ABTRACT

BOONSAENG, TULLAYA. Three Essays on the Demand of Imported and Domestic Meat and Livestock in the United States. (Under the direction of Michael Wohlgenant.)

This dissertation studies the demand for imported and domestic demand models for meat and livestock. The first essay focuses on the separability between import and domestic meat demand and the performance of static versus dynamic models of consumer behavior. A new dynamic system of demand functions is developed and used to test the separability restrictions on U.S. meat consumption data. Our results indicate that imported meat consumption is non-separable from the U.S. consumption and a dynamic specification of the AIDS model is superior to the static AIDS model.

The second essay analyzes the demand for domestic and imported livestock by the US meat processing industry and explores the existence of long-run relationships in the derived demand models which are required for the specification of dynamic demand models. The results indicate that the static inverse input demand model performed better than the dynamic models for both the beef and pork processing industries. The results of this study indicate that there is not a long run relationship in the variables of the inverse demand models for livestock.

The third essay investigates the impact of the discovery of BSE in Canadian cattle on the imported and domestic demand for livestock and meat in the United States. A multi-market partial equilibrium model is utilized to simulate the effects of policy-induced shifts in quantities of imports supplied from Canada on the meat and livestock industries. Our simulation results predict small effects on cattle and the results are similar to predictions from Armington type models even though the separability assumption is strongly rejected.

Three Essays on the Demand of Imported and Domestic Meat and Livestock in the United States

by

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To my Dad

Biography

Tullaya Boonsaeng was born on October 1, 1973, in Suphanburi, Thailand. She graduated from Satriwittaya High School, Bangkok in 1992, and attended Kasetsart University. She received a B.S. in Agricultural Economics in 1996. In August 1997, she began work on her Master's degree in Economics at University of Colorado at Denver. After finishing the Master's degree in 2000, she began studies on the Ph.D. program in Economics. She earned a Ph.D. in Economics in August of 2006.

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Chapter 1

Introduction

1.1 Some General Information on the U.S. Meat and Livestock Markets

According to the 2002 Census of Agriculture, approximately 48% of farms in the United Sates are devoted to the production of cattle and calves, hogs and pigs, and poultry and eggs. Moreover, the market value of livestock products from these farms accounted for 39 percent of the market value of total agricultural products in 2002.

The meat processing industry is also an important sector of the economy. For example, in 2002 more than one half million U.S. workers were employed by the meat processing sector. On the demand side, U.S. consumer expenditures on meat groups (meat, poultry, fishes and eggs expenditures) are approximately 15 percent of total food expenditures. These figures highlight the importance of both the meat and the livestock markets as part of the U.S. economy and in particular of the U.S. agricultural sector.

1.1.1 Beef and Cattle Markets

The United States (U.S) is the world's largest producer of beef and also the world's largest importer of beef. The U.S. share of world beef production was around 24 percent in 2002. The U.S. share of world beef imports accounted for 27.90 percent in 2002. Whereas the U.S. primarily produces high-quality and grain-fed beef, most of U.S. beef imports are lower valued grass-fed frozen beef coming from Canada and New Zealand. Canada is the source of imports of higher valued cuts (fresh and chilled beef).

The main input of the beef processing industry is domestic cattle (around 96%). The industry also imports live cattle from Canada and Mexico. Most of the live cattle imports from Canada are slaughter cattle and almost all of the imports of live cattle from Mexico are feeder cattle. The demand for imported live animals is very small relative to the domestic demand for live animals. In 2002, the U.S. processed 34.5 millions of domestic cattle and only 1.2 million heads of imported cattle. However, the demand for imported cattle is believed to play an important role as an input for U.S. meat packing industry plants since they usually have excess capacity. These plants with excess capacity rely on imports to reduce average slaughter costs (Brester and Marsh, 1999).

1.1.2 Pork and Hogs

The US is the world's third largest pork producer following China and the EU and is also the world's third largest importer of pork following Japan and Russia. US pork imports are mainly from Canada and Denmark. In 1985, Denmark and Canada each supplied about two-fifths of US pork imports. But during the early 2000s, more than four-fifths of US imports came from Canada, while Denmark only accounted for around one-tenth of imports.

The significant increase in imports of Canadian pork has been due to several reasons. Increases in efficiencies in transportation, NAFTA, and cross-border investments have together accelerated the rate of integration in the North American pork and foodservice industries. The packer and processing industries in Canada have pursued scale economies to lower per unit costs. Moreover, Canada has comparative advantages in hog production over the U.S. because the cool Canadian climate and the distance between the operations make the outbreak of diseases unlikely.

U.S. also imports from Canada slaughter and feeder hogs. Imports of Canadian slaughter hogs have declined over time relative to total hog imports (slaughter plus feeder hogs). This decline is associated with the increase in imports of Canadian pork since most of slaughter Canadian hogs are processed in the country and then shipped to the U.S. On the other hand, the increase in imports of live feeder hogs has been associated with the decline in the U.S. breeding herd numbers which has increased the demand for feeder pigs in the U.S. Canadian feeder live hogs weighing between 10 and 40 pounds are imported by US hog finishers and then housed in finishing barns.

1.2 Motivation for the study of meat and livestock demand

Previous studies of meat and livestock demand have not explored the relationship between the U.S. demand for domestic and imported meats. The study of these issues is even more important now that trade agreements such as the Canada-United States Free Trade Agreement (CUSTA) in 1989, the North American Free Trade Agreement (NATFA) in 1994, and the Uruguay Round trade negotiation in 1994 have opened U.S. meat and livestock markets. Only very minor tariffs now affect meat imports into the United States. A better understanding of the supply and demand forces underlying meat and livestock markets can improve policy and industry decisions in the United States.

The first essay of this dissertation studies the demand for domestic and imported meats. This essay specifically focuses on the separability between imported and domestic meats in the U.S. Researchers have widely used models of import demand assume that demand is separable between foreign and domestic sources (e.g. the Armington trade model). However, some authors (Winters, 1984, 1985), have argued that domestic and imported goods are the same type of goods and cannot be separable. The separability assumption has implications for the specification of import demand functions. If domestic and foreign goods are not separable, properly specified import demand functions must include the price of domestic goods as explanatory variables. The first essay also evaluates the performance of static versus dynamic models of consumer behavior.

The demand for meats by U.S. final consumers is a topic that has been studied extensively by researchers. On the other hand, the demand for livestock by the U.S. meat processing industry has received less attention. This subject is important to get a better understanding of the links between retail (consumer) demand and livestock demand. Therefore, the second essay focuses on the demand for slaughter domestic and imported cattle and hogs by the US meat processing industry. Given the fact that Canada is the main livestock trade partner with the United States, this dissertation focuses only on the livestock imports from this country.

The empirical work done using systems of demand equations (consumer and derived demands) commonly rejects the implications derived from theory (i.e., homogeneity and symmetry). Several authors have argued that the cause of this problem could be attributed to the econometric approaches used for estimation and have proposed the use of more dynamic specifications. The first and second essays compare the performance of static versus dynamic systems of demand equations.

Using the results of the first and second essay, we look at the effect on the U.S. meat and livestock markets of a shock in the supply for Canadian imports. This shock is similar to the effect of the discovery of BSE in Canada. After the discovery in Canada of an animal infected with BSE in May 2003, the U.S. closed its border to cattle from Canada causing a decrease in the supply of Canadian cattle to the United States. The United States only allowed import of Canadian boxed beef from cattle that are under 30 months of age. Previous studies on the impact of BSE on the U.S. markets have studied the effect on either the beef or livestock market ignoring the market interdependencies.

Chapter 2

Testing Separability between Imported and Domestic Meat Commodities

2.1 Introduction

The purposes of this study are first to test separability of imported meat from domestic meat, and second to formulate a dynamic model of consumer behavior. The study also compares the performance of static and dynamic demand systems, and provides estimates of long-run elasticities that can be used for policy analysis.

The meat and poultry industry is the largest segment of United States agriculture. The study of U.S. total expenditure on meat production is particularly important to the meat industry in the United States and to the economy in general since around 27 percent of food expenditure is spent on meat products (Haley, 2001). The U.S. is also one of the world's leading importers and producers of beef and pork products. However, previous studies of meat demand have not explored the relationship between U.S. demands for domestic and imported meats. The study of these issues is even more important now that trade agreements such as the General Agreement on Tariffs and Trade (GATT), the North American Free Trade Agreement (NAFTA), and the Uruguay Round Agreement on Agriculture (URAA) are opening up the U.S. meat market. Only very minor tariffs now affect meat imports into the United States. Moreover, a better understanding of the relationship between domestic and imported meats can help to analyze the impact of sanitary measures.

2.1.1 Dynamic Specification of Demand Systems

The empirical work done using systems of demand equations commonly rejects the implications derived from theory (i.e., homogeneity and symmetry). Anderson and Blundell (1982) argued that the cause of this problem could be attributed to the econometric approaches used for estimation. They suggested that the presence of more dynamic specifications should be included when modeling commodity demand equations. These specifications can accommodate habit persistence, adjustments, incorrect expectations and misinterpreted real price changes (Anderson and Blundell, 1983).

Dynamic effects have been introduced into the AIDS model in different ways including a general dynamic framework (e.g., Peeters, Surry and Cielen, 1997), incorporating lagged consumption (e.g., Blanciforti and Green, 1983 and Chen and Veeman, 1991), and adding a vector of lagged expenditure shares (e.g., Rickertsen, 1998). A dynamic AIDS model can also be derived by modifying the intercept term of the share equation from the static AIDS model (Blanciforti and Green, 1983; Alessie and Kapteyn, 1991). The intercept term will depend on budget shares lagged one period.

Cointegration techniques and non-stationary time series are a new alternative approach for introducing dynamics into demand systems. These techniques have been used by Attfield, 1997; Karagiannis et al., 2000; Kaabia and Gil, 2001; Fanelli and Mazzocchi, 2002; and Karagiannis and Mergos, 2002. In this paper, a dynamic AIDS model is developed from an Autoregressive Distributed Lag Model (ARDL) is incorporated into an error-correction model to allow for many periods of short-run dynamic adjustments to long-run equilibrium positions.

In the context of U.S. meat demand, several researchers have used dynamic demand models. Kesavan et al. (1993) studied the long-run structure of U.S. meat demand. Their approach allows merging the short-run dynamics and long-run steady state structure using a distributed lag form of the AIDS model, as proposed by Anderson and Blundell (1982; 1983). Holt and Goodwin (1997) used the Inverse Almost Ideal Demand System and included in the specification of their model habit shock terms that allow purchases from the distant past to influence current consumption (long memory). Wang and Bessler (2003) studied the dynamic Vector Error Correction Model (VECM) but the focus of their work was forecasting accuracy. All of these works suggest that the dynamic US meat demand models perform better than the static models. The dynamic specification proposed in this study is similar to the specification proposed by Kesavan et al. (1993) but uses a different transformation.

2.1.2 Separability and Demand

The concept of separability was originally introduced by Leontief (1945) and Sono (1961). This concept has been used effectively to analyze the structure of consumer preferences and its implications have been widely used in the empirical study of demand analysis for agricultural commodities in order to limit the number of estimated parameters. The separability between imported and domestic meat has not been previously studied in the context of U.S. meat demand. However, commonly used models of import demand assume that demand is separable over foreign and domestic sources (e.g. the Armington trade model). Some authors, such as Winters (1984, 1985), have argued that domestic and imported goods are the same type of goods and cannot be separable. The separability assumption has implications for the specification of import demand functions. If domestic and foreign goods are not separable, properly specified import demand functions must include the prices of domestic goods as explanatory variables.

The dynamic AIDS model developed in this paper is also utilized to test separability between domestic and import commodities in the U.S. system of meat demand, which has significant implications for how researchers model import demand for policy analysis. A misspecification testing strategy is designed to ensure that the statistical assumptions underlying the system of equations are appropriate. A systemwise test approach is used to test the statistical assumptions and takes into account information in, and interactions between, all equations in the system where systems of equations are estimated for both static and dynamic demand model.

In the context of US meat demand Eales and Unnevehr (1988) and Nayga and Capps (1994) have tested weak separability for disaggregated meat products in the static meat demand model. Eales and Unnevehr found that hamburger and whole birds are inferior goods and chicken parts and beef table cuts are normal goods. However, Nayga and Capps (1994) found that the demand for all types of meat should be estimated simultaneously. To the best of our knowledge, separability has never been tested using dynamic demand models and between imported and domestic meats in the US.

2.2 Model

2.2.1 The Static AIDS Model

Many demand systems of equations can be used for empirical analysis. The Almost Ideal Demand System proposed by Deaton and Muellbauer (1980) is a very popular choice among applied researchers. This demand system satisfies the axioms of choice exactly; it aggregates perfectly over consumers without invoking linear Engel curves; it has a functional form which is consistent with known household budget data; and it can be used to test homogeneity, symmetry, and separability restrictions. The basic AIDS model is written as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln(p_j) + \beta_i \ln(E/P^*) \qquad i = 1, 2, \ldots, n, \qquad (1)$$

where α_i is a constant, w_i is the budgetary share allocated to the i^{th} item, p_j is the price of item j (i.e. $w_i = p_i q_i / E$), E is the total expenditures on all items and P^* is aggregate price deflator defined by $\ln P^* = a_0 + \sum_{i=1}^{n} a_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j$. Due to the difficulty in estimating the nonlinear system of equations (4), in empirical analysis P* is approximated by the Stone's index ($\ln P^* = \sum_{i=1}^{n} w_i \ln p_i$). Theory of dynamics especially related to cointegration has not allowed for nonlinearities.

To be consistent with economic theory, the system of share equations in (4) must satisfy several restrictions. First, the shares w_i have to sum up to unity. Second, adding up implies the following restrictions in the parameters: ($\sum_{i=1}^{n} \alpha_i = 1$, $\sum_{i=1}^{n} \gamma_{ij} = 0$, and $\sum_{i=1}^{n} \beta_i = 0$); homogeneity implies ($\sum_{j=1}^{n} \gamma_{ij} = 0$); and symmetry implies ($\gamma_{ij} = \gamma_{ji}$).

