| $QM_d^{bv}$ | S-R | .0625 | .2326 | -.0232 | -.1349 |
| | I-R | -.6871 | .3939 | -.0392 | .1276 |
| | L-R | -16.9408 | 5.3938 | -.5370 | 5.1297 |
| (Supply) | | $P^{car}$ | $W_f$ | | |
| $QM_s^{bv}$ | S-R | .3545 | 2.3128 | | |
| | I-R | .2856 | 1.8633 | | |
| | L-R | .2968 | 1.9364 | | |

1) S-R: Short-Run, I-R: Intermediate-Run(2 periods), L-R: Long-Run.

2) The elasticities are calculated at the mean values of the variables and are given as:

$$\frac{\partial Q_t}{\partial X_{t-j}} \cdot \frac{\bar{X}}{\bar{Q}} \quad \text{where} \quad , \; j = 0, 1, 2, \cdots, n$$

increases imports by 9.8 million pounds. The negative sign on the first order lag was not expected but may reflect some meaningful information. The historical data show U.S. imports of beef and veal had serious fluctuations with a one to three year cyclical pattern. In other words, an import peak in year t usually lead to reductions in imports for year t+1 to year t+3. U.S. beef imports constitute a large share of Australia and New Zealand's exports; therefore, changes in U.S. imports in the current year are large enough for world prices to rise, causing U.S. imports to decline in the following year.[13] The short run price elasticity is very small (.063), indicating a 100 percent increase in carcass price would increase beef and veal import demand by only 6.3 percent. The very inelastic response could be expected since carcass price is an aggregate of processed meat and table cut beef. However, the long run elasticity showed a large negative number (-16.94) due to the large summation of the difference equation coefficients.

U.S. per capita disposable income showed a positive sign and the respective elasticities in the short run and long run are .23 and 5.39. The short run income elasticity of import demand is small, as expected, because imported beef is considered to be lower quality relative to U.S. table cuts. However, the large long run income elasticity reflects an extensive adjustment period as revealed by the large summation of the difference equation coefficients.

The substitutes for beef were expected to show positive coefficient signs. The price of pork demonstrated statistical significance and showed a positive substitution effect while broiler price was negative and insignificant. The results of the broiler price effect are attributed to serious multicollinearity. The evidence of the multicollinearity problem is the

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[13]In the world market for low quality beef, major exporters are Australia and New Zealand and major importer is United States.

high value of the partial correlation coefficient (among the explanatory variables) and the large condition number among the independent variables (1546.5).

The beef and veal import supply equation was estimated as a function of U.S. carcass price, wage rates, and trend variable. The trend variable partly captures information on trigger levels of U.S. beef and veal imports, world carcass prices and exchange rates of exporting countries. The final function was a first order difference equation with a first order autoregressive error. Because of the joint problems of a lagged dependent variable and autocorrelated errors, the ML method and instrumental variable techniques were employed. The statistical results and elasticities are given in Tables 3 and 4.

The coefficient of the first order difference equation is significant at the 80 percent probability level and indicates a stable geometric lag process. The distributed lag pattern of carcass import supply implies a choppy geometric adjustment after initial shocks in the exogenous variables (due to the negative coefficient); however, the lag process appears to dissipate within a relatively short period. The application of Tomek and Cochrane's (1962) adjustment formula[14] reveals that 95 percent of the equilibrium adjustment in beef and veal imports occurs by 1.8 years.

The U.S. carcass price showed a positive sign and was significant at the 90 % probability level. The partial derivatives indicate that a one dollar increase in carcass price results in an increase of beef import supply by 5.5 million pounds. The import supply elasticities with respect to U.S. carcass prices are .355, .286, and .297 in the short run, immediate run, and long run, respectively. Hourly earnings per worker in food

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[14]According to Tomek and Cochrane (1962) the length of the lag adjustment can be computed by the following formula: $\lambda^n \leq .05$, where $\lambda$ is the coefficient of the lagged dependent variable and n is the number of adjustment periods. Complete adjustment is arbitrarily defined to be 95 percent or more within n time periods. The arbitrary specification is required because $\lambda^n = 0$ only if n goes to infinity.

manufacturing was used as a proxy of wage rates in the meat packing industry. Wage rates is positively related to the dependent variable, and is statistically significant at the 1 percent level. The result reflects the fact that meat packers often import more beef and veal when their costs of production increase (Langemeier and Thompson, 1967). The short run and long run elasticities are 2.31 and 1.93, respectively, indicating long run elasticities of import supply are less than their short run elasticities. This result suggests that the exporters of beef and veal, primarily Australia and New Zealand, may adjust in a short time period to the changes in U.S. carcass prices and wage rates in the meat packing industry.

The coefficient of the trend variable is also positively significant at the 1 percent significance level, suggesting that beef and veal import supplies have been historically increasing and may capture other information which is not reflected in other variables in the model.

## Beef and Veal Export Demand and Supply

The U.S. beef and veal export demand equation was estimated using the ML method with instrumental variables due to the estimation problems arising from endogeneity, a lagged dependent variable, and an autoregressive error. The statistical results are given in Table 5 and the short run, immediate run, and long run elasticities are given in Table 6.

A first order lag on price difference and contemporaneous values of Japanese national income, exchange rate (Yen to dollars), and the beef import quota were the structure of the independent variables in the estimated equation. The coefficient of the price difference[15] variable in year t did not show the expected positive sign; however, the coefficient in year t-1 was significant at the 99 percent probability level with the sign as expected. The summation of the contemporaneous and one period lag coefficients is positive, which implies that Japanese distributors of imported beef increase their demand for U.S. beef and veal when the price difference increases (capturing the benefits from changes in the trade margin). The long run elasticity was .46, which indicates that a 10 percent increase of price difference increases Japanese import demand by 4.6 percent. This price inelasticity is similar to the findings of Mori et al. (1987) who indicated the Japanese demand for imported beef was not price elastic (ranging from -.836 to -.985).

The coefficient on Japanese income was positive but insignificant. The inelastic response was expected since imported beef is regarded as lower quality beef in Japan; also, the impacts of changes in income might not be completely transferred to Japanese import demand due to trade protection. Overall, it is not clear whether the insignificant Japanese income effect results from statistical problems[16] or whether it is consistent with the maintained hypothesis. Mori et al. (1987) argued that the demand for imported beef was income elastic (ranging from 1.2 to 1.4). However, they did not consider trade arguments between importing and exporting countries which affect prices and quantities in the world market such as exchange rates, quotas, and tariffs. In other words, the elastic

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[15]The price difference was adjusted by exchange rates and units and produced by the following computations:
Price difference (Yen/Kg) = Japanese carcass price(Yen/Kg) - adjusted U.S. carcass price(Yen/Kg), where adjusted U.S carcass price = U.S. carcass price($/cwt) x exchange rate(Yen/dollar) x 45.359(Kg/cwt)

[16]The huge condition number (4911.5) and the partial correlation coefficients between $Y_{jap}$ and Pdiff, EXR, Quota (.827, -.879, .844, respectively) indicated the serious multicollinearity.

Table 5. Statistical results for the beef and veal export demand and supply equations[a]

| Equation | Intercept | Explanatory Variables[b] | | | | | | Statistics[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $Pdiff_t$ | $Pdiff_{t-1}$ | $Y_{jap,t}$ | $EXR_t$ | $EXR_{t-1}$ | $Quota_t$ | $R^2$ | $S_y$ | D-W |
| $QX_d^{bv}$ | 110.81 | -.0327 | .0541 | .000008 | -.1441 | -.0848 | .00051 | .9461 | 19.827 | 1.414 |
| | | (-1.406) | (2.796) | (.0422) | (-.8753) | (-1.492) | (3.082) | | | |
| | | $HP^{car}_t$ | $Quota_t$ | $Quota_{t-1}$ | | | | $R^2$ | $S_y$ | D-W |
| $QX_s^{bv}$ | 152.38 | -.8426 | .00046 | .00029 | | | | .9533 | 19.948 | 1.415 |
| | | (4.497) | (2.925) | (-2.005) | | | | | | |

[a] The t-ratios are given in parentheses under each coefficient.