The static model assumes an instantaneous adjustment to equilibrium but consumers are unlikely to adjust to equilibrium in every time period. This lack of instantaneous adjustment can be caused by several reasons, e.g., habit persistence, adjustment costs, incorrect expectations or misinterpreted real price changes. Many applied researchers in previous studies have found evidence of the presence of habit persistence in the consumption patterns of consumers. Therefore, the static model is unlikely to explain all of the changes observed in the demand for goods in time series data. Hence, a more general structure for a dynamic demand system needs to be constructed.

2.2.2 The Dynamics AIDS Model

There are several ways to specify a dynamic AIDS model. Some economists include lagged budget share or lagged consumption into the AIDS model to account for the habit effects. In this study a dynamic AIDS model is developed from an Autoregressive Distributed Lag Model (ARDL) incorporated into an error-correction model (ECM) to allow for many periods of short-run dynamic adjustments to long-run equilibrium positions. These fully modified techniques are used to remove nuisance parameters from the limiting distributions which arise with non-stationary data.

An ARDL model is a model in which the value of the dependent variable at time t depends on lagged values of the dependent variable and also in the current and lagged values of a vector of explanatory variables. An ECM is a dynamic model in which the movement of a variable in any period is related to the previous period's gap from long-run equilibrium.

In equation form, an ARDL for a dependent variable y_t with explanatory variables x_t can be written as (Harvey, 1993):

$$y_t = \sum_{k=1}^{r} \phi_k y_{t-k} + \sum_{m=0}^{s} \omega_m x_{t-m} + \varepsilon_t \ , \tag{2}$$

where ϕ and ω are parameters, r and s are the number of lags. Therefore, the ARDL model of the general static AIDS model is as follows

$$w_{it} = \alpha_i + \sum_{k=1}^{r} \varphi_k w_{it-k} + \sum_{m=0}^{s} \sum_{j} \gamma^{*}_{ijm} \ln(p_j)_{t-m} + \sum_{m=0}^{s} \beta^{*}_{im} \ln(E/P^{*})_{t-k} + \tilde{u}_{it} , \tag{3}$$

where $\gamma^{*}_{ijm} = \omega_m \gamma_{ij}$, $\beta^{*}_{im} = \omega_m \beta_i$, and $\tilde{u}_{it}$ is residual of the ARDL model of the general static AIDS model.

Usually, autoregressive distributed lags model are used with the variables in levels. However, if the variables are non-stationary, the lag structure can be re-parameterised as

$$\Delta w_{it} = \alpha_i + (\varphi_i - 1) w_{it-1} + \sum_{k=1}^{r-1} \varphi'_{ik} \Delta w_{it-k} + \sum_j \gamma^*_{ij0} \Delta \ln(p_j)_t + \sum_j \gamma^*_{ij} (\ln p_j)_{t-1}$$

$$+ \sum_{m=1}^{s-1} \sum_j \gamma'_{ijm} \Delta \ln(p_j)_{t-m} + \beta^*_{i0} \Delta \ln(E/P^*)_t + \beta^*_i \ln(E/P^*)_{t-1}$$

$$+ \sum_{m=1}^{s-1} \beta'_{im} \Delta \ln(E/P^*)_{t-m} + \tilde{u}_{it}, \qquad (4)$$

where $\varphi'_{ik} = -\sum_{n=k+1}^{r} \varphi_{in}$, $k = 1, 2, \ldots, r-1$, $\qquad \varphi_i = \sum_{n=1}^{r} \varphi_{in}$

$$\gamma'_{ijm} = -\sum_{n=m+1}^{s} \gamma^*_{ijn} \text{ , } m = 1, 2, \ldots, r-1, \qquad \gamma^*_{ij} = \sum_{n=1}^{s} \gamma^*_{ijn}$$

$$\beta'_{im} = -\sum_{n=m+1}^{s} \beta^*_{in} \text{ , } m = 1, 2, \ldots, r-1, \qquad \beta^*_i = \sum_{n=m+1}^{s} \beta^*_{in}$$

If the contributions from the levels variables in (equation 4) are put together we have:

$$\begin{aligned} &(\varphi_i - 1) w_{it-1} + \alpha_i + \sum_j \gamma^*_{ij} (\ln p_j)_{t-1} + \beta^*_i \ln(E/P^*)_{t-1} \\ &= (\varphi_i - 1)[w_{it-1} - (\alpha^\circ_i + \sum_j \gamma^\circ_{ij} (\ln p_j)_{t-1} + \beta^\circ_i \ln(E/P^*)_{t-1})] \end{aligned} \qquad (5)$$

The model in equation (4) can be rewritten in the following form after substituting the new form derived in equation (5):

$$\Delta w_{it} = \sum_{k=1}^{r-1} \varphi'_{ik} \Delta w_{it-k} + \sum_j \gamma^*_{ij0} \Delta \ln(p_j)_t + \sum_{m=1}^{s-1} \sum_j \gamma'_{ijm} \Delta \ln(p_j)_{t-m}$$

$$+ \beta^*_{i0} \Delta \ln(E/P^*)_t + \sum_{m=1}^{s-1} \beta'_{im} \Delta \ln(E/P^*)_{t-m}$$

$$+ (\varphi_i - 1)[w_{it-1} - (\alpha^\circ_i + \sum_j \gamma^\circ_{ij} (\ln p_j)_{t-1} + \beta^\circ_i \ln(E/P^*)_{t-1})] + \tilde{u}_{it}, \qquad (6)$$

Equation (6) is an ECM model. This model can be called the general AIDS error correction model (GAECM). The long run relationship between w_{it} and the vector of explanatory variables is given by the error correction term in brackets. In other words, this term captures the influence of the previous period's deviation from the long run equilibrium. The lag values of Δw_{it} capture habit persistence effects since previous distribution of food expenditure affects current decisions. This model also captures the short run effects of the explanatory variables in the current and previous periods.

The GAECM allows more time periods to adjust to disequilibrium happening in the short run due to strong habitual consumption, adjustment costs, and imperfect information and uncertainty toward the long run equilibrium because the process of adjustment may not be complete in the single period of time. In the period before these adjustments are completed, consumers will be 'out of equilibrium' and their short-run responses to changes in prices, and income may be little guide as to their long-run effects. Furthermore, the GAECM presumes the existence of a unique long-run relationship among the variables, it is easy to estimate and makes economic sense.

To be consistent with economic theory, the following restrictions must be imposed in the GAECM. These restrictions are:

Adding up: $\sum_{i=1}^{n} \alpha_i^{\circ} = 1$, $\sum_{i=1}^{n} \gamma_{ij}^{\circ} = 0$, $\sum_{i=1}^{n} \beta_i^{\circ} = 0$, $\Delta w_{it} = 0$, $\sum_{k=1}^{r-1} \varphi'_{ik} = 0$

$\sum_{j} \gamma_{ij0}^{*} = 0$, $\sum_{m=1}^{s-1} \sum_{j} \gamma'_{ijm} = 0$, $\beta_{i0}^{*} = 0$, $\sum_{m=1}^{s-1} \beta'_{im} = 0$, $(\varphi_i - 1) = 0$

Homogeneity: $\sum_{j} \gamma_{ij}^{\circ} = 0$

Symmetry: $\gamma_{ij}^{\circ} = \gamma_{ji}^{\circ}$

2.2.3 Diagnostic Tests

Model misspecification may lead to biased and inconsistent estimators and/or inappropriate statistical inferences. Therefore, it is important to perform diagnostic tests in the models. In the context of demand systems of equations practitioners usually perform misspecification tests separately for all the equations in the system and then combine the results in an ad hoc manner. A more appropriate approach is to conduct the misspecification tests for the system as a whole (McGuirk et al., 1995; Shukur, 2002).

If we consider the static AIDS and GAECM system of equations as multiequation regression models they can be written as $\tilde{Y}_t = \tilde{B}'\tilde{X}_t + \tilde{\varepsilon}_t$, where $\tilde{X}_t = (\tilde{x}_{1t}, \tilde{x}_{2t}, ..., \tilde{x}_{Kt})$ is a vector of exogenous variables including the intercept, $\tilde{Y}_t = (\tilde{y}_{1t}, \tilde{y}_{2t}, ..., \tilde{y}_{nt})$ is a vector of endogenous variables, $\tilde{B}'$ is a $K \times n$ matrix of unknown parameters, and $\tilde{\varepsilon}_t$ is a *n x 1* vector of random disturbances. Misspecification tests of autocorrelation, heteroscedasticity, autoregressive conditional heteroskedasticity (ARCH), and functional form will be applied to this model. All the tests are done using a multivariate F-test proposed by Rao (1973). Shukur and Edgerton (2002) have shown that using this test leads to superior properties for systemwise tests of misspecification over the Wald, Likelihood Ratio and Lagrange Multiplier test statistics.

Following Shukur (2002), the Breusch-Godfrey (BG) systemwise test is used to test for autocorrelation; the Breusch-Pagan (BP) test is used for heteroscedasticity; and the systemwise RESET test is utilized for functional misspecification. The following regressions need to be estimated to perform the tests:

$$\text{BG: } \hat{\varepsilon}_t = \tilde{B}'\tilde{X}_t + \tilde{Y}_{t-1}\Gamma_1 + ... + \tilde{Y}_{t-H}\Gamma_H + \hat{\varepsilon}_{t-1}\Psi_1 + ... + \hat{\varepsilon}_{t-G}\Psi_G + \delta_t \quad (7)$$

$$\text{BP: } \hat{\varepsilon}_t^2 = \alpha_0 + \alpha_1\hat{\tilde{Y}}_t + \alpha_2\hat{\tilde{Y}}_t^2 + ... + \alpha_p\hat{\tilde{Y}}_t^p + \delta_t \quad (8)$$

$$\text{RESET: } \tilde{Y}_t = \tilde{B}'\tilde{X}_t + \hat{\tilde{Y}}_t^2\Psi_1^* + \hat{\tilde{Y}}_t^3\Psi_2^* + \ldots + \hat{\tilde{Y}}_t^{G+1}\Psi_G^* + \delta_t, \tag{9}$$

where $\hat{\varepsilon}_t = \tilde{Y}_t - \hat{\tilde{Y}}_t$, and $\hat{\tilde{Y}}_t = (\tilde{X}_t(\tilde{X}_t'\tilde{X}_t)^{-1}\tilde{X}_t')\tilde{Y}_t$.

In equation (7), autocorrelation is tested using the null hypothesis that $\Psi_1 = \ldots = \Psi_G = 0$. In this study, due to the shortage of degrees of freedom, the specification of (7) only includes a lagged value of the independent variable and the predicted errors. In equation (8), the null hypothesis $\alpha_1 = \alpha_2 = \ldots = \alpha_p = 0$ is tested for heteroscedasticity and only a second degree polynomial of the predicted value of the dependent variable is used. In equation (9), the RESET test is performed by testing the null hypothesis $\Psi_1^* = \Psi_2^* = \ldots = \Psi_G^* = 0$. This test was done using only a second degree polynomial.

Engle suggested that heteroscedasticity might occur in time series. He formulated the notion that the recent past might give information about the conditional disturbance variance. Thus, he came up with an autoregressive conditional heteroskedasticity (ARCH) test. The ARCH test is performed by testing the joint hypothesis that $\rho_0 = \rho_1 = \ldots = \rho_p = 0$ in the following equation:

$$\hat{\varepsilon}_t^2 = \rho_0 + \rho_1\hat{\varepsilon}_{t-1}^2 + \ldots + \rho_p\hat{\varepsilon}_{t-p}^2 + \delta_t \tag{10}$$

The number of lags used in this study was four ($p = 4$). The ARCH test is only performed in the dynamic model.

2.2.4 Separability

The separability assumption is often invoked by researchers doing empirical demand analysis. This assumption allows specifying conditional (second stage) demand systems of equations, thus the system of equations is only applied to the group of goods that is the focus of the research. However, there are undesirable features associated with the empirical use of conditional demand systems. For example, the resulting estimated elasticities are of limited value because group expenditures in conditional demand systems are endogenous (LaFrance, 1991). For these reasons, unconditional demands are more appropriate to obtain elasticities for policy and welfare analysis. The systems in the first stage are also suitable for testing separability.

To test for separability, we consider the work in asymmetric separable structures by Blackorby, Primont, and Russell (1978). This approach is suitable for this study since the number of goods is not the same for all groups. Let $q = [q_1, q_2, ..., q_n]$, a vector of n goods, be the vector that maximizes a strictly quasi-concave utility function $U(q)$ of a consumer subject to the budget constraint $pq \le y$, where $[p_1, p_2, ..., p_n]$ is the vector of prices and y is the available food expenditures. To characterize separability, let the set of n goods be separable into S groups in which all groups are mutually exclusive and define the exhaustive partition $I = \{I_1, I_2, ..., I_s\}$ of the set of n goods. To allow for asymmetric separability, some of the groups include only one good. Assume that 1, 2, …, r are the groups in I that include only one good. Thus, the utility function can be written as:

$$U(q) = [q_1, ..., q_r, U^{r+1}(q^{r+1}), ..., U^s(q^s)], \tag{11}$$

where q_1, ..., q_r are the one commodity groups of goods, $U^{r+1}(.)$ is subutility function that contains a subset q^{r+1} of goods, and $U^s(.)$ is a subutility functions that contain a subset q^s of goods. These utility functions satisfy strong monotonicity, strict quasi-concavity, and differentiability.

Consider the elements I_d and I_m from the partition I. Based on the results of Blackorby, Davidson, and Schworm (1991), the separable utility in (11) implies that, for all $i \in I_d$ and $k \in I_m$, and for all $d \ne m$:

$$\frac{\partial h_i(p,u)}{\partial p_k} = \mu_{dm}(p,y)\frac{\partial q_i(p,y)}{\partial y}\frac{\partial q_k(p,y)}{\partial y}, \tag{12}$$

where $h_i(p,u)$ is the Hicksian demand function, $q_i(p,y)$ is the Marshallian demand function. The $\mu_{gs}(p,y)$ term is the same for all goods in the two groups involved. If n_d is the number of goods in group d and n_m is the number of goods in group $m,$ then the weak separability restrictions for these two groups entail $(n_d \times n_m - 1)$ restrictions.

The restrictions in equation (12) can be written in elasticity terms:

$$\frac{\varepsilon_{ik}^*}{w_k} x = \mu_{dm}(p,y)\eta_i\eta_k \tag{13}$$

where $\varepsilon_{ik}^* = \partial \log(h_i) / \partial \log(p_k)$ is the Hicksian demand elasticity, $w_k = p_k q_k / y$ is the k^{th} budget share, and $\eta_i = \partial \log(q_i) / \partial \log(y)$ is the income elasticity.

The common proportionality term $\mu_{gs}(p,y)$ can be eliminated in equation (13) and the restrictions can be expressed only in elasticity terms and shares. Let $\sigma_{ik} = \varepsilon_{ik}^* / w_k$ and consider any two goods $(i,j) \in I_d$, and any two goods $(m,k) \in I_m$ and $d \neq m,$ then the substitution terms between goods belonging to different groups are proportional to the respective income terms as follow:

$$\frac{\sigma_{ik}}{\sigma_{jm}} = \frac{\eta_i\eta_k}{\eta_j\eta_m} \tag{14}$$

From equation (14), it is clear that the restrictions for testing separability depend only on the elasticities of the demand system. In the LA/AIDS model, the restrictions are:

$$\frac{\gamma_{ik} + w_i w_k}{\gamma_{jm} + w_j w_m} = \frac{(w_i + \beta_i)(w_k + \beta_k)}{(w_j + \beta_j)(w_m + \beta_{m)}}, \tag{15}$$

for all $(i,j) \in I_d$ and $(k,m) \in I_m$, for all $d \neq m,$

where $\sigma_{ij} = \varepsilon_{ij}^* / w_j$ is the Allen-Uzawa elasticity of substitution, $\eta_i = 1 + (\beta_i / w_i)$ is the expenditure elasticities, and $\varepsilon_{ij}^* = \delta_{ij} + (\gamma_{ij} / w_i) + w_j$ is the Hicksian (compensated) price elasticity.

2.3 Data and Procedure

2.3.1 Domestic Meat Data

The data used to estimate the model are quarterly time series data from 1971 to 2002. The domestic meats considered are beef (beef and veal), pork, and poultry (broiler, other chicken, and turkey). The import meats are only beef and pork since the U.S. does not import a significant amount of poultry. The quantity data are pounds per capita consumption.

USDA beef and pork production data are inaccurate and overestimated because these data also include imported fed cattle and hogs slaughtered in the U.S. packing plants (Brester and Marsh, 2002). U.S. production data can be derived from the total USDA production data by subtracting from this figure the product of the U.S. average dressed weight and the number of imported cattle and hogs that are immediately slaughter. Imported cattle and imported hog data are divided into three and two weight categories, respectively. In this study, only imported cattle weighing more than 700 pounds and imported hogs weighing more than 50 pounds were considered to be slaughtered. Average dressed weights for cattle and hogs were obtained from the *Red Meat Yearbook* published by the USDA.

U.S. per capita consumption of domestic meat was obtained by dividing U.S. domestic total disappearance by the U.S. population. U.S. domestic total disappearance in every period was calculated by adding U.S. production to beginning stocks and subtracting exports and ending stocks.

Total USDA production, beginning stocks, imports, exports, and ending stocks data for beef and pork were taken from several issues of the *Livestock and Meat Statistics* and the *Red Meat Yearbooks* published by the ERS from the USDA.

Pounds of U.S. per capita consumption data for all meats were converted to constant dollar expenditures by multiplying them by the average wholesale price in 1982 as suggested by Christensen and Manser (1977). Current expenditures on individual meats were obtained by multiplying constant dollar expenditures of individual meats times the PPI of individual meats.

The wholesale price of U.S. beef and pork is reported by the ERS and is available online. The poultry wholesale price was constructed as the average wholesale price for broilers, “other chicken” and turkey (*Poultry Yearbook*). The 12-city composite wholesale price (ready to cook basis) was used as the wholesale price of broiler. The wholesale price of roasters and hens in Chicago (ready to cook basis) was used as the wholesale price of the “other chicken” category. The wholesale costs of production of turkey (ready to cook basis) was used as the wholesale price of turkey.

Food expenditures and the U.S. population were obtained from the Bureau of Economic Analysis (BEA) from the U.S. Department of Commerce. Producer Price Indexes (PPI) of domestic prices are from the Producer Price Index Commodity Data (Bureau of Labor Statistics).

2.3.2 Imported Meat Data

Imported meat quantity and expenditure data were obtained from various issues of *Foreign Agricultural Trade of the United States* published by the Foreign Agricultural Service (FAS) of the USDA. Beef and pork data are given in two combined categories: the fresh and frozen category and the prepared and preserved category. The import prices for individual items are not publicly available so unit values are used as proxy for prices. Unit import values (import prices) were obtained by dividing import values by import quantities. The import price index combining the two categories was computed as a Laspeyres Index (LI) using 1982 as the reference base (1982=100). The formula of the LI is $P_{ot} = \sum p_t q_o \Big/ \sum p_o q_o$, where p_t is the current price, p_o is the reference base price, q_t is the current quantity, and q_o is the reference base price.

Consumption per capita of imported meat can be obtained by dividing total meat imports by the U.S. population. Meat imports equal imported meat quantity plus meat production from imported cattle and hogs slaughtered in the US (see explanation above). Constant dollar and current expenditures on imported meats were obtained following the same procedure outlined for domestic meat consumption.

2.4 **Econometric Model**

This study considers an unconditional demand system for U.S. food consumption[1]. The complete demand system for U.S. food consumption contains six equations representing the demand for: domestic beef, domestic pork, domestic poultry, import beef, import pork, and nonmeat.

2.4.1 The Static AIDS Demand Model

The static econometric LA/AIDS model of U.S. food consumption can be written as follows:

$$w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln(p_j)_t + \beta_i \ln(E / P^*)_t + A_i D_t + u_{it}, \qquad (16)$$

where i = 1, 2 , … 6 refer to nonmeat, domestic beef, domestic pork, domestic poultry, import beef, and import pork equation respectively, D_t is a deterministic term including several dummy variables.

The system of demand equations (16) can be written in matrix form:

[1] Food commodities are assuming weak separability to nonfood commodities.

$$Y_t = \alpha + \Gamma X_t + dD_t + u_t, \tag{17}$$

where $Y = (w_1, w_2, w_3, w_4, w_5, w_6)'$ is a (6 × 1) vector of the expenditure shares for nonmeat, domestic beef, domestic pork, domestic poultry, import beef, and import pork, respectively; $X = (\ln P_1, \ln P_2, \ln P_3, \ln P_4, \ln P_5, \ln P_6, \ln(E/P^*))'$ is a (7 × 1) vector of producer price indexes for nonmeat, domestic beef, domestic pork, domestic poultry, import beef, and import pork, and real food expenditures; $D = (t, d_1, d_2, d_3, d_{sm}, d_{sp}, d_{ft}, d_{sc}, d_{cvd})'$ is a (9 × 1) vector including a time trend, seasonal dummy variables (d_1, d_2, d_3), structural change dummy variables (d_{sm}, d_{sp}), free trade agreement dummy variables (d_{ft}), production dummy variable (d_{sc}) and an countervailing duty dummy variable (d_{cvd}); $u_t = (u_{1t}, u_{2t}, u_{3t}, u_{4t}, u_{5t}, u_{6t})'$ is a (6 × 1) vector of residuals ; $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6)'$ is a (6 × 1) vector of constant parameters; Γ is a (6 × 7) matrix containing the parameters of the exogenous variables; d is a (9 × 9) matrix containing the parameters of the dummy variables.

The price index for non-meat was computed using the following equation (Wohlgenant, 1989):

$$P_{1t} = (P_t^f - \sum_{i=2}^{6} w_{it} P_{it}) / w_{1t}, \tag{17}$$

where P_t^f is the producer price index of food. The other terms in the equation were defined previously.

Quarterly dummy variables were used to capture seasonality effects. Several dummy variables utilized in this model were used to capture structural change, free trade agreements and the exchange rate between US and Canada.

There is some evidence of a structural change in the demand for U.S. meats in the mid-1970’s (Choi and Sosin, 1990). This dummy variable is for the period of 1974:1-1977:1 in all meats except for a poultry dummy variable for structural change for the period of 1973:1-1974:2. Changes in trade policy also affect imports. In 1994, the two free trade agreements (NAFTA and GATT) were signed to reduce the barriers among countries. A dummy variable for the period 1994:4 to the present is used to capture the free trade agreements for all meat equations.

In the late 1998 and early 1999, pork production has increased due to a shock in supply. Slaughter capacity was constrained and hog producers were forced to sell their animals to the market at low prices. This caused hog producer reduced the breeding inventory. Afterward, pork production was expected to decline. Poultry production also slowed due to a low price of poultry and uncertainty in the export markets around 2000. A dummy variable for the period of 1999:4-2002:4 is used to capture the decline in production due to uncertainty about demand for exports.

During the 1990s, the U.S. imposed countervailing duties (CVD) on Canadian pork and live hogs which influenced the amount of imports of these products. The U.S. imposed this duty arguing that the subsidization of Canadian pork production had led to more pork entering the U.S. market, which in turn injured U.S. producers. A dummy variable for the period of 1992:3-1995:2 is used to capture the CVD on Canadian pork and live hogs. Although one might expect prices to reflect the CVD, disruptions to slaughter in plants close to the Canadian border might be expected to decrease demand for live hogs.

2.4.2 The Dynamic GAECM Demand Model

The conditions for the use of the GAECM are two: 1) all the variables in the model have to be I(1), and 2) the residuals of the static AIDS model have to be stationary. Therefore, the analysis of the data was done in the following sequence:

1. The statistical properties of the data were analyzed. Specifically, the order of integration of the variables was evaluated using the Augmented Dickey Fuller (ADF) tests. The ADF of unit root requires estimating the following regression:

$$\Delta y_t = a_0 + b y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + dt + \varepsilon_t \,, \tag{18}$$

where the lag levels (k) are chosen by either AIC or SBC criterion and the ADF statistics are computed with lag lengths of 4 thorough 8. If all in level-variables are not stationary that would imply that the static AIDS model is inappropriate.

2. The static AIDS model was estimated and the statistical properties of the residuals analyzed using the ADF test.

The empirical specification of the GAECM in equation (6) is as follows:

$$\begin{aligned}
\Delta w_{it} = {} & \sum_{k=1}^{r-1} \varphi'_{ik} \Delta w_{it-k} + \sum_{j} \gamma^{*}_{ij0} \Delta \ln(p_j)_t + \sum_{m=1}^{s-1} \sum_{j} \gamma'_{ijm} \Delta \ln(p_j)_{t-m} \\
& + \beta^{*}_{i0} \Delta \ln(E/P^{*})_t + \sum_{m=1}^{s-1} \beta'_{im} \Delta \ln(E/P^{*})_{t-m} \\
& + (\varphi_i - 1)[w_{it-1} - (\alpha^{\circ}_i + \sum_{j} \gamma^{\circ}_{ij} (\ln p_j)_{t-1} + \beta^{\circ}_i \ln(E/P^{*})_{t-1} \\
& + A^{\circ}_i D_{t-1})] + \tilde{u}_{it}
\end{aligned} \tag{19}$$

The system of dynamic demand equations based on equation (19) can be written in matrix form as:

$$\Delta Y_t = \sum_{k=1}^{r-1} \vec{\varphi}_k \Delta Y_{t-k} + \sum_{m=0}^{s-1} \Gamma^{*}_m \Delta X_{t-m} + \lambda [Y_{t-1} - (\alpha + \Gamma X_{t-1} + dD_{t-1})] + \tilde{u}_t \,, \tag{20}$$

where Δ represents the first difference, λ is the speed of adjustment toward the long-run

$(-1 < \lambda < 0$ for stability), $\tilde{u}_t = (\tilde{u}_{1t}, \tilde{u}_{2t}, \tilde{u}_{3t}, \tilde{u}_{4t}, \tilde{u}_{5t}, \tilde{u}_{6t})'$ is a (6 × 1) vector of residuals, $\sum_{k=1}^{r-1} \vec{\varphi}_k$ is a

$(r-1)\times 1$ vector of parameter corresponding to the first difference of the budget shares, and

$\sum_{k=0}^{s-1}\Gamma_m^*$ is a $((s-1)\times 6)\times(6+1)$ vector of parameter corresponding to the first difference of prices.

2.4.3 The Dynamic Seemingly Unrelated Regressions (DSUR)

Meat demand models are commonly estimated under the assumption that the right-hand-side variables in the model are predetermined; however, prices may not be predetermined. In the case of aggregate data it is possible that prices and quantities may be jointly determined (Eales and Unnevehr, 1993). Moreover, in the case of the AIDS demand model, the use of the Stone's price index leads to a violation of predetermined right-hand-side variables (Buse, 1994).

Several researchers have examined the endogeneity issues on prices and quantities in empirical work. Eales and Unnevehr (1993) found that prices are not predetermined in meat demand systems. Prices and quantities are both endogenous in the meat demand system as whole; however, tests of individual variables indicate that beef quantity could be predetermined. Some researchers avoid this endogeneity problem by using vector autoregressive (VAR) models in which lagged (predetermined) variables are used as right hand side variables (e.g., Wang and Bessler (2002, 2006); Fanelli and Mazzocchi (2002)).