[b] The letter 'H' before a variable indicates that it is an instrument.

[c] Regression test statistics are defined as: $R^2$= adjusted R-squared, $S_y$=standard error of the estimate, D-W=Durbin-Watson statistic, and Dh=Durbin's h statistic.

Table 6. Estimates of the short, immediate, and long run demand and supply elasticities for the beef and veal export demand and supply model

| Equation | | Explanatory Variables | | | |
|---|---|---|---|---|---|
| (Demand) | | Pdiff | $Y_{jap}$ | EXR | Quota |
| $QX_d^{bv}$ | S-R | -.7013 | .0247 | -.0514 | .6549 |
| | I-R | .4596 | .0247 | -.3539 | .6549 |
| | L-R | .4596 | .0247 | -.3539 | .6549 |
| (Supply) | | $P^{car}$ | Quota | | |
| $QX_s^{bv}$ | S-R | -1.3138 | .5889 | | |
| | I-R | -1.3138 | .9617 | | |
| | L-R | -1.3138 | .9617 | | |

1) S-R: Short-Run, I-R: Intermediate-Run(2 periods), L-R: Long-Run.

2) The elasticities are calculated at the mean values of the variables and are given as:

$$\frac{\partial Q_t}{\partial X_{t-j}} \cdot \frac{\bar{X}}{Q} \quad \text{where} \quad , \; j = 0, 1, 2, \cdots, n$$

income responses for imported beef (as shown in their results) is justified if all other trade variables are fixed.

The significant negative coefficient on exchange rates demonstrates that Japanese beef imports would become more expensive and thus decline if the value of the Yen was depreciated. The long run elasticity with respect to the exchange rate was -.35, indicating that a 10 percent rise in the exchange rate causes a 3.5 percent decline in import demand.

Quotas are important institutional factors affecting beef and veal trade between the U.S. and Japan. The contemporaneous coefficient on the quota variable was significant at the 99 percent probability level. The positive sign of the coefficient indicates that an increase in the Japanese beef import quota results in increasing import demand. The impact is relatively inelastic with the value of the elasticity coefficient at .65.

The beef and veal export supply equation was estimated by the ML method with instrumental variables due to the presence of a lagged dependent variable and first order autocorrelation in the error term. Tables 5 and 6 show the estimation results and the elasticities of the short run, immediate run, and long run. The final equation consisted of a first order difference equation with contemporaneous independent variables for U.S. carcass price and the Japanese beef import quota. All estimated coefficients were statistically significant and the signs were consistent with the maintained hypothesis.

U.S. carcass price was expected to show a negative relationship with the dependent variable. The empirical results indicate that, other factors constant, an increase in U.S. carcass price by $10 per hundredweight reduces excess supply (the source of export) and U.S. beef and veal export supplies to Japan by 6.4 million pounds. The response tends to be relatively elastic as given by the elasticity coefficient of -1.314.

The coefficients of the contemporaneous and one year lag on quotas were positive, which is consistent with the maintained hypothesis. U.S. beef and veal export supply was expected to increase as the quota increases since Japanese imports constitute a large share of U.S. beef and veal exports; also, the U.S. has received a preferential quota treatment from the Japanese government (Alston et al., 1989). The results indicate that a 1,000 metric ton increase in the Japanese beef import quota will increase U.S. beef and veal export supply by .46 million pounds. The elasticities were .589 and .962 for the short run and long run, respectively.

## Domestic Slaughter Demand and Supply

The domestic slaughter demand equation was estimated as a function of slaughter steer price, carcass price, wage rates, farm level by-products, and carcass level by-products. The estimation procedure incorporated several statistical problems such as endogeneity, a lagged dependent variable, an autoregressive error, and a recursive relationship with foreign trade in by-products. The ML method and instrumental variables were employed for these statistical problems. The statistical results and elasticities are represented in Tables 7 and 8.

By-product value at the farm level recursively enters from the foreign trade by-product equation given later. The covariance of the error terms between slaughter demand and foreign trade in by-product is very small with the first order correlation coefficients estimated at .0076. Thus, the recursive structure does not violate assumptions of classical linear regression model.

The final function is a first order difference equation with first order lags on slaughter price, carcass price, and by-product value and contemporaneous values on carcass level by-

Table 7. Statistical results for domestic slaughter demand and supply equations[a]

| Equation | Intercept | Explanatory Variables[b] | | | | | | | | | Statistics[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $HQ^{sl}_{t-1}$ | $HP^{sl}_{t}$ | $HP^{sl}_{t-1}$ | $HP^{car}_{t}$ | $HP^{car}_{t-1}$ | $BPVF_t$ | $BPVF_{t-1}$ | $BPVC_t$ | $W_t$ | $R^2$ | $S_y$ | Dh |
| $Q_d^{sl}$ | -15962 | .1414 | -757.73 | -375.68 | 322.23 | 160.91 | 105.75 | 211.84 | 1765.5 | 8067.4 | .8521 | 939.6 | -.0599 |
| | | (2.030) | (-4.194) | (-2.065) | (3.143) | (1.552) | (.8068) | (1.617) | (2.442) | (6.321) | | | |

| Equation | Intercept | $HQ^{sl}_{t-1}$ | $HP^{sl}_{t}$ | $HP^{fd}_{t}$ | $HP^{fd}_{t-1}$ | $P^{crn}_{t}$ | $R^2$ | $S_y$ | Dh |
|---|---|---|---|---|---|---|---|---|---|
| $Q_s^{sl}$ | 43579 | .2309 | 44.268 | -158.93 | -81.124 | 711.82 | .8763 | 966.9 | 1.055 |
| | | (6.974) | (.7663) | (-5.661) | (-6.097) | (1.804) | | | |

[a] The t-ratios are given in parentheses under each coefficient.

[b] The letter 'H' before a variable indicates that it is an instrument.

[c] Regression test statistics are defined as: $R^2$= adjusted R-squared, $S_y$=standard error of the estimate, D-W=Durbin-Watson statistic, and Dh=Durbin's h statistic.

Table 8. Estimates of the short, immediate, and long run demand and supply elasticities for the domestic slaughter demand and supply model

| Equation | | Explanatory Variables | | | | |
|---|---|---|---|---|---|---|
| (Demand) | | $P^{sl}$ | $P^{car}$ | BPVF | BPVC | $W_f$ |
| $Q_d^{sl}$ | S-R | -1.3973 | .9452 | .0494 | .1290 | 1.6529 |
| | I-R | -2.2876 | 1.5509 | .1555 | .1472 | 1.8867 |
| | L-R | -2.4343 | 1.6506 | .1729 | .1502 | 1.9252 |
| (Supply) | | $P^{sl}$ | $P^{fd}$ | $P^{crn}$ | | |
| $Q_s^{sl}$ | S-R | .0816 | -.3112 | .0610 | | |
| | I-R | .1005 | -.5419 | .0751 | | |
| | L-R | .1061 | -.6111 | .0793 | | |

1) S-R: Short-Run, I-R: Intermediate-Run(2 periods), L-R: Long-Run.

2) The elasticities are calculated at the mean values of the variables and are given as:

$$\frac{\partial Q_t}{\partial X_{t-j}} \cdot \frac{\bar{X}}{\bar{Q}} \quad \text{where} \quad , \; j = 0, 1, 2, \cdots, n$$

products and wage rates. The function is stable and the equilibrium adjustment period shows that 95 percent of the lag adjustment dissipates by 1.5 years.

The negative own price effect for slaughter demand is highly significant and quite sensitive, which is not surprising since slaughter price is a major component of factor costs. The results show a 1 dollar per hundredweight increase in slaughter price decreases contemporaneous slaughter demand by 757 thousand head. In the long run the demand for slaughter cattle is very price elastic, i.e., a 1 percent increase in slaughter price decreases slaughter demand by 2.4 percent.