To explore the potential endogeneity bias, in this study the Dynamic Seemingly Unrelated Regressions (DSUR) proposed by Mark et al. (2005) is utilized. The DSUR is formed by adding lags and leads of the first difference of the independent variables. The DSUR based on the static econometric LA/AIDS model can be written as:

$$w_{it}=\alpha_i+\sum_j\gamma_{ij}\ln(p_j)_t+\beta_i\ln(E/P^*)_t+A_iD_t+\sum_{m=0}^{s-1}\sum_j\dot{\gamma}_{ijm}\Delta\ln(p_j)_{t-m}$$

$$+\sum_{m=0}^{s-1}\dot{\beta}_{im}\Delta\ln(E/P^{*})_{t-m}+\sum_{j}\ddot{\gamma}_{ij}\Delta\ln(p_{j})_{t+1}+\ddot{\beta}_{i}\Delta\ln(E/P^{*})_{t+1}+\dot{u}_{it}$$

To be consistent with economic theory, the following restrictions must be imposed in the DSUR. These restrictions are adding up ($\sum_{i=1}^{n}\alpha_i=1, \sum_{i=1}^{n}\gamma_{ij}=0$, and $\sum_{i=1}^{n}\beta_i=0$); homogeneity ($\sum_{j=1}^{n}\gamma_{ij}=0$); and symmetry ($\gamma_{ij}=\gamma_{ji}$).

In matrix form the DSUR can be written as:

$$Y_t=\alpha+\Gamma X_t+dD_t+\sum_{m=0}^{s-1}\dot{\Gamma}_m\Delta X_{t-m}+\ddot{\Gamma}\Delta X_{t+1}+\dot{u}_t$$

where Δ represents the first difference, $\dot{u}_t=(\dot{u}_{1t},\dot{u}_{2t},\dot{u}_{3t},\dot{u}_{4t},\dot{u}_{5t},\dot{u}_{6t})'$ is a (6 × 1) vector of residuals ; $\alpha=(\alpha_1,\alpha_2,\alpha_3,\alpha_4,\alpha_5,\alpha_6)'$ is a (6 × 1) vector of constant parameters; Γ is a (6 × 7) matrix containing the parameters of the exogenous variables; d is a (9 × 9) matrix containing the parameters of the dummy variables; $\sum_{k=0}^{s-1}\dot{\Gamma}_m$ is a $((s-1)\times 6)\times 7)$ vector of parameter corresponding to the first difference of prices and lag values; and $\ddot{\Gamma}$ is a (6 × 7) matrix containing the parameters of the first period lead of the first difference variables.

2.4.4 Elasticities

As shown by Asche and Wessells (1997), there is not difference in the formulas used to calculate price and expenditure elasticities between the AIDS and the LA/AIDS as long as the calculations are made at the point of normalization. The unconditional price elasticities, the conditional price elasticities and the expenditure elasticities of the complete demand system for the

LA/AIDS model at the point of normalization which is 1990:1 can be calculated by using the following equations (Green and Alston , 1991):

$$\varepsilon_{ij} = \delta_{ij} + \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} \tag{21}$$

$$\varepsilon_{ij}^* = \delta_{ij} + \frac{\gamma_{ij}}{w_i} + w_j \tag{22}$$

$$\eta_i = 1 + \frac{\beta_i}{w_i}, \tag{23}$$

where δ is the Kronecker delta, which is equal to -1 when $i = j$ for the own-price elasticities and $i \neq j$ for the cross-price elasticities, and w_i is the mean expenditure share across the sample for good i. The own price elasticities are expected to be negative at all data points due to the global concavity of the expenditure function. The coefficient β_i determines the characteristic of the goods. If it is positive, it will be a luxury good and if it is negative, it will be a necessary good.

The formulas for standard errors (s.e.) of the unconditional price elasticities, the conditional price elasticities and the expenditure elasticities are as follows:

$$s.e.(\varepsilon_{ij}) = \frac{1}{w_i}[Var(\gamma_{ij}) + w_j^2 Var(\beta_i) - 2w_j Cov(\gamma_{ij}, \beta_i)]^{1/2}$$

$$s.e.(\varepsilon_{ij}^*) = \frac{s.e.(\gamma_{ij})}{w_i}$$

$$s.e.(\eta_i) = \frac{s.e.(\beta_i)}{w_i},$$

where $Var(\gamma_{ij})$ is the variance of the coefficient of price variables, $Var(\beta_i)$ is the variance of the coefficient of real income variable, $Cov(\gamma_{ij}, \beta_i)$ is the covariance between coefficients γ_{ij} and β_i, $s.e.(\gamma_{ij})$ is the standard error of price coefficient, and $s.e.(\beta_i)$ is the standard error of income coefficient. Because these elasticities are computed only at the point of normalization, the expenditure shares are taken as fixed.

To identify whether the goods are substitutes or complements, the Morishima elasticities were calculated using the following equation (Blackorby and Russell, 1989):

$$M_{ij} = \varepsilon_{ij}^{*} - \varepsilon_{ii}^{*} \ . \tag{24}$$

These elasticities measure the percentage change in the consumption ratio $h_i(p,u) / h_j(p,u)$ due to a one percent change in the corresponding ratio p_i / p_j. Therefore, the Morishima elasticity of substitution is a very natural measure of substitutability, because by focusing on price and quantity ratios it reflects the curvature of indifference curves. If the Morishima elasticities are positive, the goods are considered to be substitutes.

2.4.5 Testing Separability

First, food commodities are assumed to be weakly separable from nonfood commodities. Second, six commodities were considered to test separability in the food demand system: nonmeat, domestic beef, domestic pork, domestic poultry, imported beef and imported pork. The utility function for the six commodities can be written as:

$$U(q) = U^0[q_1, q_2, q_3, q_4, q_5, q_6] \, . \tag{25}$$

Different types of weakly separable structures can be considered to test against the unrestricted utility function $U(q)$ in equation (25). For example, nonmeat goods can be postulated as weakly separable from meat goods. This structure can be written as:

$$U(q) = U^0[q_1, f(q_2, q_3, q_4, q_5, q_6)]. \tag{26}$$

This structure contains four non-redundant restrictions relative to the unrestricted utility $U(q)$ which follows from our earlier discussion about separability restrictions. Using equation 15 and letting $\pi_{ik} / \pi_{jm} = \dfrac{(\gamma_{ik} + w_i w_k)}{(\gamma_{jm} + w_j w_m)}$ and $\theta_{ik} / \theta_{jm} = \dfrac{(w_i + \beta_i)(w_k + \beta_k)}{(w_j + \beta_j)(w_m + \beta_m)}$, then the four nonredundant restrictions based on the LA/AIDS model can be represented as follows:

$$\frac{\pi_{12}}{\pi_{16}} = \frac{\theta_2}{\theta_6}, \quad \frac{\pi_{13}}{\pi_{16}} = \frac{\theta_3}{\theta_6}, \quad \frac{\pi_{14}}{\pi_{16}} = \frac{\theta_4}{\theta_6}, \quad \frac{\pi_{15}}{\pi_{16}} = \frac{\theta_5}{\theta_6} \tag{27}$$

In this study, the nonmeat group is assumed to be separable from the meat group. Our focus is to test if domestic meat commodities are separable (asymmetrically) from the imported meat commodities. The utility function for this structure is written as:

$$U(q) = U^0[q_1, f(d(q_2, q_3, q_4), m(q_5, q_6))] \tag{28}$$

This structure entails nine nonredundant restrictions, which for the LA/AIDS model specification can be represented as (27) plus the following five restrictions:

$$\frac{\pi_{25}}{\pi_{26}} = \frac{\theta_5}{\theta_6}, \quad \frac{\pi_{35}}{\pi_{36}} = \frac{\theta_5}{\theta_6}, \quad \frac{\pi_{45}}{\pi_{46}} = \frac{\theta_5}{\theta_6}, \quad \frac{\pi_{26}}{\pi_{46}} = \frac{\theta_2}{\theta_4}, \quad \frac{\pi_{36}}{\pi_{46}} = \frac{\theta_3}{\theta_4} \tag{29}$$

All of the separability restrictions were applied to both LA/AIDS and GAECM models. The separability restrictions were tested as nonlinear parametric restrictions. The likelihood Ratio was used to test these restrictions. The likelihood ratio is calculated using the equation $LR \equiv 2[L(\hat{\Gamma}) - L(\tilde{\Gamma})]$, where $L(\cdot)$ denotes the maximized value of the log-likelihood function, $\hat{\Gamma}$ is the unrestricted estimator of the parameter vector, and $\tilde{\Gamma}$ is the estimated parameter vector under the separability restrictions (Moschini et al., 1994).

The complete demand system contains six equations. Since the expenditure shares in the demand system have to sum to one due to the adding up restriction, one of the equations has to be dropped to avoid a singular covariance matrix. The nonmeat equation was dropped out. The parameters of the unrestricted demand systems were estimated using the iterated seemingly unrelated regressions (ITSUR) procedure. The parameters of the restricted demand models were estimated with the seemingly unrelated regression (SUR) method using the variance covariance matrix of the residuals (S matrix) estimated in the unrestricted model. The MODEL procedure from SAS was utilized for estimation purposes.

2.5 Results

2.5.1 Misspecification Tests Results

The results of the single equation and systemwise misspecification tests are presented in *Table 2.1*. *Table 2.1a* shows the misspecification test results for the static LA/AIDS model. The DW tests indicate the presence of autocorrelation in the demand equations since the value of this statistic is well below 2 in most cases. Moreover, the individual equation and the systemwise BG autocorrelation tests reject the null hypothesis that there is no autocorrelation. The BP tests for homoscedasticity of individual demand equations provide evidence of the presence of heteroscedasticity except in the demand equation for domestic pork ($p<0.05$). The systemwise test rejects the null hypothesis of no heteroscedasticity for the demand system of equations ($p<0.05$). The RESET tests for individual and system demand equations identified functional form misspecification problems in all of the equations ($p<0.05$). These results provide evidence that the parameter estimates and the standard errors from the LA/AIDS static might not be consistent.

Table 2.1b shows the misspecification test results for the GAECM model. The individual BG autocorrelation tests fail to reject the null hypothesis that there is no autocorrelation except in the demand equation for imported pork ($p<0.05$). The results from the BP tests for homoscedasticity for the single equations show no evidence of the presence of heteroscedasticity. The ARCH(1) tests for the presence of heteroscedasticity of dynamic form of the single equations show no evidence of the presence of heteroscedasticity except the demand equations for domestic beef ($p<0.05$). The RESET tests for the individual demand equations indicate that there is no functional form misspecification ($p<0.05$). The BP, ARCH(1) and RESET systemwise misspecification tests failed to reject the null hypothesis that there is not a misspecification problem ($p<0.10$). The BG systemwise misspecification tests failed to reject the null hypothesis that there is no misspecification problem ($p<0.01$).

2.5.2 Results of the Static Demand Model

The results from the restricted LA/AIDS demand model are presented in *Table 2.2*. All the equations have high R^2's (except the imported pork equation) and the estimated parameters are mostly significant. The price, income and Morishima elasticities for this model are presented in *Table 2.3*. Some of the elasticities have incorrect signs. For example, own price uncompensated elasticities should be negative but the imported beef shows a positive own price elasticity. The Morishima elasticities also show some problems. Imported beef and domestic beef appear to be complements; however, we would expect imported meat to be a substitute for domestic meat.

2.5.3 Results of the Dynamic Demand Models

Results for the ADF tests are presented in *Tables 2.4, 2. 5,* and *2.6*. *Table 2.4* shows the calculated t statistics to test the null hypothesis of a unit root in the levels of the variables. The model used for this test included a time trend. The number of lags in the models was selected using the AIC and SC criteria. The null hypothesis of a unit root in the levels of the variables can not be rejected according to these tests except domestic pork price (lnp2). Suggesting, lnp2 is I(0).

Table 2.5 shows the calculated t statistics to test the null hypothesis of a unit root in the first difference of the variables. The model used for this test did not include a time trend. The number of lags in the models was also selected using the AIC and SC criteria. The null hypothesis of a unit root in the first difference of the variables is rejected for all the first differences of the variables. Therefore all the variables, except lnp2 are I(1).

Table 2.6 shows the results of the ADF tests for the residuals of the LA/AIDS static model. The residuals were obtained by subtracting the fitted values from the observed value of the expenditure shares. The null hypothesis of a unit root in the residuals is rejected for the residuals of all the equations. This indicates that the residuals are stationary.

Estimation results of the GAECM are shown in *Table 2.7.* All equations have high R^2's except imported pork. The variable λ captures the speed of adjustment towards the long-run equilibrium. In all of the equations, this parameter is significant, and has the correct sign and magnitude. If λ is close to one in absolute value then that implies a rapid adjustment, i.e. the disturbance quickly disappears and we are back along the long-run path. The smaller the λ value, the slower the model moves back to long run equilibrium. The demand for imported beef presents the highest speed of adjustment to equilibrium. The demands for imported and domestic pork and the demand for domestic beef and poultry have similar speeds of adjustment. To interpret the parameter λ consider the error correction term λ for domestic beef whose value is -0.2945. This implies that 29.45% of the disturbance to the long-run equilibrium in the previous period is corrected or adjusted back to long-run equilibrium in this period.

The variables d_1, d_2, and d_3 are used to capture seasonality effects. Some of the dummy variables indicate that there is a significant seasonal effect in the demand for the meats. The variable d_{sm} which captures the structure change in U.S. beef and pork demand in the mid-1970's was found to have a significant and negative effect on demand for domestic pork. The variable d_{sp} which captures the structure change in U.S. poultry demand in the mid-1970's was found to have a significant and positive effect on demand for domestic poultry.