The positive coefficient on carcass price indicates that higher output prices result in increasing meat packer demand for slaughter cattle. According to the results, a $1 per hundredweight increase in contemporaneous carcass price increases slaughter cattle demand by 323.2 thousand head. The carcass price elasticities increase from the short run to the long run (.945 and 1.65, respectively), which indicates that packers more fully adjust to constraints in the market over time.

By-products are joint products in the meat packing industry. The contemporaneous value of by-products at the farm level is not significant; however, the one period lag is significant at the 90 percent probability level. By-products at the carcass level are significant at the 5 percent significance level. Meat packing firms rely upon revenues from by-products to cover slaughter costs and profit margins. The positive signs of both by-product variables reflect this phenomenon. For example, a contemporaneous increase in the value of farm level by-product by 1 cent per pound increases slaughter cattle demand by 1765.5 thousand head. The slaughter demand elasticities with respect to both farm and carcass level by-product prices are relatively inelastic for all lengths of run. The reason may be that packers are more concerned about carcass and boxed beef prices in profit management with by-products being produced in relatively fixed proportions.

Wage rates are an important component of production costs for meat packing firms. Thus, it was expected that wage rates should have a negative relationship with the slaughter demand. However, the empirical results displayed a positive coefficient sign on wage rates which may be a product of high correlation between income and wage rates in the meat packing industry (Brester and Marsh, 1985).

The domestic slaughter supply equation was a first order difference equation with the independent variables being contemporaneous slaughter price, corn price, and a first order lag on feeder cattle price. The function is stable and the Tomek and Cochrane 95 percent adjustment period is 2.04 years. All coefficients are highly significant and the signs agree with theoretical reasoning.

The positive sign on slaughter price and negative sign on feeder price is consistent with feedlot managers being margin operators. That is, feedlot operators supply more slaughter cattle when the price of output (slaughter cattle) rises and/or the price of the input (feeder cattle) falls. The positive relationship between corn price and slaughter cattle supply indicates that feedlot suppliers increase fed cattle marketings in the current year since it would be costly to carry cattle to heavier weights in the following year. The empirical results indicates that a $1 per bushel increase in corn price increases the supply of slaughter cattle by 711.8 thousand head. The elasticities are very low in all lengths of run (.061, .075, and .079).

## Live Cattle Import Demand and Supply

The equation of live cattle import demand was a function of feeder cattle price and cattle inventory. Range conditions for the states of the southwest (mentioned in the maintained hypothesis) were not available and therefore omitted. OLS with an instrumental variable was employed because of the jointly endogenous feeder price variable. All right-hand-side variables in the model were statistically significant at the 5 percent level of significance although the model contained a low $R^2$ due, primarily, to missing information. The statistical results and the elasticities are given in Tables 9 and 10.

A priori an increase in U.S. feeder price should increase domestic excess demand (given world price) and, thus, increase import demand for live cattle. However, a negative sign from the summation of contemporaneous and one year lag on feeder cattle price resulted. Part of the reason may be missing information as mentioned above. The price of feeder cattle in the current year shows positive impacts on live cattle imports, but the larger negative sign results from the one year lag. Perhaps this may be explained by the large share of the U.S. in world trade of live cattle. For Canadian and Mexican exports of live cattle, the share of exports to the U.S. is large so that exports in the current year may decrease quantity and increase prices in the world market in the following year. The higher price in the following year may decrease U.S. import demand (although U.S. price increases).

The level of U.S. cattle inventory is expected to be an important variable affecting live cattle imports. The summation of the contemporaneous and one year lag effects of cattle

Table 9. Statistical results for live cattle import demand and supply equations[a]

| Equation | Intercept | Explanatory Variables[b] | | | | Statistics[c] | | |
|---|---|---|---|---|---|---|---|---|
| | | $HP^{fd}_{t}$ | $HP^{fd}_{t-1}$ | $INV_t$ | $INV_{t-1}$ | $R^2$ | $S_y$ | D-W |
| $QM_d^c$ | 2293.6 | 5.214 | -7.165 | -.0197 | .0094 | .4086 | 196.39 | 1.879 |
| | | (1.719) | (-2.443) | (-3.520) | (3.650) | | | |
| | | $QM^c_{t-1}$ | $HP^{fd}_{t}$ | $HP^{fd}_{t-1}$ | | $R^2$ | $S_y$ | Dh |
| $QM_s^c$ | 832.42 | .5866 | .9344 | -6.338 | | .2228 | 206.35 | -.6366 |
| | | (3.432) | (.3481) | (-2.923) | | | | |

[a] The t-ratios are given in parentheses under each coefficeint.

[b] The letter 'H' before a variable indicates that it is an instrument.

[c] Regression test statistics are defined as: $R^2$= adjusted R-squared, $S_y$=standard error of the estimate, D-W=Durbin-Watson statistic, and Dh=Durbin's h statistic.

Table 10. Estimates of the short, immediate, and long run demand and supply elasticities for the live cattle import demand and supply model

| Equation | | Explanatory Variables | |
|---|---|---|---|
| (Demand) | | $P^{fd}$ | INV |
| $QM_d^c$ | S-R | .4307 | -2.353 |
| | I-R | -.1612 | -1.233 |
| | L-R | -.1612 | -1.233 |
| (Supply) | | $P^{fd}$ | |
| $QM_s^c$ | S-R | .0155 | |
| | I-R | -.0804 | |
| | L-R | -.2163 | |

1) S-R: Short-Run, I-R: Intermediate-Run(2 periods), L-R: Long-Run.

2) The elasticities are calculated at the mean values of the variables and are given as:

$$\frac{\partial Q_t}{\partial X_{t-j}} \cdot \frac{\bar{X}}{Q} \quad \text{where} \quad , \; j = 0, 1, 2, \cdots, n$$

inventory is negative, which agrees with theoretical reasoning. The results show that an increase in current year inventory by 100 thousand head results in a decrease of live cattle imports by 1.97 thousand head. The elasticities are -2.35 and -1.23 in the short run and long run, respectively, so that long run impacts are less than short run impacts. It indicates that U.S. importers adjust to changes in the inventory level within a relatively short period of time.

The live cattle import supply equation was a first order difference equation with a one year lag on the U.S. feeder price. The function was estimated by ML with an instrumental variable due to the lagged dependent variable and first order autoregressive error. Feeder prices and cattle inventory levels in Canada and Mexico were not incorporated in the empirical model because of data limitations. This explains part of the reason for a low adjusted $R^2$. Interpretation of the results is somewhat limited but the negative sign of the one year lag on U.S. feeder price is due to the same reasoning as in the case of import demand.

## Foreign Trade in By-Products

The by-product equation was estimated as a function of U.S. by-product production, per capita disposable income, hide and leather product price, exports of hides and skins, and exports of variety meats. The model includes a lagged dependent variable and autoregressive error so that the ML and instrumental variable techniques were employed. All estimated coefficients were significant at the 95 percent probability level except for the contemporaneous hide and skin exports. The statistical results and calculated elasticities are provided in Tables 11 and 12.

Table 11. Statistical results for the foreign trade of beef by-products (hides, skins, and variety meats) equation[a]

| Equation | Intercept | Explanatory Variables | | | | | | | | | Statistics[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $BPVF_{t-1}$ | $QP^{bp}_{t}$ | $P^{hl}_{t}$ | $QX^{hd}_{t}$ | $QX^{hd}_{t-1}$ | $QX^{vm}_{t}$ | $QX^{vm}_{t-1}$ | $Y_{d,t}$ | $Y_{d,t-1}$ | $R^2$ | $S_y$ | Dh |
| BPVF | 24.045 | .5480 | -.21386 | .4549 | .00035 | -.00048 | -.000026 | .00015 | .0016 | -.00102 | .8704 | 1.1434 | -.2251 |
| | | (4.368) | (-4.382) | (8.368) | (2.167) | (-2.700) | (-1.019) | (4.417) | (3.179) | (-3.999) | | | |

[a] The t-ratios are given in parentheses under each coefficeint.