The variable d_{ft}, which is intended to capture changes in trade policy after 1994, was found to be significant on demand for domestic beef, domestic poultry, imported beef and imported pork. It has a negative effect on demand for domestic poultry and imported beef, and positive effect on demand for domestic beef and imported pork. The change in trade policy for the domestic poultry equation has a negative effect because the U.S. is exporter country for poultry products. In the imported beef demand equation, there is negative sign on the change in trade policy because the U.S. is not only the importer but also the exporter of beef products. Therefore, the net effect of the trade policy on beef products is negative.

The variable d_{sc} which captures the decrease in domestic production for pork and poultry is found to be significant. It has a negative effect on demand for domestic pork and domestic poultry as expected. The variable d_{cvd} which captures the countervailing duty events between U.S. and Canada is not significant. It has negative effect on demand for imported pork.

The residuals from the unrestricted dynamic GAECM were also checked using the standard augmented Dickey Fuller (ADF) test. The results of these test show that the residuals from all the dynamic equations are stationary at the 5% level of significance (*Table 2.9*).

The parameter estimates of the DSUR model are shown in *Table 2.8*. These parameter estimates have similar values to the parameter estimates of the GAECM model. This indicates that the endogeneity problem is either absent or does not significantly bias the parameters obtained using the GAECM model.

2.5.4 Elasticity Results

The elasticities and standard errors of elasticities are calculated at the point of normalization which is 1990:1. The price and income elasticities for the GAECM and DSUR models are shown in *Table 2.10* and *Table 2.11*, respectively. Values in parentheses are standard errors. The income elasticities for all meats are positive in both models. In both models, the income elasticity for imported beef is lower than that for domestic beef in absolute value because most of the beef imported to the United States is low quality beef from Australia and New Zealand, and the income elasticity for imported pork is greater than one, which indicates that this is a luxury good. One explanation for this result is that a large part of the U.S. imported pork belongs to the preserved and prepared pork category, which has a higher price than fresh and frozen pork. Income elasticities of the domestic poultry equation are less than one for GAECM and DSUR model. In line with previous studies, the domestic meats have income elasticities that are less than one (necessary goods).

In both GAECM and DSUR models, the Marshallian own price elasticities for domestic meats are smaller in absolute value than the Marshallian own price elasticities for imported meats. These elasticities have the expected signs and reasonable magnitudes, in contrast to the static AIDS model. The Morishima elasticities indicate that domestic meats are substitutes for imported meats in both models in *Table 2.12*.

The own price elasticities of meat demand were estimated to be -0.2552 (-0.3456) for domestic beef, -0.6053 (-0.5966) for domestic pork, and -0.2531 (-0.4443) for domestic poultry in the GAECM model (DSUR model). These ranges fall in the ranges reported by U.S. Environmental Protection Agency (EPA) cited by Piggott and Marsh (2004).

2.5.5 Results of Restriction of Parametric Tests

The results of tests of the homogeneity and symmetry restrictions in the LA/AIDS, GAECM, and DSUR model are presented in *Table 2.13*. In the static LA/AIDS model, the null hypothesis that the homogeneity and symmetry restrictions are satisfied is rejected for the whole demand system of equations ($p<0.05$). On the other hand, in both GAECM and DSUR models, the null hypothesis that the homogeneity restrictions are satisfied is not rejected for the complete demand system of equation and the symmetry restrictions for the complete demand system of equation cannot be rejected either ($p<0.05$). Likelihood ratio tests were used to test the restrictions.

Separability tests were performed in the LA/AIDS, GAECM, and DSUR models by using likelihood ratio tests to test the restrictions. Therefore, an unrestricted and a restricted model need to be considered. In the unrestricted model, the homogeneity and the symmetry restrictions were imposed and the restricted model also included the separability restrictions in addition to the homeogeneity and symmetry restrictions. Separability test results are presented in *Table 2.14*. In all models, the separability restrictions are rejected. These results imply that imported meats are not separable from domestic meats.

2.6 Conclusions

The results of this study suggest that the dynamic specifications of the AIDS model are superior to the static model of consumer behavior. Homogeneity and symmetry restrictions of consumer theory are found to be reasonable descriptions of aggregate behavior in the dynamics demand model, but these demand properties all fail in the static demand model. The dynamic AIDS model has the better misspecification test performance than the static LA/AIDS model.

The own price and income elasticities of the dynamic AIDS model in both the GAECM and DSUR model have reasonable signs and magnitudes. In the long run, domestic meats are found to be price inelastic, in line with previously published estimates. Demand for imported beef is found to be inelastic but imported demand for pork is elastic. The expenditure elasticities indicate that domestic beef, domestic pork, domestic poultry and imported beef may be considered as necessities. Imported pork may be considered a luxury.

The separability test for the static AIDS, GAECM, and DSUR models conclude the same thing, that import meat consumption is a part of U.S. consumption so import meat should be included in the analysis of U.S. consumer demand for meat. Moreover, researchers estimating import demand for beef or pork should take into account the influence of domestic demand on imports. The separability assumption of demand between foreign and domestic sources maintained in trade models such as the Armington trade model should not be considered. In addition, our results of elasticities and separabiltiy tests are robust to endogeneity because the elasticities and separability test results from the GAECM and DSUR models are not different.

Table 2.1: Misspecification Tests for the LA/AIDS and the GAECM Model

Table (2.1a): The single equation and systemwise misspecification test results for the static demand model

Test	Domestic Beef	Domestic Pork	Domestic Poultry	Imported Beef	Imported Pork	System
DW[1]	1.0008	1.1326	1.2478	1.8975	0.7927	
BG[2]	<0.0001	<0.0001	0.0001	0.0088	<0.0001	<0.0001
BP[2]	0.0171	0.1145	0.0044	<0.0001	0.0158	<0.0001
RESET[2]	<0.0001	0.0279	<0.0001	0.0032	<0.0001	<0.0001

Table (2.1b): The single equation and systemwise misspecification test results for dynamic demand model

Test	Domestic Beef	Domestic Pork	Domestic Poultry	Imported Beef	Imported Pork	System
BG[2]	0.0966	0.0596	0.4371	0.1875	0.0236	0.0122
BP[2]	0.0848	0.5699	0.2281	0.5340	0.1286	0.1295
ARCH(1)[2]	0.0311	0.6308	0.3220	0.5604	0.2705	0.2059
RESET[2]	0.0513	0.8189	0.6660	0.2095	0.4044	0.4744

BG=Breush-Godfrey
BP=Breush-Pagan
ARCH(1)=Autoregressive Conditional Heteroskedasticity

[1] Calculated Value
[2] P-values

Table 2.2: Parameter Estimates for the Restricted Static LA/AIDS Meat Demand Model

Variables	**Domestic Beef**	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Constant	0.160568 (0.0123)*	0.103549 (0.00669)*	0.040952 (0.00356)*	0.012173 (0.00284)*	0.00337 (0.00162)*
ln(D. Beef Price)	0.044242 (0.0025)*	0.005389 (0.00117)*	0.00142 (0.000845)**	-0.00222 (0.000809)*	-0.00191 (0.000465)*
ln(D. Pork Price)	0.005389 (0.00117)*	0.012062 (0.00106)*	-0.00245 (0.000563)*	0.001945 (0.000513)*	0.002387 (0.000477)*
ln(D. Poultry Price)	0.00142 (0.000845)**	-0.00245 (0.000563)*	0.01387 (0.000762)*	-0.0005 (0.00046)	0.000505 (0.000313)
ln(Im. Beef Price)	-0.00222 (0.000809)*	0.001945 (0.000513)*	-0.0005 (0.00046)	0.006314 (0.00053)*	0.000723 (0.0003)*
ln(Im. Pork Price)	-0.00191 (0.000465)*	0.002387 (0.000477)*	0.000505 (0.000313)	0.000723 (0.0003)*	-0.00181 (0.000444)*
ln(Nonmeat Price)	-0.04692 (0.00244)*	-0.01933 (0.00141)*	-0.01285 (0.000927)*	-0.00627 (0.0006)*	0.000104 (0.000346)
Real Income	-0.01092 (0.00221)*	-0.01048 (0.00122)*	-0.00556 (0.000656)*	-0.00177 (0.000512)*	-0.00029 (0.000296)
Time Trend	-0.00027 (0.000031)*	0.000015 (0.000018)	0.000185 (0.000011)*	0.000045 (0.00000775)*	4.26E-06 (5.10E-06)
d_1	-0.00066 (0.000607)	-0.00257 (0.000315)*	-0.00249 (0.000169)*	0.00036 (0.00014)*	0.000056 (0.000077)
d_2	0.000611 (0.000613)	-0.00361 (0.000318)*	-0.00149 (0.000171)*	0.000536 (0.000142)*	-0.00005 (0.000079)
d_3	0.001508 (0.000611)*	-0.00213 (0.000323)*	-0.00087 (0.000173)*	0.000533 (0.000143)*	-0.00021 (0.000082)*
d_{sm}	0.001908 (0.000826)*	0.000711 0.000449		-0.00021 (0.000206)	-0.00026 (0.000116)*
d_{sp}			0.000258 (0.000352)		
d_{ft}	0.005723 (0.000958)*	0.00057 (0.000513)	-0.00181 (0.000288)*	-0.00009 (0.000233)	-0.00014 (0.000166)*
d_{sc}		-0.00241 (0.000491)*	-0.00238 (0.000265)*		
d_{cvd}					-0.00048 (0.000106)*
DW	0.7301	0.9131	1.1311	1.7650	0.7717
R^2	0.9868	0.9615	0.8680	0.7426	0.4753
Adjusted R^2	0.9856	0.9579	0.8555	0.7206	0.4256

Significance levels of 0.05 and 0.10 are indicated by * and **, respectively

Table 2.3: Elasticities for the Static LA/AIDS Meat Demand Model

	Income Elasticity
Domestic Beef	0.8299 (0.0344)*
Domestic Pork	0.6899 (0.0361)*
Domestic Poultry	0.6782 (0.0380)*
Imported Beef	0.6034 (0.1147)*
Imported Pork	0.8336 (0.1699)*

	Marshallian Elasticities				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-0.2998 (0.0390)*	0.0897 (0.0183)*	0.0251 (0.0132)**	-0.0338 (0.0126)*	-0.0295 (0.0073)*
Domestic Pork	0.1793 (0.0347)*	-0.6327 (0.0314)*	-0.0671 (0.0167)*	0.0589 (0.0152)*	0.0712 (0.0141)*
Domestic Poultry	0.1029 (0.0490)*	-0.1309 (0.0326)*	-0.1916 (0.0441)*	-0.0275 (0.0266)	0.0298 (0.0181)
Imported Beef	-0.4720 (0.1814)*	0.4493 (0.1150)*	-0.1052 (0.1031)	0.4167 (0.1188)*	0.1627 (0.0672)*
Imported Pork	-1.0856 (0.2671)*	1.3756 (0.2738)*	0.2927 (0.1797)	0.4157 (0.1722)*	-2.0386 (0.2548)*

	Hicksian Elasticities				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-0.2465 (0.0390)*	0.1178 (0.0182)*	0.0394 (0.0132)*	-0.0301 (0.0126)*	-0.0280 (0.0072)*
Domestic Pork	0.2236 (0.0346)*	-0.6093 (0.0314)*	-0.0552 (0.0167)*	0.0620 (0.0152)*	0.0724 (0.0141)*
Domestic Poultry	0.1464 (0.0489)*	-0.1080 (0.0326)*	-0.6209 (0.0441)*	-0.0245 (0.0266)	0.0310 (0.0181)**
Imported Beef	-0.4333 (0.1813)*	0.4697 (0.1150)*	-0.0948 (0.1031)	0.4194 (0.1188)*	0.1638 (0.0672)*
Imported Pork	-1.0321 (0.2669)*	1.4038 (0.2738)*	0.3071 (0.1796)**	0.4194 (0.1722)*	-2.0371 (0.2548)*

Significance levels of 0.05 and 0.10 are indicated by * and **, respectively

Table 2.4: Augmented Dickey Fuller Tests of All Variables in Level: $\Delta y_t = a_0 + by_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + dt + \varepsilon_t$

# of lags (k)		lnp1	lnp2	lnp3	lnp4	lnp5	lnp6	w1	w2	w3	w4	w5	Y
8	parameter	-0.22	-0.38	-0.21	-0.20	-0.21	-0.29	-0.11	-0.25	-0.26	-0.28	-0.11	-0.11
	ADF stat	-2.86	-3.63	-2.18	-3.34	-2.89	-3.32	-1.11	-2.56	-2.27	-2.63	-1.90	-3.84
	AIC	-2.98	-2.74	-2.96	-2.46	-2.63	-4.52	-8.13	-9.92	-10.55	-11.55	-14.08	-4.76
	SC	-2.73	-2.48	-2.70	-2.20	-2.37	-4.27	-7.88	-9.66	-10.29	-11.29	-13.83	-4.50
7	parameter	-0.21	-0.36	-0.18	-0.17	-0.19	-0.38	-0.17	-0.27	-0.21	-0.31	-0.10	-0.14
	ADF stat	-2.79	-3.62	-1.87	-3.11	-2.62	-4.62	-1.63	-2.82	-1.76	-3.11	-1.67	-5.34
	AIC	-2.97	-2.75	-2.89	-2.46	-2.64	-4.45	-8.03	-9.86	-10.51	-11.56	-14.08	-4.71
	SC	-2.74	-2.52	-2.66	-2.23	-2.40	-4.22	-7.80	-9.62	-10.28	-11.33	-13.85	-4.48
6	parameter	-0.21	-0.37	-0.25	-0.15	-0.20	-0.32	-0.21	-0.35	-0.33	-0.36	-0.11	-0.12
	ADF stat	-2.97	-4.07	-2.58	-2.82	-2.90	-4.06	-2.19	-3.73	-2.76	-3.81	-1.95	-5.02
	AIC	-2.99	-2.77	-2.84	-2.47	-2.66	-4.41	-8.04	-9.83	-10.40	-11.57	-14.08	-4.70
	SC	-2.78	-2.56	-2.63	-2.26	-2.45	-4.20	-7.83	-9.62	-10.19	-11.36	-13.88	-4.49
5	parameter	-0.20	-0.40	-0.29	-0.14	-0.21	-0.30	-0.23	-0.40	-0.41	-0.31	-0.12	-0.11
	ADF stat	-2.95	-4.93	-3.09	-2.67	-3.22	-4.15	-2.50	-4.72	-3.64	-3.43	-2.19	-4.85
	AIC	-3.01	-2.78	-2.84	-2.48	-2.67	-4.43	-8.06	-9.83	-10.38	-11.53	-14.10	-4.68
	SC	-2.83	-2.60	-2.66	-2.29	-2.49	-4.25	-7.88	-9.65	-10.20	-11.34	-13.91	-4.50
4	parameter	-0.21	-0.50	-0.40	-0.18	-0.26	-0.32	-0.27	-0.34	-0.52	-0.31	-0.16	-0.10
	ADF stat	-3.26	-7.26	-4.51	-3.63	-4.33	-4.64	-3.08	-4.31	-4.96	-3.69	-2.80	-4.49
	AIC	-3.04	-2.75	-2.78	-2.43	-2.65	-4.40	-8.07	-9.83	-10.37	-11.55	-14.05	-4.64
	SC	-2.88	-2.59	-2.62	-2.27	-2.49	-4.24	-7.91	-9.67	-10.21	-11.39	-13.89	-4.48

ADF=Augmented Dickey Fuller Test. AIC=Akaike Information Criterion. SC=Schwarz Information Criterion.