[c] Regression test statistics are defined as: $R^2$= adjusted R-squared, $S_y$=standard error of the estimate, D-W=Durbin-Watson statistic, and Dh=Durbin's h statistic.

Table 12. Estimates of the short, immediate, and long run demand and supply elasticities for the foreign trade of beef by-product model

| Equation | | Explanatory Variables | | | | |
|---|---|---|---|---|---|---|
| Reduced form | | $QP^{bp}$ | $P^{hl}$ | $QX^{hd}$ | $QX^{vm}$ | $Y_d$ |
| BPVF | S-R | -4.933 | 2.710 | .4184 | -.2258 | 1.374 |
| | I-R | -7.635 | 4.196 | .0820 | .9534 | 1.258 |
| | L-R | -10.914 | 5.996 | -.3258 | 2.383 | 1.117 |

1) S-R: Short-Run, I-R: Intermediate-Run(2 periods), L-R: Long-Run.

2) The elasticities are calculated at the mean values of the variables and are given as:

$$\frac{\partial Q_t}{\partial X_{t-j}} \cdot \frac{\bar{X}}{\bar{Q}} \quad \text{where} \quad , \quad j = 0, 1, 2, \cdots, n$$

The final distributed lag form was a first order difference equation with contemporaneous U.S. by-product production, U.S. hide and leather product price, and first order lags on hide and skin exports, variety meat exports, and per capita disposable income. The coefficient of the lagged dependent variable (.548) indicates a stable function with a 95 percent geometric adjustment 4.98 years.

The effect of U.S. by-product production on the price of by-products is negative, which satisfies the law of demand. The short run elasticity of by-product price indicates that a 1 percent increase in by-product production decreases the price of farm level by-products by 4.9 percent, while the long run elasticity is large at 10.9. The contemporaneous producer price index for hides, skins, leather, and related products is used as a proxy for output price. The empirical results show the price of by-product increase when its output price rises. For example, the elasticity coefficient shows that a 1 percent change in hide and leather product price increases by-product price by 2.7 percent in the short run, 4.2 percent in the immediate run, and 6.0 percent in the long run.

The summation of the per capita disposable income coefficients is positive, which is the combined income impact on hides and variety meats as discussed in the theoretical model. These results occur even if variety meats are regarded as inferior goods (Smith and Goodwin, 1989). For example, a 1 percent increase in per capita disposable income increases the value of by-products at farm level by 1.4 percent in the short run, by 1.3 percent in the intermediate run and by 1.1 percent in the long run. The larger short run price could fall due to an increase in domestic supply. In the following year, the world price could rise because of the reduction in U.S. exports of the previous year, which again could lead to an increase in supply to the world market (instead of the domestic market). Overall, this explains the negative sign on contemporaneous variety meat exports and the positive sign for the one year lag. In the case of both hide and skin exports and variety meat exports, there is not an absolute theory for which signs should be specific to year t and year t-1; it largely depends upon the price elasticities and market conditions specific to the periods and market share influence on world prices.

## Policy Implications

In general, calculation of the long run policy effects of trade variables is based on the combined use of the estimated long run partial derivatives of the structural equations and price transmission equations[17]. The long run partial coefficients and elasticities are given in Table 13.

The results show that changes in the Japanese beef import quota have a positive impact on prices of U.S. beef. For example, a 1,000 metric ton increase in the Japanese import quota increases the prices of retail beef, carcass, slaughter cattle, and feeder cattle by 1.1 cents per pound, and .9, .5, and .7 dollars per hundredweight, respectively. The long run elasticities are generally inelastic, ranging from .396 to .902.

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[17]See Appendix E for the price transmission equations. An example combining the two is:

$$Q_t = X^T_t \beta_t + Z^T_t \gamma_t + u_{1t} \quad \text{(structural equations)}$$

$$P_{H,t} = P^T_{L,t} \alpha_t + u_{2t} \quad \text{(price transmission equations)}$$

where $X^T_t$, is transpose of $X_t$ and Q, Z, $P_{H,t}$, and $P_{L,t}$ are the respective quantity, policy, and price vectors at the different levels of the beef market. $P_L$ is part of the $X^T$ arguments. Therefore, the impact of a policy on price, $P_H$, is given as:

$$\frac{\partial P_{H,t}}{\partial Z_{t-j}} = \frac{\partial P_{H,t}}{\partial \hat{P}_{L,t-j}} \cdot \frac{\partial P_{L,t}}{\partial Q_{t-j}} \cdot \frac{\partial Q_t}{\partial Z_{t-j}} \quad where, j = 1,2,\ldots,n$$

Table 13. Impacts of Policy Variables on the Prices and Quantities of the U.S. Beef Market

| Policy Variables | U.S. Beef Market Prices | | | |
|---|---|---|---|---|
| | $P^{bf}$ (cent/lb.) | $P^{car}$ ($/cwt) | $P^{sl}$($/cwt) | $P^{fd}$($/cwt) |
| Quota (M/T) | .0011[a]<br>(.396)[b] | .0009<br>(.732) | .0005<br>(.708) | .0007<br>(.902) |
| $QM^{bv}$ (mil.lbs.) | -.0054<br>(-.038) | -.0038<br>(-.059) | -.0023<br>(-.057) | -.0031<br>(-.073) |
| $QM^{c}$ (1,000 head) | -.0686<br>(-.251) | -.0484<br>(-.391) | -.0338<br>(-.434) | -.0765<br>(-.926) |
| $QX^{hd}$ (1,000 piece) | -.00104<br>(-.089) | -.00073<br>(-.138) | -.00051<br>(-.153) | -.00069<br>(-.195) |
| $QX^{vm}$ (M/T) | .00102<br>(.640) | .00072<br>(1.000) | .00050<br>(1.113) | .00068<br>(1.406) |

[a] The long run partial coefficients with respect to each policy variable.

[b] The long run elasticities are given in parentheses under each partial coefficients.

The amount of U.S. beef and veal imports from Australia and New Zealand is relatively small compared to consumption of domestically produced beef and veal. Therefore, small impacts on domestic prices are not surprising. The estimated long run partial coefficients suggest that an increase of beef and veal imports by 100 million pounds decreases the prices of retail beef, carcass, slaughter cattle, and feeder cattle by .54, .38, .23, and .31 dollars per hundredweight, respectively. The multipliers of a 100 million pound increase in beef imports were previously reported by Freebairn and Rausser (1975). Their empirical results demonstrated that a 100 million pound increase in beef imports will decrease prices of choice beef, hamburger, slaughter steers, cull cows, and feeder calves by .65, 1.1, .3, .55, and .58 dollars per hundredweight, respectively. The relatively larger impact on hamburger price is common in other studies (Arzac and Wilkinson, 1979; Houck, 1974; Langemeir and Thompson, 1967), since they used separate price data for fed and nonfed beef. In this study the U.S. carcass price includes both fed and nonfed beef prices so that the impact of beef and veal on carcass price (.54) is slightly larger than Freebairn and Rausser's results. The long run impact on feeder cattle price (-.31) is very close to the Arzac and Wilkinson results (-.36).

The long run impacts of live cattle imports from Canada and Mexico on the domestic prices were inelastic. A 10,000 head increase in live cattle imports decreases retail beef price by .69 cents per pound and the other prices ranging from .34 to .77 dollars per hundredweight. The long run elasticities range from -.39 to -.93.

The volume of by-products have been increasing as a proportion of total U.S. beef product exports, and the U.S. share in the world market is considerably large. However, its impact on the U.s. beef market is relatively small because the value portion of by-products in total value of slaughter cattle and carcasses is small. In the long run, a one million piece increase in hide and skin exports decreases slaughter and feeder cattle prices by .51 and .69 dollars per hundredweight, respectively. The estimated long run elasticities are very small (-.09 to -.19). The long run partial coefficients of variety meat exports are nearly the same as those of hide and skin exports. A 100 million pound increase in variety meat exports increases domestic retail beef and other prices by .1 and from .5 to .7 dollars per hundredweight, respectively. However, the elasticities are higher than those reported for hide and skin exports; i.e., .64 to 1.41.

# CHAPTER 4

## SUMMARY AND CONCLUSIONS

The main objective of this study was to develop a dynamic structural model of the U.S. wholesale carcass and slaughter beef markets. The model incorporated pertinent domestic variables and also foreign trade variables such as imports and exports of beef and veal, live cattle imports, and by-product exports. The foreign trade variables were used to proxy policy implications and their effects on market level prices.

The empirical model was estimated within a rational distributed lag framework, using econometric methods specific to the types of statistical problems encountered. Short run, immediate run, and long run elasticities with respect to the exogenous arguments were calculated using the distributed lag coefficients of the structural demand and supply equations. The distributed lag impacts of policy trade variables on U.S. beef prices were derived using partial derivatives of the structural equations and conjunctively with a system of price transmission equations.

Domestic carcass demand was estimated as a function of carcass price, retail beef price, per capita disposable income, and prices of substitutes. The demand function for carcasses included the explicit arguments underlying primary demand since the system did not include the retail level. The empirical form of the equation included one year lags on the price of carcass, the price of retail beef, wholesale broiler price, and contemporaneous per capita disposable income and wholesale pork price. ML and instrumental variables were jointly employed to correct for joint dependency and autocorrelation in the errors. All estimated coefficients were significant and showed expected signs. The demand elasticities with respect to the own price and retail beef price were elastic and the income elasticity of demand was inelastic. These results were in general agreement with most other studies.

The domestic carcass supply equation was recursively determined from domestic slaughter demand and was estimated as a function of domestic slaughter demand and a marketing margin. Because of nonzero covariance between the errors of carcass supply and slaughter demand, instrumental variables were used. The final equation was a first order difference equation with a white noise error. All signs of the coefficients were consistent with the maintained hypothesis and were statistically significant. The estimated supply elasticities with respect to both the slaughter demand and marketing margin were relatively inelastic.

The beef and veal import demand equation was estimated as a second order difference equation with a fourth order autoregressive error. The independent variables were first order lags on carcass price and pork price and contemporaneous effects of income and broiler price. The high order autoregressive error captures some missing information in the beef and veal import structure. The real roots of the second order difference equation indicate long run impacts of the exogenous variables on beef and veal imports asymptotically converge to zero after a peak effect in period $t+j$. The short run import demand elasticities with respect to carcass price and income were inelastic; however, the long run elasticities were elastic.

The beef and veal import supply equation was estimated as a function of the U.S. carcass price, wage rates, and a trend variable. The final form of the estimated equation was a first order difference equation with a first order autoregressive error. The coefficient of the first order difference equation was significant but small and indicated a stable geometric adjustment process. For example, 95 percent of distributed lag adjustment in the beef and veal import supply was completed in an average of 1.8 years. Because of the joint problems of a lagged dependent variable and serial correlation, the ML method with instrumental variables were employed. The carcass price elasticity of import supply was inelastic in all lengths of run. Wage rates strengthened the explanatory power of the import supply equation and its elasticities were elastic in all lengths of run.

The beef and veal export demand equation was estimated as a function of the carcass price difference between Japan and U.S., exchange rates, Japanese income, and Japanese import quotas. The import quotas were thought to be an important institutional factor in affecting U.S. beef and veal exports to Japan. The ML method and instrumental variables were applied because of estimation problems with joint dependency and autocorrelation. The variables of the estimated equation were statistically significant and contained the a priori signs. The export demand elasticities with respect to the price difference and Japanese income were inelastic, results that were contrary to some previous studies. A partial explanation is that previous models did not incorporate beef trade information between Japan and the U.S. such as exchange rates and quotas.

The beef and veal export supply equation included contemporaneous independent variables for U.S. carcass price and a one period lag in the Japanese beef import quota. Because of the existence of the joint dependency and autocorrelation, ML with instrumental variables was applied.

The domestic slaughter demand equation was estimated as a function of slaughter steer price, carcass price, wage rates in the food manufacturing industry, farm level by-products, and carcass level by-products. The equation incorporated statistical problems such as joint dependency and a lagged dependent variable with autocorrelation. A recursive structure with foreign trade in by-products was also part of the system. The joint use of the ML method and instrumental variables for both endogenous explanatory and lagged dependent variables was applied to yield consistent estimators. The mean zero correlation between errors of domestic slaughter demand and by-product exports indicated the recursive structure did not contain a seemingly unrelated regression problem. The estimated function was a first order difference equation with first order lags on slaughter price, carcass price, and by-product value at the farm level and contemporaneous carcass by-product value and wage rates. The function was stable and 95 percent of the lag adjustment dissipated by 1.5 years. As expected, by-products at both the farm level and carcass level were important factors in affecting slaughter cattle demanded.

The domestic slaughter supply equation was estimated as a first order difference equation with the independent variables of contemporaneous slaughter, corn price, and a first order lag on feeder cattle price. Because of endogeneity, a lagged dependent variable, and serial correlation, the ML method with instrumental variables were employed. The function was stable and showed a 95 percent adjustment period of 2.04 years. All estimated coefficients were highly significant and demonstrated coefficient signs consistent with economic theory.

The estimated equation of live cattle import demand was a function of U.S. feeder price and January 1 cattle inventories. The model had a low $R^2$ which reflected the fact that the empirical model contained missing information. However, the lagged variables of the U.S. feeder price and inventory levels were highly significant.

The live cattle import supply equation was estimated by ML with an instrumental variable because of the lagged dependent variable and autocorrelation. The final equation was a first order difference equation with a one year lag on U.S. feeder price. The problem of low explanatory power was serious so that its interpretation was limited.

Foreign trade in by-products was estimated as a function of U.S. by-product production, hide and leather producer price index, per capita disposable income, hide and skin exports, and variety meat exports. The dynamic structure was a first order difference equation with first order lags on hide and skin exports and variety meat exports, while the other independent variables were specified on a contemporaneous basis. The estimation included the statistical problems of the lagged dependent variable with autoregressive errors so that ML and instrumental variables were jointly employed. The coefficient of the first order difference equation indicated a stable function and 4.98 years were required for a 95 percent adjustment period. All the estimated coefficients are significant and the estimated elasticities are generally consistent with market behavior. Particularly, hide and skin exports and variety meat exports were highly significant in explaining the variation in the domestic by-product price.

Overall, the empirical results of the domestic demand and supply equations at the carcass and slaughter level were consistent with the maintained hypothesis and generally agreed with the most previous studies. Most of the foreign trade variables in the model were statistically significant and demonstrated theoretically correct signs. Some of the unexpected signs could be explained by the dynamic nature of economic variables in the market environment and by statistical problems such as multicollinearity. Consequently, incorporating both domestic and foreign market arguments in the framework of dynamic analysis is important in the U.S. beef model.

The long run impacts of the selected policy variables on U.S. domestic prices of retail beef, carcass, slaughter, and feeder cattle were analyzed using the structural system with price transformation equations. The impacts of the Japanese beef import quota on domestic prices were relatively inelastic for the sample period. For example, a 10 percent increase in the import quota increases U.S. prices by 7-9 percent. As discussed in earlier studies, the impact of beef and veal imports on domestic prices is small. The estimated long run coefficients in this study indicated that a 100 million pound increase in beef and veal imports decreased domestic retail beef price by .54 cents per pound and the other prices by .23 to .38 dollars per hundredweight, respectively. The estimated long run elasticities were very small, ranging from -.04 to -.07. The long run elasticities of live cattle imports with respect to domestic beef prices were -.25 to -.93 while the long run impacts of by-product exports were relatively small. The long run elasticities of hide and skin exports ranged from .01 to .03 but the long run elasticity coefficients of variety meat exports were relatively less inelastic. Overall, the long run impacts of foreign trade in beef products were generally small but were large enough for researchers to incorporate these relationships in modeling the U.S. beef industry.