Critical value 1% = - 4.03
5% = -3.45
10% = -3.15

Table 2.5: Augmented Dickey Fuller Tests of All Variables in the First Difference: $\Delta^2 y_t = a_0 + b\Delta y_{t-1} + \sum_{j=1}^{k} c_j \Delta^2 y_{t-j} + \varepsilon_t$

# of lags (k)		dlnp1	dlnp2	dlnp3	dlnp4	dlnp5	dlnp6	dw1	dw2	dw3	dw4	dw5	Dy
8	parameter	-1.36	-1.73	-2.88	-0.99	-1.69	-1.76	-3.17	-2.48	-3.24	-2.25	-1.67	-0.71
	ADF stat	-3.63	-5.06	-6.30	-3.61	-5.06	-5.40	-5.88	-5.68	-6.27	-4.99	-4.34	-4.05
	AIC	-2.93	-2.63	-3.02	-2.38	-2.60	-4.53	-8.10	-9.86	-10.65	-11.49	-14.17	-4.67
	SC	-2.70	-2.40	-2.79	-2.15	-2.36	-4.29	-7.86	-9.63	-10.42	-11.26	-13.94	-4.43
7	parameter	-1.59	-1.74	-2.42	-1.01	-1.46	-1.55	-3.16	-2.50	-2.81	-2.28	-1.75	-0.62
	ADF stat	-4.63	-5.86	-5.80	-3.92	-4.78	-5.11	-7.18	-6.93	-5.84	-5.82	-4.76	-3.69
	AIC	-2.94	-2.66	-2.95	-2.39	-2.59	-4.46	-8.12	-9.89	-10.53	-11.51	-14.08	-4.64
	SC	-2.73	-2.44	-2.74	-2.18	-2.38	-4.25	-7.91	-9.68	-10.32	-11.30	-13.87	-4.43
6	parameter	-1.52	-1.72	-2.84	-1.07	-1.57	-1.31	-2.56	-2.05	-3.43	-1.99	-1.99	-0.49
	ADF stat	-4.84	-6.96	-8.50	-4.53	-5.94	-4.29	-6.50	-6.40	-9.43	-5.72	-6.29	-2.78
	AIC	-2.93	-2.67	-2.89	-2.41	-2.61	-4.31	-8.03	-9.82	-10.51	-11.51	-14.09	-4.49
	SC	-2.75	-2.48	-2.71	-2.22	-2.42	-4.12	-7.85	-9.63	-10.33	-11.32	-13.91	-4.30
5	parameter	-1.45	-1.46	-2.17	-1.15	-1.42	-1.55	-2.17	-1.57	-2.47	-1.61	-1.75	-0.54
	ADF stat	-5.10	-7.01	-7.63	-5.52	-6.21	-5.71	-6.34	-5.25	-7.76	-5.04	-6.38	-3.21
	AIC	-2.94	-2.66	-2.81	-2.43	-2.62	-4.30	-8.02	-9.74	-10.36	-11.48	-14.08	-4.50
	SC	-2.78	-2.50	-2.65	-2.26	-2.46	-4.14	-7.86	-9.58	-10.20	-11.32	-13.92	-4.34
4	parameter	-1.41	-1.17	-1.86	-1.14	-1.24	-1.50	-1.97	-1.26	-1.93	-1.63	-1.55	-0.67
	ADF stat	-5.68	-6.43	-8.03	-6.41	-6.28	-6.46	-6.81	-4.42	-7.02	-5.68	-6.64	-4.15
	AIC	-2.97	-2.62	-2.79	-2.44	-2.62	-4.32	-8.03	-9.69	-10.31	-11.46	-14.09	-4.48
	SC	-2.83	-2.49	-2.65	-2.31	-2.48	-4.18	-7.90	-9.55	-10.17	-11.32	-13.95	-4.34

Critical value 1% = -2.58
5% = -1.94
10% = -1.62

Table 2.6: Augmented Dickey Fuller Test of OLS Residual from Static Model:

$$\Delta u_{it} = bu_{it-1} + \sum_{j=1}^{k} c_{ij} u_{it-j} + \hat{\varepsilon}_{it}$$

# of lags (k)		u_{1t}	u_{2t}	u_{3t}	u_{4t}	u_{5t}
8	Parameter	-0.28	-0.57	-0.61	-1.27	-0.27
	ADF stat	-2.15	-3.91	-3.75	-4.45	-2.35
	AIC	-9.73	-11.09	-12.28	-12.47	-13.94
	SC	-9.52	-10.88	-12.07	-12.26	-13.73
7	Parameter	-0.29	-0.49	-0.52	-1.44	-0.25
	ADF stat	-2.27	-3.41	-3.22	-5.73	-2.20
	AIC	-9.73	-11.04	-12.18	-12.48	-13.95
	SC	-9.55	-10.85	-11.99	-12.29	-13.76
6	Parameter	-2.28	-0.51	-0.58	-1.17	-0.29
	ADF stat	-0.28	-3.82	-3.80	-5.03	-2.63
	AIC	-9.75	-11.06	-12.17	-12.44	-13.95
	SC	-9.59	-10.90	-12.01	-12.27	-13.79
5	Parameter	-0.39	-0.59	-0.52	-1.02	-0.35
	ADF stat	-3.23	-4.74	-3.62	-4.66	-3.30
	AIC	-9.66	-11.05	-12.17	-12.41	-13.94
	SC	-9.52	-10.91	-12.04	-12.27	-13.80
4	Parameter	-0.47	-0.55	-0.48	-0.92	-0.45
	ADF stat	-4.12	-4.71	-3.60	-4.58	-4.50
	AIC	-9.66	-11.01	-12.19	-12.41	-13.91
	SC	-9.54	-10.90	-12.08	-12.30	-13.79
3	Parameter	-0.38	-0.42	-0.40	-0.84	-0.38
	ADF stat	-3.43	-3.64	-3.16	-4.54	-3.94
	AIC	-9.60	-10.94	-12.17	-12.43	-13.87
	SC	-9.51	-10.85	-12.08	-12.33	-13.77
2	Parameter	-0.41	-0.47	-0.58	-1.16	-0.40
	ADF stat	-4.01	-4.37	-4.82	-7.28	-4.48
	AIC	-9.61	-10.95	-12.09	-12.37	-13.87
	SC	-9.54	-10.88	-12.02	-12.30	-13.81
1	Parameter	-0.55	-0.65	-0.75	-1.23	-0.42
	ADF stat	-6.00	-6.86	-7.32	-10.37	-5.19
	AIC	-9.58	-10.86	-12.04	-12.35	-13.90
	SC	-9.53	-10.81	-12.00	-12.30	-13.85

Critical value[2] 1% = -3.77
5% = -3.17
10% = -2.84

[2] Engle and Granger (1987) provided critical values for a sample of 100 observations based upon the results of Monte Carlos simulations for 10,000 replications.

Table 2.7: Parameter Estimates for the Restricted GAECM Model of U.S. Meat Demand

Variables	**Domestic Beef**	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Constant	0.20504	0.077911	0.01711	0.017536	-0.00598
	(0.0374)*	(0.0167)*	(0.0107)	(0.00378)*	(0.00681)
ln(D. Beef Price)	0.046632	0.012737	0.001619	0.002903	-0.00477
	(0.00745)*	(0.00307)*	(0.00205)	(0.00202)	(0.00159)*
ln(D. Pork Price)	0.012737	0.01308	-0.00239	-0.00064	0.007157
	(0.00307)*	(0.00337)*	(0.00179)	(0.00136)	(0.00203)*
ln(D. Poultry Price)	0.001619	-0.00239	0.012873	-0.00079	0.00075
	(0.00205)	(0.00179)	(0.00264)*	(0.00101)	(0.00139)
ln(Im. Beef Price)	0.002903	-0.00064	-0.00079	0.002765	0.002976
	(0.00202)	(0.00136)	(0.00101)	(0.00149)**	(0.000951)*
ln(Im. Pork Price)	-0.00477	0.007157	0.00075	0.002976	-0.00599
	(0.00159)*	(0.00203)*	(0.00139)	(0.000951)*	(0.00175)*
ln(Nonmeat Price)	-0.05912	-0.02995	-0.01207	-0.00722	-0.00011
	(0.00822)*	(0.00446)*	(0.00278)*	(0.00125)*	(0.00182)
Real Income	-0.01826	-0.00772	-0.00174	-0.00276	0.00165
	(0.0066)*	(0.00288)*	(0.00183)	(0.000696)*	(0.00125)
Time Trend	-0.00021	0.000056	0.000135	0.000063	-0.00003
	(0.000086)*	(0.000042)	(0.000029)*	(0.000012)*	(0.00002)
d_1	0.000611	0.002171	0.003644	-0.00023	-0.00041
	(0.00219)	(0.00137)	(0.0014)*	(0.000205)	(0.000372)
d_2	0.00055	0.002943	0.003002	0.00045	-0.00042
	(0.00232)	(0.00159)**	(0.00125)*	(0.000262)**	(0.000397)
d_3	-0.00424	0.008566	0.006146	-0.00021	0.000024
	(0.00246)**	(0.00252)*	(0.00205)*	(0.000217)	(0.000358)
d_{sm}	0.001652	-0.00207		-0.00036	-0.00077
	(0.00235)	(0.00115)**		(0.000365)	(0.00059)
d_{sp}			0.001703		
			(0.00081)*		
d_{ft}	0.007762	0.000283	-0.00132	-0.00063	0.001454
	(0.00228)*	(0.000978)	(0.000601)*	(0.0003)*	(0.000678)*
d_{23}		-0.00233	-0.00179		
		(0.000889)*	(0.000576)*		
d_{cvd}					-0.00003
					(0.000349)
λ	-0.29445	-0.38076	-0.40899	-0.88863	-0.22266
	(0.072)*	(0.0918)*	(0.1247)*	(0.2316)*	(0.0879)*
R^2	0.9098	0.9372	0.9539	0.8072	0.4905
Adjusted R^2	0.8739	0.9113	0.9348	0.7305	0.2797

Significance levels of 0.05 and 0.10 are indicated by * and **, respectively

Table 2.8: Parameter Estimates for the Restricted DSUR Meat Demand Model

Variables	**Domestic Beef**	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Constant	0.152179	0.096603	0.033907	0.018261	0.00062
	(0.0146)*	(0.00759)*	(0.0036)*	(0.00445)*	(0.00205)
ln(D. Beef Price)	0.041408	0.011225	0.002439	0.003573	-0.00466
	(0.00444)*	(0.00193)*	(0.00154)	(0.00273)	(0.00106)*
ln(D. Pork Price)	0.011225	0.013307	-0.00318	-0.0002	0.004793
	(0.00193)*	(0.00185)*	(0.000909)*	(0.00124)	(0.000784)*
ln(D. Poultry Price)	0.002439	-0.00318	0.009534	-0.00193	0.001288
	(0.00154)	(0.000909)*	(0.00114)*	(0.00108)**	(0.000591)*
ln(Im. Beef Price)	0.003573	-0.0002	-0.00193	0.002575	0.002485
	(0.00273)	(0.00124)	(0.00108)**	(0.00203)	(0.00078)*
ln(Im. Pork Price)	-0.00466	0.004793	0.001288	0.002485	-0.00494
	(0.00106)*	(0.000784)*	(0.000591)*	(0.00078)*	(0.000601)*
ln(Nonmeat Price)	-0.05398	-0.02594	-0.00815	-0.0065	0.001034
	(0.00348)*	(0.00248)*	(0.00123)*	(0.00147)*	(0.000768)
Real Income	-0.00924	-0.00965	-0.00386	-0.00287	0.000375
	(0.00259)*	(0.00139)*	(0.000641)*	(0.000816)*	(0.000376)
Time Trend	-0.0003	0.00004	0.000132	0.000058	-0.00001
	(0.000035)*	(0.000023)**	(0.000011)*	(0.000014)*	(0.000006827)*
d_1	0.000332	-0.00253	-0.00186	0.00013	0.000014
	(0.000859)	(0.000421)*	(0.000207)*	0.000234	(0.000112)
d_2	0.001221	-0.00355	-0.00117	0.000212	0.000012
	(0.000912)	(0.000455)*	(0.000218)*	0.000252	(0.00012)
d_3	0.002421	-0.00252	-0.00073	0.000476	-0.00016
	(0.000892)*	(0.000439)*	(0.000212)*	(0.000243)**	(0.000116)
d_{sm}	0.002333	-0.00145		-0.00027	-0.00006
	(0.00102)*	(0.0006)*		0.000422	(0.000192)
d_{sp}			-0.00012		
			(0.000341)		
d_{ft}	0.008292	0.000889	-0.00126	-0.00055	0.000454
	(0.000869)*	(0.000446)*	(0.000232)*	(0.000306)**	(0.000168)*
d_{23}		-0.00245	-0.00197		
		(0.000431)*	(0.000208)*		
d_{cvd}					-0.00043
					(0.000094)*
R^2	0.9950	0.9892	0.9630	0.8597	0.7841
Adjusted R^2	0.9921	0.9826	0.9405	0.7777	0.6534