## Limitations and Future Studies

Interpretation of the empirical results of the annual model may be somewhat limited since market adjustments are usually based on shorter time periods than a year. Most trading decisions in beef and veal, live cattle, and by-products are frequently negotiated within a year and physical movements of commodities take place many times within a year so that monthly or quarterly data would be more desirable.

By-products consist of many products such as hides and skins, variety meats, tallow and grease, etc. Furthermore, the hides and skins are divided into cattle part hides, cattle whole hides, and calf and kip skins, while the variety meats include products from the inner organs, head meat, and offals. Thus, another limitation was the use of aggregate price and quantity data such as U.S. by-product production and prices of by-products, which should be disaggregated by the proper theoretical treatments. The ability to do so would reduce the aggregation bias and enhance the prediction ability of the model.

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# APPENDICES

# APPENDIX A

## BEEF PRODUCT EXPORTS FOR SELECTED YEARS AND SHARES OF U.S. BEEF PRODUCT EXPORTS, 1988 AND 1989

Table 14. Beef product exports for selected years

| Year | QXbv | QMbv | QXvm | QXhd | QMc |
|---|---|---|---|---|---|
| | mil.lb | mil.lb | 1,000 tons | mil.lb | 1,000 head |
| 1965 | .5 | 1501.2 | 103.4 | 15.8 | 1020.2 |
| 1975 | 11.8 | 1840.2 | 127.3 | 20.2 | 834.6 |
| 1980 | 61.3 | 2179.4 | 179.1 | 26.0 | 956.6 |
| 1985 | 141.1 | 1921.4 | 224.5 | 26.1 | 839.0 |
| 1988 | 234.2 | 2158.6 | 231.8 | 28.3 | 1086.2 |

Source: Dairy, Livestock, and Poultry: U.S. Trade and Prospects, USDA.
Agricultural Statistics, USDA.
QXbv:Beef and veal exports; QMbv:Beef and veal imports; QXvm:Variety meat exports; QXhd:Hide and skin exports; QMc:Live cattle imports.

Table 15. Shares of U.S. beef product exports, 1988 and 1989

| Beef Products / Year | 1988 mil. dollar | 1989 mil.dollar |
|---|---|---|
| Beef & Veal | 1,369.4 (30.9) | 1,418.2 (32.5) |
| Hides & Skins | 2,034.5 (46.0) | 2,052.9 (47.0) |
| Variety Meats | 375.1 ( 8.5) | 301.6 ( 6.9) |
| Animal Fats & Oils | 559.1 (12.7) | 510.2 (11.7) |
| Beef Cattle | 35.1 ( .8) | 29.1 ( .7) |
| Bull semen | 45.6 ( 1.0) | 53.0 ( 1.2) |
| Total | 4,418.8(100.0) | 4,365.0(100.0) |

( ) represents percentage.
Source: Dairy, Livestock, and Poultry: U.S. Trade and Prospects, USDA.

# APPENDIX B

# DATA CALCULATIONS FOR SELECTED VARIABLES

1. $P^{ck}$ : Wholesale chicken price, ready to cook, cents/lbs.

Two kinds of data were collected;

1) 9 cities average: 1964-1982

2)10 cities average: 1983-1988

Data 2) was converted to 9 cities average using the ratio of the overlapping years. The calculated values are as follows;

1983:48.10, 1984:53.02, 1985:48.51, 1986:54.31, 1987:45.21, 1988:53.726

2. $P^{pk}$ : Wholesale pork price, cents/lbs.

1) 1964,1965: value of wholesale-quantity equivalent of 1.14 lb. to 1 lb. of retail cuts.

2) 1966-1988: value of wholesale-quantity equivalent of 1.06 lb. to 1 lb. of retail cuts.

The equivalent value of 1) based upon 2) was calculated using 12 overlapping years.

3. $P^{crn}$ : Price of corn, #2 yellow corn, $/bushel

Two different market data were collected;

1) Omaha: 1964-1984

2) Central Illinois: 1985-1988

Data 2) was converted to the price of Omaha using the ratio of overlapping years('85,'86). The calculated values: 1987: 1.07, 1988: 1.42

4. $Q^{car}$ : Quantity demanded of carcasses: mil.lbs, carcass weight. $Q^{car}$ = commercial beef production(mil.lbs) + commercial veal production.

5. $Q^{sl}$ : Quantity demanded of slaughter cattle: mil.lbs.

(# of cattle slaughter/ year/ 1,000 h) + (# of calves slaughter/ year/ 1,000 h)

6. $P^{car}_{jp}$ : Japanese wholesale beef price: Yen/Kg

1) The missing observations: 1964 and 1988

2) These data were estimated by the distributed lag structure w/ AR(1);

$U_t = \rho U_{t-1} + e_t$, $e_t$ - i.i.d.

For estimating of 1988's observation;

$$P^{car}_{jp,t} = 192.2419 + \underset{(18.895)}{.9263}\, P^{car}_{jp,t-1} + U_{1t}$$

$R^2 = .9539$

For estimation of 1964's observation;

$$P^{car}_{jp,t} = -\ 111.069 + \underset{(20.038)}{1.02}\, P^{car}_{jp,t+1} + U_{2t}$$

$R^2 = .9580$

The predicted values: 1964: 409.13, 1988: 2222.6

# APPENDIX C

# SUMMARY OF DATA

Table 16. Summary of data

| Name | Mean | Standard deviation | Units |
|---|---|---|---|
| $Q^{car}$ | 22723 | 1866.6 | mil.lb. |
| $P^{car}$ | 117.7 | 20.1 | $/cwt. |
| $P^{bf}$ | 259.7 | 29.2 | cents/lb. |
| $Y_d$ | 16056 | 5120.2 | dollars |
| $P^{ck}$ | 65.7 | 15.5 | cents/lb. |
| $P^{pk}$ | 139.5 | 35.0 | cents/lb. |
| $QM^{bv}$ | 1843.7 | 394.5 | mil.lb. |
| $W_f$ | 8.2 | .4 | dollars/hour |
| $QX^{bv}$ | 75.5 | 92.4 | mil.lb. |
| $P^{car}_{jap}$ | 2340.2 | 315.1 | Yen/Kg |
| $Y_{jap}$ | 243030 | 86341 | Yen |
| EXR | 269.3 | 76.0 | Yen/dollar |
| QUOTA | 97015 | 73048 | M/T |
| $Q^{sl}$ | 40108 | 3153.9 | 1,000 head |
| BPVF | 18.8 | 4.1 | cents/lb. |
| BPVC | 2.9 | .86 | cents/lb. |
| $P^{sl}$ | 74.0 | 11.9 | $/cwt. |
| $P^{fd}$ | 78.5 | 16.0 | $/cwt. |
| $P^{crn}$ | 3.4 | 1.3 | $/bushel |
| $QM^{fd}$ | 950.8 | 255.4 | 1,000 head |
| INV | 113760 | 7908.4 | 1,000 head |
| $QP_{bp}$ | 432.5 | 10.8 | mil.lb. |
| $P^{hl}$ | 111.7 | 7.2 | % |
| $QX^{hd}$ | 22189 | 5252.9 | 1,000 piece |
| $QX^{vm}$ | 162880 | 53312 | M/T |

# APPENDIX D

# STATISTICAL PROBLEMS AND ESTIMATION TECHNIQUES

Table 16. Statistical problems and estimation techniques

| Equation[1] | Econometric Problems[2] | OLS Estimator | Estimation Method[3] |
|---|---|---|---|
| Equation 1-D | AR(2), Endogeneity, Lagged Dep. | Biased and Inconsistent | ML with IV |
| Equation 1-S | Endogeneity, Lagged Dep., Recursive System | Biased and Inconsistent | OLS with IV |
| Equation 2-D | AR(4), Endogeneity, Lagged Dep. | Biased and Inconsistent | ML with IV |
| Equation 2-S | Endogeneity, Lagged Dep. | Biased and Inconsistent | OLS with IV |
| Equation 3-D | AR(1), Endogeneity | Biased and Inconsistent | ML with IV |
| Equation 3-S | AR(1), Endogeneity | Biased and Inconsistent | ML with IV |
| Equation 4-D | AR(2), Endogeneity, Recursive System | Biased and Inconsistent | ML with IV |
| Equation 4-S | AR(1), Endogeneity, Lagged Dep. | Biased and Inconsistent | ML with IV |
| Equation 5-D | Endogeneity | Biased and Inconsistent | OLS with IV |
| Equation 5-S | AR(1), Endogeneity | Biased and Inconsistent | ML with IV |
| Equation 6 | AR(1), Lagged Dep. | Biased and Inconsistent | ML with IV |

[1] Equation 1: Domestic Carcass; Equation 2: Beef and Veal Import; Equation 3: Beef and Veal Export; Equation 4: Domestic Slaughter; Equation 5: Live Cattle Import; and Equation 6: Foreign Trade of By-products. D and S represent demand and supply, respectively.

[2] AR: Autoregressive errors, numbers in the parenthesis representing its order.
Endogeneity: Endogenous variables as regressors
Lagged Dep.: Lagged dependent variables as regressors

[3] OLS: Ordinary Least Squares Estimation
ML : Maximum Likelihood Estimation
IV : Instrumental Variables.

# APPENDIX E

# ESTIMATION RESULTS OF PRICE TRANSMISSION EQUATIONS

1. Carcass-slaughter price transmission[18]

$$P^{car}_t = 11.503 + \underset{(10.366)}{1.4338}\, HP^{sl}_t{}^{19} + U_{1t}$$

$R^2$ = .9269, ( ): t ratio

2. Slaughter-carcass price transmission

$$P^{sl}_t = 2.07 + \underset{(12.277)}{.5689}\, HP^{car}_t + \underset{(1.893)}{.0431}\, HP^{car}_{t-1} + U_{2t}$$

$R^2$ = .9319, ( ): t ratio

3. Feeder-slaughter price transmission

$$P^{fd}_t = -20.908 + \underset{(7.260)}{1.346}\, HP^{sl}_t + U_{3t}$$

$R^2$ = .7880, ( ): t ratio

4. Slaughter-feeder price transmission

$$P^{sl}_t = 38.298 + \underset{(5.905)}{.4416}\, HP^{fd}_t + U_{4t}$$

$R^2$ = .8253, ( ): t ratio

5. Slaughter-by-product price transmission

$$P^{sl}_t = 38.03 + \underset{(6.786)}{1.562}\, HBPVF_t + \underset{(1.58)}{.2763}\, HBPVF_{t-1} + U_{5t}$$

$R^2$ = .8615, ( ): t ratio

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18

All equations are estimated with the first order autoregressive errors. The difference equations showed lower adjusted $R^2$'s and higher standard errors of the estimates than those of the static models.

19

The letter 'H' before a variable indicates that it is an instrument.

# APPENDIX F

## BEEF IMPORT IMPACTS: COMPARISON WITH PREVIOUS STUDIES

1. Current study (1990)[20]: 1964-88 annual data

| | |
|---|---|
| Retail choice beef | -.54 |
| Choice steer carcass | -.38 |
| Choice slaughter steers | -.23 |
| Feeder steers | -.31 |

* Impacts of 100 mil.lb. increase in beef and veal imports.

2. Arzac and Wilkinson (1979): 1956-75 quarterly data

| | |
|---|---|
| Retail fed beef | .08 |
| Retail nonfed beef | 1.14 |
| Choice slaughter steers | .03 |
| Utility cows | .34 |
| Feeder steers | .36 |

* Impacts of 100 mil.lb decrease in beef imports.

3. Freebairn and Rausser(1975): 1956-71 annual data

| | |
|---|---|
| Retail choice beef | -.65 |
| Retail hamburger | -1.15 |
| Choice slaughter steers | -.30 |
| Cull cows | -.55 |
| Feeder calves | -.58 |

* Impacts of 100 mil.lb. increase in beef and veal imports.

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20

Numbers are read as dollars per cwt change given a 100 mil.lb. change in beef and veal imports.

# APPENDIX G

# DATA SOURCES

1. USDA, Agricultural Statistics

2. ----, Livestock and Meat Situation

3. ----, Livestock and Poultry, Situation and Outlook

4. ----, Dairy, Livestock, and Poultry: U.S. Trade and Prospects

5. ----, Poultry and Egg Situation

6. ----, U.S. Egg and Poultry Statistical Series (1960-87)

7. ----, Feed Situation

8. ----, Feed Outlook and Situation

9. Council of Economic Advisers, Economic Report of the President

10. USDC, The Survey of Current Business

11. WLMIP(Western Livestock Marketing Information Projects) Data Base

12. MAF, Japan, Meat Statistics.

13. IMF, International Financial Statistics

# APPENDIX H

# ORIGINAL DATA

| Year | $P^{car}$ | $P^{bf}$ | $P^{sl}$ | $P^{fd}$ | $P^{pk}$ | $P^{ck}$ | $P^{crn}$ | $P^{hl}$ | INV | BYPC |
|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 39.48 | 77.80 | 22.41 | 21.92 | 42.50 | 25.37 | 1.26 | 34.4 | 107903 | 1.0 |
| 1965 | 42.50 | 81.67 | 24.99 | 24.12 | 53.02 | 26.45 | 1.29 | 35.9 | 109000 | 1.1 |
| 1966 | 43.04 | 84.40 | 25.71 | 27.43 | 58.11 | 27.64 | 1.30 | 39.4 | 108862 | 1.1 |
| 1967 | 43.43 | 84.62 | 25.29 | 26.68 | 51.89 | 25.15 | 1.14 | 38.1 | 108783 | 1.1 |
| 1968 | 43.82 | 88.67 | 26.87 | 28.09 | 52.17 | 27.15 | 1.20 | 39.3 | 109371 | 1.2 |
| 1969 | 47.73 | 98.59 | 29.45 | 31.78 | 59.25 | 29.06 | 1.28 | 41.5 | 110015 | 1.3 |
| 1970 | 47.33 | 101.66 | 29.39 | 33.70 | 59.85 | 26.42 | 1.44 | 42.0 | 112369 | 1.3 |
| 1971 | 52.67 | 108.08 | 32.39 | 34.87 | 53.70 | 27.16 | 1.23 | 43.4 | 114578 | 1.4 |
| 1972 | 55.63 | 118.66 | 35.78 | 41.40 | 67.30 | 28.14 | 1.80 | 50.0 | 117862 | 1.5 |
| 1973 | 67.83 | 141.99 | 44.54 | 53.18 | 90.41 | 42.19 | 2.79 | 54.5 | 121539 | 1.8 |
| 1974 | 67.85 | 146.31 | 41.89 | 37.88 | 80.64 | 38.25 | 3.05 | 55.2 | 127788 | 1.8 |
| 1975 | 73.17 | 154.84 | 44.61 | 33.91 | 108.79 | 45.07 | 2.66 | 56.5 | 132028 | 2.0 |
| 1976 | 61.00 | 148.18 | 39.11 | 39.39 | 99.29 | 40.21 | 2.15 | 63.9 | 127980 | 1.7 |
| 1977 | 62.69 | 148.35 | 40.38 | 40.19 | 93.35 | 40.81 | 2.08 | 68.3 | 122810 | 1.9 |
| 1978 | 80.43 | 181.88 | 52.34 | 58.78 | 101.59 | 44.54 | 2.28 | 76.1 | 116375 | 2.3 |
| 1979 | 101.62 | 226.29 | 67.75 | 83.08 | 94.68 | 44.41 | 2.49 | 96.1 | 110864 | 2.8 |
| 1980 | 104.44 | 237.63 | 66.96 | 75.23 | 92.46 | 46.84 | 3.13 | 94.7 | 111242 | 2.3 |
| 1981 | 99.90 | 238.72 | 63.84 | 66.24 | 100.61 | 46.29 | 2.46 | 99.3 | 114351 | 2.1 |
| 1982 | 101.31 | 242.47 | 64.22 | 64.82 | 114.91 | 43.96 | 2.82 | 100.0 | 115444 | 2.2 |
| 1983 | 97.83 | 242.06 | 62.52 | 63.71 | 102.73 | 48.10 | 3.20 | 103.2 | 115001 | 1.9 |
| 1984 | 100.11 | 239.55 | 65.34 | 65.29 | 103.83 | 53.02 | 2.60 | 109.0 | 113700 | 2.9 |
| 1985 | 90.76 | 232.58 | 58.34 | 64.56 | 95.41 | 48.51 | 2.25 | 108.9 | 109749 | 1.8 |
| 1986 | 88.98 | 230.71 | 57.75 | 62.79 | 104.65 | 54.31 | 1.53 | 113.0 | 105468 | 1.2 |
| 1987 | 97.21 | 242.09 | 64.60 | 75.36 | 106.64 | 45.21 | 1.07 | 120.4 | 102000 | 1.4 |
| 1988 | 103.34 | 254.67 | 69.62 | 83.67 | 95.28 | 53.74 | 1.42 | 131.4 | 98994 | 1.7 |