Significance levels of 0.05 and 0.10 are indicated by * and **, respectively

Table 2.9: Augmented Dickey Fuller Test of Residuals from the GECM Model

$$\Delta\tilde{u}_{it} = b\tilde{u}_{it-1} + \sum_{j=1}^{k} c_{ij}\tilde{u}_{it-i} + \hat{\varepsilon}_{it}$$

# of lags (k)		$\tilde{u}_{1t}$	$\tilde{u}_{2t}$	$\tilde{u}_{3t}$	$\tilde{u}_{4t}$	$\tilde{u}_{5t}$
8	Parameter	-1.12	-2.30	-0.74	-1.44	-1.28
	ADF stat	-3.51	-5.03	-2.21	-4.05	-4.06
	AIC	-10.36	-11.76	-12.88	-12.88	-14.71
	SC	-10.15	-11.54	-12.67	-12.66	-14.50
7	Parameter	-1.26	-2.27	-0.92	-1.48	-1.27
	ADF stat	-4.37	-5.71	-2.85	-4.61	-4.38
	AIC	-10.37	-11.78	-12.88	-12.90	-14.74
	SC	-10.18	-11.59	-12.69	-12.71	-14.55
6	Parameter	-1.18	-2.01	-1.10	-1.53	-1.41
	ADF stat	-4.56	-5.78	-3.66	-5.40	-5.53
	AIC	-10.39	-11.79	-12.88	-12.92	-14.75
	SC	-10.22	-11.63	-12.72	-12.76	-14.58
5	Parameter	-1.08	-1.87	-0.98	-1.43	-1.29
	ADF stat	-4.49	-6.28	-3.44	-5.78	-5.75
	AIC	-10.36	-11.79	-12.88	-12.94	-14.75
	SC	-10.22	-11.65	-12.74	-12.80	-14.61
4	Parameter	-0.98	-1.55	-1.23	-1.34	-1.25
	ADF stat	-4.49	-5.91	-4.66	-6.28	-6.35
	AIC	-10.37	-11.78	-12.87	-12.95	-14.72
	SC	-10.25	-11.66	-12.75	-12.83	-14.60
3	Parameter	-1.03	-1.48	-1.47	-1.15	-1.01
	ADF stat	-5.32	-6.67	-6.50	-6.13	-5.66
	AIC	-10.37	-11.79	-12.85	-12.93	-14.67
	SC	-10.28	-11.69	-12.75	-12.84	-14.58
2	Parameter	-1.07	-1.36	-1.44	-1.05	-0.99
	ADF stat	-6.49	-7.53	-7.67	-6.53	-6.48
	AIC	-10.39	-11.80	-12.82	-12.94	-14.69
	SC	-10.32	-11.73	-12.75	-12.87	-14.62
1	Parameter	-1.07	-1.29	-1.33	-1.05	-0.95
	ADF stat	-8.08	-9.38	-9.36	-8.16	-7.65
	AIC	-10.37	-11.80	-12.82	-12.94	-14.70
	SC	-10.32	-11.75	-12.78	-12.89	-14.66

Critical value[3] 1% = -3.77
5% = -3.17
10% = -2.84

[3] Engle and Granger (1987) provided critical values for a sample of 100 observations based upon the results of Monte Carlos simulations for 10,000 replications.

Table 2.10: Elasticities for the Generalized AIDS Error Correction Model

	Income Elasticity
Domestic Beef	0.7155 (0.1028)*
Domestic Pork	0.7716 (0.0852)*
Domestic Poultry	0.8993 (0.1059)*
Imported Beef	0.3815 (0.1560)*
Imported Pork	1.9470 (0.7174)*

	Marshallian Elasticities				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-0.2552 (0.1163)*	0.2081 (0.0480)*	0.0301 (0.0320)	0.0465 (0.0315)	-0.0738 (0.0248)*
Domestic Pork	0.3915 (0.0910)*	-0.6053 (0.0998)*	-0.0668 (0.0530)	-0.0179 (0.0402)	0.2122 (0.0601)*
Domestic Poultry	0.1002 (0.1189)	-0.1349 (0.1037)	-0.2531 (0.1528)**	-0.0453 (0.0585)	0.0436 (0.0805)
Imported Beef	0.6902 (0.4528)	-0.1225 (0.3048)	-0.1663 (0.2263)	-0.3776 (0.3339)	0.6680 (0.2131)*
Imported Pork	-2.7985 (0.9137)*	4.0757 (1.1654)*	0.4141 (0.7979)	1.7038 (0.5458)*	-4.4396 (1.0044)*

	Hicksian Elasticities				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-0.2093 (0.1161)**	0.2322 (0.0478)*	0.0425 (0.0319)	0.0497 (0.0315)	-0.0726 (0.0248)*
Domestic Pork	0.4410 (0.0908)*	-0.5792 (0.0997)*	-0.0534 (0.0530)	-0.0145 (0.0402)	0.2135 (0.0601)*
Domestic Poultry	0.1579 (0.1187)	-0.1045 (0.1036)	-0.5898 (0.1528)*	-0.0413 (0.0585)	0.0452 (0.0805)
Imported Beef	0.7147 (0.4527)	-0.1096 (0.3048)	-0.1598 (0.2263)	-0.3759 (0.3339)	0.6686 (0.2131)*
Imported Pork	-2.6735 (0.9126)*	4.1415 (1.1651)*	0.4477 (0.7978)	1.7125 (0.5458)*	-4.4362 (1.0044)*

Significance levels of 0.05 and 0.10 are indicated by * and **, respectively

Table 2.11: Elasticities for the DSUR Meat Demand Model

	Income Elasticity
Domestic Beef	0.8560 (0.0404)*
Domestic Pork	0.7145 (0.0411)*
Domestic Poultry	0.7766 (0.0371)*
Imported Beef	0.3569 (0.1829)**
Imported Pork	1.2152 (0.2158)*

	Marshallian Elasticities				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-0.3456 (0.0692)*	0.1798 (0.0301)*	0.0405 (0.0240)**	0.0563 (0.0425)	-0.0724 (0.0165)*
Domestic Pork	0.3504 (0.0572)*	-0.5966 (0.0548)*	-0.0892 (0.0269)*	-0.0046 (0.0367)	0.1423 (0.0232)*
Domestic Poultry	0.1555 (0.0892)**	-0.1765 (0.0526)*	-0.4443 (0.0660)*	-0.1107 (0.0625)**	0.0749 (0.0342)*
Imported Beef	0.8420 (0.6119)	-0.0231 (0.2779)	-0.4214 (0.2420)**	-0.4201 (0.4549)	0.5580 (0.1748)*
Imported Pork	-2.6884 (0.6085)*	2.7436 (0.4500)*	0.7355 (0.3392)*	1.4253 (0.4477)*	-3.8357 (0.3449)*

	Hicksian Elasticities				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-0.2907 (0.0692)*	0.2087 (0.0301)*	0.0553 (0.0240)*	0.0601 (0.0425)	-0.0709 (0.0165)*
Domestic Pork	0.3963 (0.0571)*	-0.5725 (0.0547)*	-0.0768 (0.0269)*	-0.0015 (0.0367)	0.1436 (0.0232)*
Domestic Poultry	0.2054 (0.0891)*	-0.1503 (0.0526)*	-0.5832 (0.0660)*	-0.1073 (0.0625)**	0.0763 (0.0342)*
Imported Beef	0.8649 (0.6118)	-0.0110 (0.2779)	-0.4152 (0.2420)**	-0.4185 (0.4549)	0.5586 (0.1748)*
Imported Pork	-2.6104 (0.6084)*	2.7847 (0.4500)*	0.7565 (0.3392)*	1.4307 (0.4477)*	-3.8335 (0.3449)*

Significance levels of 0.05 and 0.10 are indicated by * and **, respectively

Table 2:12 Morishima Elasticities for the LA/AIDS, GAECM, and DSUR Meat Demand Model

	Morishima Elasticities for the LA/AIDS model				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-	0.4701	0.3929	-0.1868	-0.7855
Domestic Pork	0.7271	-	0.5013	1.0790	2.0131
Domestic Poultry	0.6603	0.5657	-	0.5262	0.9281
Import Beef	-0.4495	-0.3574	-0.4438	-	0.00007
Import Pork	2.0091	2.1095	2.0681	2.2009	-

	Morishima Elasticities for the GAECM model				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-	0.6503	0.3672	0.9240	-2.4643
Domestic Pork	0.8115	-	0.4747	0.4696	4.7207
Domestic Poultry	0.6323	0.5363	-	0.4300	1.0375
Import Beef	0.4256	0.3615	0.3347	-	2.0885
Import Pork	4.3636	4.6497	4.4813	5.1048	-

	Morishima Elasticities for the DSUR model				
	Domestic Beef	**Domestic Pork**	**Domestic Poultry**	**Imported Beef**	**Imported Pork**
Domestic Beef	-	0.6870	0.4960	1.1555	-2.3197
Domestic Pork	0.7812	-	0.4222	0.5615	3.3572
Domestic Poultry	0.6385	0.5064	-	0.1680	1.3397
Import Beef	0.4786	0.4171	0.3113	-	1.8492
Import Pork	3.7627	3.9771	3.9098	4.3921	-

Table 2.13: Test of demand restrictions in the LA/AIDS and the GAECM Models

Table (2.13a): Single equation and system tests for homogeneity

sum of price coefficients	**Domestic beef**	**Domestic pork**	**Domestic Poultry**	**Imported beef**	**Imported pork**	**System**
The LA/AIDS model						
L.R. statistic	4.56	14.48	0.29	0.04	0.10	26.48
Pr>ChiSq	0.0328	0.0001	0.5899	0.8363	0.7481	<.0001
The GAECM model						
L.R. statistic	4.92	0.01	1.67	0.53	0.02	6.36
Pr>ChiSq	0.0265	0.9411	0.1958	0.4664	0.8976	0.2725
The DSUR Model						
L.R. statistic	0.29	0.33	4.97	0.18	1.42	6.73
Pr>ChiSq	0.5920	0.5682	0.0258	0.6735	0.2335	0.2417

Table (2.13b): Paired and system tests for symmetry

	The LA/AIDS model		**The GAECM model**		**The DSUR Model**	
	L.R. statistic	Pr>Chisq	L.R. statistic	Pr>Chisq	L.R. statistic	Pr>Chisq
System tests for symmetry	73.73	<.0001	6.72	0.7516	15.83	0.1045

Table 2.14: P-value of the Separability Tests

Model	L.R. statistic	P-value
The LA/AIDS Model	80.1437	<.0001
The GAECM Model	18.6056	0.0023
The DSUR Model	54.4985	<.0001

Chapter 3

The Demand for Livestock by the U.S. Meat Processing Industry

3.1. Introduction

The demand for meats by U.S. final consumers is a topic that has been studied extensively by researchers. However, the demand of livestock by the U.S. meat processing industry has received less attention. This subject is important to get a better understanding of the links between retail (consumer) demand and livestock demand. Therefore, this study focuses on the demand for slaughter cattle and hogs by the US meat processing industry.

The differentiation between domestic and imported livestock is also important given the trends of increasing liberalization of trade. Also, the presence of diseases such as the mad cow disease in the United States, Canada and other countries has motivated countries to adopt import barriers that have different effects on consumers, producers and processors. For example, meat processors have claimed that the ban on imported cattle from Canada was causing them financial losses. The results generated in this study will be useful to evaluate the effect of these policies.

Previous studies on the traditional model of producer behavior are based on a static theoretical framework which assumes that producers adjust instantaneously to changes in the market and technological environments in which they operate; however, some authors suggest that producers do not react instantaneously to changes in price and other exogenous factors (e.g., Reziti and Ozanne, 1999). Fox and Kivanda (1994) and Shumway (1995) summarize the articles published in major journals of agricultural economics on the topics of testing the neoclassical theory of production. They found that many researchers rejected tests of the neoclassical production theory such as monotonicity, curvature, symmetry and homogeneity. Clark and Grant (2000) show that the rejection of the parametric restrictions of symmetry and homogeneity may be due to inappropriate considerations of the time-series characteristics of the data. Due to these results, the existence of long run relationships of livestock derived demand should be explored.

Therefore, the objectives of this study are first to analyze the demand for domestic and imported livestock by the US meat processing industry and second to explore the existence of long run relationships in the derived demand models which are required for the specification of dynamic demand models.

3.1.1 Description of the Meat Processing Industry

The beef processing industry in the United States is very important since this country is the world’s largest producer of beef. The main input of the beef processing industry is domestic cattle (around 96% share of costs). The industry also imports live cattle from Canada and Mexico. The U.S. imports of live cattle had been increasing substantially since the late 1980s due to many free trade agreements such as the Canada-United States Free Trade Agreement (CUSTA), North American Free Trade Agreement (NATFA), and the Uruguay Round trade negotiation. However, things changed after discovery of BSE in Canadian Cattle in May 2003. Currently, the border trade between the US and Canada for live Canadian cattle and beef is very restricted.

The US is the world's third largest pork producer following China and the EU. Moreover, the United States is also a large net importer of hogs. Canada is the most important exporter of live hogs to the United States. The number of hogs imported annually from Canada has increased more than five-fold since 1989. However, this increase is mainly due to the increase in the number of imported feeder pigs. Slaughter pig imports have been decreasing since 1989.