| Year | BYPF | $Q^{car}$ | $Q^{sl}$ | $QP_{bp}$ | $QX^{hd}$ | $QX^{vm}$ | $QM^{c}$ | $QM^{bv}$ | $QX^{bv}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1964 | 5.3 | 18965 | 38072 | 438.00 | 13893 | 104979 | 547 | 1085 | .1 |
| 1965 | 6.1 | 19261 | 39770 | 436.83 | 15768 | 101210 | 1128 | 942 | .1 |
| 1966 | 6.7 | 20355 | 4.374 | 436.17 | 16784 | 96732 | 1100 | 1204 | .1 |
| 1967 | 5.2 | 20740 | 39788 | 432.25 | 14314 | 100842 | 752 | 1328 | .4 |
| 1968 | 5.2 | 21358 | 40649 | 425.67 | 15081 | 102170 | 1039 | 1518 | .4 |
| 1969 | 6.2 | 21600 | 40100 | 422.67 | 16430 | 108761 | 1042 | 1640 | .6 |
| 1970 | 6.3 | 22063 | 39097 | 424.90 | 16537 | 108652 | 1168 | 1816 | 1.1 |
| 1971 | 6.2 | 22250 | 39274 | 421.92 | 18184 | 125861 | 991 | 1756 | 1.7 |
| 1972 | 9.4 | 22679 | 38832 | 420.05 | 19650 | 115238 | 1186 | 1996 | 1.6 |
| 1973 | 12.6 | 21414 | 35938 | 419.65 | 18753 | 127860 | 1039 | 2021 | 24.8 |
| 1974 | 10.1 | 23285 | 39800 | 422.42 | 20596 | 134220 | 568 | 1646 | 13.4 |
| 1975 | 9.6 | 24499 | 46123 | 420.88 | 13672 | 133188 | 389 | 1782 | 17.7 |
| 1976 | 10.4 | 26479 | 48006 | 411.54 | 27432 | 172246 | 984 | 2095 | 34.3 |
| 1977 | 11.8 | 25779 | 47375 | 427.83 | 26983 | 173060 | 1133 | 1963 | 44.5 |
| 1978 | 15.0 | 24608 | 43724 | 428.92 | 27222 | 18531 | 1253 | 2322 | 74.6 |
| 1979 | 22.6 | 21673 | 36503 | 428.17 | 26053 | 163930 | 732 | 2432 | 77.7 |
| 1980 | 16.9 | 21848 | 36397 | 436.75 | 22063 | 200417 | 681 | 2085 | 75.5 |
| 1981 | 16.0 | 22628 | 37752 | 439.50 | 22730 | 209281 | 680 | 1761 | 96.3 |
| 1982 | 15.0 | 22789 | 38865 | 440.25 | 26546 | 230344 | 1005 | 1958 | 117.2 |
| 1983 | 15.6 | 23488 | 39726 | 441.33 | 24507 | 218311 | 921 | 1950 | 133.5 |
| 1984 | 18.6 | 23897 | 40879 | 442.83 | 28479 | 217019 | 753 | 1847 | 174.1 |
| 1985 | 15.3 | 24056 | 39678 | 447.67 | 28148 | 247582 | 836 | 2091 | 184.5 |
| 1986 | 15.6 | 24722 | 40696 | 450.00 | 29881 | 249460 | 1335 | 2156 | 250.2 |
| 1987 | 19.7 | 23821 | 38462 | 446.67 | 27324 | 230174 | 1175 | 2293 | 281.0 |
| 1988 | 22.0 | 23811 | 36808 | 450.67 | 27691 | 214565 | 1332 | 2406 | 359.6 |

| Year | $Y_d$ | CPI | $W_f$ | $Y_{jap}$ | EXR | QOUTA | $P^{car}_{jap}$ |
|---|---|---|---|---|---|---|---|
| 1964 | 6727 | 31.0 | 2.37 | 95518.8 | 358.3 | 3000 | 1538.1 |
| 1965 | 7027 | 31.5 | 2.43 | 99763.3 | 360.9 | 10100 | 1802.1 |
| 1966 | 7280 | 32.4 | 2.52 | 110427.6 | 362.5 | 10000 | 2037.0 |
| 1967 | 7513 | 33.4 | 2.64 | 125016.1 | 361.9 | 19000 | 2458.1 |
| 1968 | 7728 | 34.8 | 2.80 | 140036.8 | 357.7 | 21438 | 2530.7 |
| 1969 | 7891 | 36.7 | 2.96 | 156078.7 | 357.8 | 23200 | 2370.3 |
| 1970 | 8134 | 38.8 | 3.16 | 172222.2 | 357.7 | 25400 | 2284.6 |
| 1971 | 8322 | 40.5 | 3.38 | 176722.7 | 314.8 | 37200 | 2188.3 |
| 1972 | 8562 | 41.8 | 3.60 | 194240.3 | 302.0 | 77830 | 2257.3 |
| 1973 | 9042 | 44.4 | 3.83 | 214200.0 | 280.0 | 169455 | 3084.8 |
| 1974 | 8867 | 49.3 | 4.16 | 204925.9 | 301.0 | 5650 | 2548.5 |
| 1975 | 8944 | 53.8 | 4.57 | 323886.3 | 300.2 | 85000 | 2590.8 |
| 1976 | 9175 | 56.9 | 4.97 | 310034.6 | 292.8 | 96500 | 2865.8 |
| 1977 | 9381 | 60.6 | 5.37 | 302160.2 | 240.0 | 92500 | 2679.6 |
| 1978 | 9735 | 65.2 | 5.80 | 304822.0 | 194.6 | 112000 | 2481.4 |
| 1979 | 9829 | 72.6 | 6.27 | 309445.7 | 239.7 | 134500 | 2538.3 |
| 1980 | 9722 | 82.4 | 6.85 | 299739.7 | 203.0 | 134800 | 2478.2 |
| 1981 | 9769 | 90.9 | 7.43 | 295821.0 | 219.9 | 126800 | 2338.4 |
| 1982 | 9725 | 96.5 | 7.92 | 296839.5 | 235.0 | 135000 | 2290.1 |
| 1983 | 9930 | 99.6 | 8.20 | 301021.9 | 232.2 | 141000 | 2263.1 |
| 1984 | 10419 | 103.9 | 8.39 | 309200.0 | 251.1 | 150000 | 2186.7 |
| 1985 | 10625 | 107.6 | 8.57 | 317252.0 | 200.5 | 159000 | 2158.0 |
| 1986 | 10905 | 109.6 | 8.75 | 323825.1 | 159.1 | 168000 | 2167.0 |
| 1987 | 10970 | 113.6 | 8.93 | 337942.4 | 123.5 | 214000 | 2176.8 |
| 1988 | 11337 | 118.3 | 9.10 | 354563.1 | 125.9 | 274000 | 2191.9 |