Even though the demand for imported live animals is very small relative to the domestic demand for live animals, this demand plays an important role as an input for the U.S. meat packing industry plants since they usually have excess capacity. These plants with excess capacity rely on imports to reduce average slaughter costs (Brester and Marsh, 1999). Imports from Canada are also important since U.S. prices of livestock, in general, are higher than Canadian prices of livestock.

The meat processing plants in the United States are becoming larger and fewer, and scattered around the country with clusters of livestock farms (Herath et al., 2003). They are also becoming specialized in specific type of animals. The beef and hog segments of the industry are highly concentrated. In 2001, the four largest beef processing firms handled approximately 80 percent of all cattle slaughter in the U.S., compared to 36 percent in 1980. In the case of the hog industry, the four largest companies accounted for 58 percent of animals slaughtered in 2001, compared to 32 percent in 1985 (ERS/USDA).

The greater concentration in both beef and pork processing has prompted concerns about the possibility of anti-competitive behavior in the market for slaughter cattle and hogs because the large packers may be able to use their market power to depress cattle and hog prices below competitive levels. However, some studies suggest that there is little evidence to justify these fears because plants operate cheaper at optimal capacity. These studies argue that packers often are willing to bid significantly higher prices for cattle or hogs from longer distances, when the number of cattle or hogs purchased is below 80-90 percent of plant capacity. This is because the marginal costs of killing and processing cattle or hogs are quite low relative to expected prices for the end products.

3.2 Literature Review

Only a few researchers have studied the demand for domestic and import livestock by the U.S. meat processing industries. Buhr and Kim (1997) estimated dynamic inputs demands for total U.S. cattle slaughter, imports of live cattle from Canada and imports of carcass-weight equivalent beef products. The derived demand equations for livestock in this study are for the processing and wholesale beef sectors as a whole (i.e. both sectors are considered as one industry).

In a study about evaluating the impacts of shifts in retail beef demand on U.S. farm demand price and production, Marsh (2003) also estimated demand equations for slaughter cattle (U.S. cattle and imported cattle). However, this study does not differentiate between domestic and imported cattle.

There are other aspects of the industry that have received more attention. One of these aspects is the question of market power in meat packing. However, these studies have drawn different conclusions (Muth and Wohlgenant (1999), Paul (2001), Schroeter (1988), Schroeter and Azzam (1990)). Other studies have focused on technological change in the meat packing industries. For example, Brester and Marsh (2001) estimated the long-term effects of changes in farm-level and processing-level technologies on farm-wholesale marketing margins and livestock prices in the beef and pork sectors. They found that technological change in the meat packing industry has reduced farm-wholesale marketing margins and has caused real livestock prices to increase. On the other hand, farm-level technological change has had a negative effect on real livestock prices. Overall, the negative effects from the farm level has dominated the positive effects and contributed to lower real livestock prices.

Mattson et al. (2001) studied the effect of trade liberalization on exports of live cattle and live hogs from Canada to the U.S. during the period 1981-1999. They concluded that trade liberalization has significantly influenced the exports of live cattle; however, its effect on exported live hogs has been minor because neither the United States nor Canada levied tariffs or quotas on pork and live hogs during the period of study. They also found that the appreciation of the US exchange rate relative to Canada has a positive influence on the amount of exports from Canada for pork and hogs.

In summary, few researches have studied the demand for domestic and import cattle by the U.S. beef processing industry. Moreover, previous studies have not differentiated between domestic and imported cattle. There is also a paucity of studies investigating the demand for domestic and import hogs by the pork processing industry.

3.3 Theoretical Model

Duality theory (Diewert, 1974) allows us to derive systems of input demand equations which are consistent with profit maximizing or cost minimizing firm behavior. In this study, static factor demand equations are derived from the Generalized Fuss Normalized Quadratic profit function. One of the advantages of this functional form over a translog or other functions is that this profit function is flexible and allows for flexible returns to scale.

3.3.1 Profit maximization

Let p be the firm's output price, $y = f(x)$ the production function, x the vector of factor inputs, and w the vector of factor prices. The profit function is the mathematical representation of the solution to the producer's optimization problem (profit maximization). The profit function is as follows:

$$\pi(p,w) = \max_{x \geq 0}\{pf(x) - w \cdot x\} \qquad (1)$$

The profit functions satisfy the following properties Chambers (1994):

1) The profit function is nonnegative. $\pi(p,w) \geq 0$.

2) The profit function is nondecreasing in p. If $p^1 \geq p^2$, then $\pi(p^1,w) \geq \pi(p^2,w)$.

3) The profit function is nonincreasing in w. If $w^1 \geq w^2$, then $\pi(p,w^1) \geq \pi(p,w^2)$.

4) The profit function is convex and continuous in output price (p) and input price (w). This implies that the Hessian matrix of the profit function is positive semidefinite.

5) π is a positive homogeneous of degree one in output and input prices. $\pi(tp,tw) = t\pi(p,w)$, $t > 0$.

6) Based on Hotelling's Lemma, if the profit function is differentiable in w, the unique profit-maximizing derived-demand functions are

$$x_i(p,w) = -\frac{\partial \pi(p,w)}{\partial w_i} \qquad \forall i. \qquad (2)$$

The derived demands $x_i(p,w)$ depend on output price and input prices. The beef packing industries require plants with stronger carrying lines and larger equipment because beef carcasses are about five times larger than pork, and the products of beef and pork packing are also different and require different amounts of handling and processing (Melton and Huffman, 1995). Hence, the structure of slaughter, packing or processing plants is different between cattle and hog animals. Therefore, the beef and pork processing industries are analyzed separately and the slaughter and processing plants tend to specialize in individual species.

The general profit maximization problem for both industries can be written as

$$\pi(p,w) = \max_{x,l,e\geq 0}\{p_j f(x_{jd}, x_{jm}, l, e) - w_{jd}\cdot x_{jd} - w_{jm}\cdot x_{jm} - w_l \cdot l - w_e \cdot e\}, \qquad (3)$$

where p_j is the price of the output (wholesale price of meat which processors take as given), x_{jd} is the input quantity of domestic slaughter animals j, x_{jm} is the input quantity of import slaughter animal j, l is the amount of labor, e is the amount of energy, w_{jd} is the input price for domestic slaughter animal j, w_{jm} is the input price for imported slaughter animal j, w_l is the average wage of meat processing industry, and w_e is the energy price. If the subscript $j = b$ it refers to the beef processing industry and if $j = p$ it refers to the pork processing industry.

Assuming that the profit function in equation (3) satisfies conditions 1) – 5) and applying Hotelling's Lemma, the input-demand or derived demand functions for domestic and imported slaughtered animals are

$$-\frac{\partial\pi(p,w)}{\partial w_{jd}} = x_{jd} = g_d(p_j, w_{jd}, w_{jm}, w_l, w_e) \qquad (4)$$

$$-\frac{\partial\pi(p,w)}{\partial w_{jm}} = x_{jm} = g_m(p_j, w_{jd}, w_{jm}, w_l, w_e) \qquad (5)$$

3.4 Empirical Model – Normalized Quadratic Profit Function

The Generalized Fuss Functional form was developed by Diewert and Ostensoe (1987), Diewert and Wales (1987) and Fuss (1977). This function has been used in empirical studies by Adrangi et al. (1995) and Muth and Wohlgenant (1999). This profit function allows having both constant and non-constant returns to scale technology. The flexible constant returns to scale case is nested as a special case of the general functional form for the non-constant returns to scale case. This function can be written as

$$\pi(\tilde{p}, z)/p_j z_1 = \alpha_0 + \sum_{i=1}^{N-1} \alpha_i (w_i/p_j) + \sum_{i=1}^{N-1}\sum_{h=1}^{N-1} \phi_{ih}(1/2)(w_i/p_j)(w_h/p_j)$$

$$+ \sum_{i=1}^{M}\sum_{h=1}^{M} \beta_{ih}(1/2)(z_{i+1}/z_1)(z_{h+1}/z_1) + \sum_{i=1}^{N-1}\sum_{h=1}^{M} \theta_{ij}(1/2)(w_i/p_j)(z_{h+1}/z_i)$$

$$+ \sum_{i=1}^{M} \gamma_{ih}(z_{i+1}/z_i) \qquad (6)$$

where $\tilde{p} \equiv [w_1, ..., w_{N-1}, p_j] >> 0_N$ denotes a vector of positive prices for variable inputs and outputs, $z = (z_1, z_2, ..., z_M)$ is a nonnegative capital input vector, $\alpha,\ \phi,\ \beta$ and θ are model parameters. Symmetry implies that $\phi_{ih} = \phi_{hi}$ and $\beta_{ih} = \beta_{hi}$. The ϕ matrix must be positive semidefinite in order for $\pi(p, w; z)$ to be a convex function of p_j (output price) and w (input price) for each fixed z.

From Hotelling's lemma, the Fuss normalized quadratic profit function in equation (6) can be differentiated with respect to input price ($w_1, \ldots, w_{N-1}$) to obtain input demands which are

$$-x_i(\tilde{p}, z)/z_1 = -\left[\alpha_i + \sum_{h=1}^{N-1} \phi_{ih}(w_h/p_j) + \sum_{h=1}^{M} \theta_{ih}(z_{h+1}/z_1)\right], \qquad (7)$$

These input demands are of special interest in this study since our objective is to estimate derived demands for domestic and imported live animals where $i = \{jd, jm\}$.

3.4.1 Static Model

In this section we specify the empirical static derived demand equations corresponding to equation (7). Meat processing industries require live animals, labor, electricity, and capital. Capital is assumed to be fixed in the short run. Live animals can be differentiated between domestic and imported animals. Hence, the input demands of live animals for the processing beef and pork industries can be written as

$$-\frac{x_{js}}{z_{j1}} = -\left[\alpha_s + \phi_{s1}\frac{w_{jd}}{p_j} + \phi_{s2}\frac{w_{jm}}{p_j} + \phi_{s3}\frac{w_l}{p_j} + \phi_{s4}\frac{w_e}{p_j} + \theta_{s1}\frac{z_j}{z_{j1}}\right],\ s = d, m \qquad (8)$$

where z_{j1} is the total number of slaughter plants, z_j is the amount of fixed capital. The subscript of $s = d$ refers to slaughter domestic animals and the subscript of $s = m$ refers to slaughter imported animals.

For each industry (pork and beef industries), equation (8) defines a system of two derived demands equations which can be estimated simultaneously. Moreover, the symmetry restriction ($\phi_{d2} = \phi_{m1}$) between the domestic and imported derived demand equations can be imposed. This restriction implies that the cross-price effects in the domestic and imported derived demand functions are equal. The derived demands are also homogenous of degree zero in prices and therefore the quantities of inputs demanded remain unchanged when all prices are multiplied by the same amount.

3.4.2 Dynamic Model

As mentioned previously, Fox and Kivanda (1994) summarized the results of several empirical studies that have tested one or more of four restrictions (homogeneity, symmetry, curvature, and monotonicity) in the estimated static derived demand equations. They found that these restrictions are often rejected. Clark and Grant (2000) argue that rejection of the restrictions might be due to inappropriate consideration of the time series properties of the data. They show that the F statistics used to test for homogeneity and symmetry need to be modified if the variables are I(1).

A second explanation for the failure of the static model is that producers' decisions might be the result of a more dynamic optimization problem or the possibility of the presence of additional constraints in the static model. Therefore, two general approaches have been proposed to account for the dynamic aspects of production: the theory-based and the data-based approach (Reziti and Ozanne, 1999).

The theory based approach derives input demand equations utilizing the adjustment cost theory of the firm (Buhr and Kim, 1997). On the other hand, the data-based approach allows the data themselves to select the underlying data generation process and to capture the long-run equilibrium structure (e.g., Reziti and Ozanne, 1999).

Previous studies using the data based approach have used the Error Correction Model (ECM) which assumes that all variables must have the same order of integration. However, all variables may not have the same order of integration and therefore the results of the ECM model may not be reliable. In this study we use an unrestricted error correction model (UECM) which can be derived from an autoregressive distributed lag (ARDL) model and allows us to test the existence of a long run relationship by using the bounds test procedure (Pesaran et al., 2001). Pesaran et al. argue that this procedure has two advantages over the common practice of cointegration analysis (Engle and Granger, 1987; Johansen, 1988; Johansen and Juselius, 1990): 1) the bounds test procedure can be applied irrespective of whether the explanatory variables are I(0) or I(1) (Pesaran et al., 2001) and 2) this procedure can be applied to small sample sizes. The UECM corresponding to the static normalized quadratic derived demands stated in equation (8) is:

$$
\begin{aligned}
\Delta\left(\frac{x_{js}}{z_{j1}}\right)_t &= \sum_{k=1}^{n}\xi_s\Delta\left(\frac{x_{js}}{z_{j1}}\right)_{t-k} + \sum_{k=1}^{n}\varphi_{s1}\Delta\left(\frac{w_{jd}}{p_j}\right)_{t-k} + \sum_{k=1}^{n}\varphi_{s2}\Delta\left(\frac{w_{jm}}{p_j}\right)_{t-k} \\
&+ \sum_{k=1}^{n}\varphi_{s3}\Delta\left(\frac{w_l}{p_j}\right)_{t-k} + \sum_{k=1}^{n}\varphi_{s4}\Delta\left(\frac{w_e}{p_j}\right)_{t-k} + \sum_{k=1}^{n}\omega_s\Delta\left(\frac{z_j}{z_{j1}}\right)_{t-k} \\
&+ \lambda_{s0}\left(\frac{x_{js}}{z_{j1}}\right)_{t-1} + \lambda_{s1}\left(\frac{w_{jd}}{p_j}\right)_{t-1} + \lambda_{s2}\left(\frac{w_{jm}}{p_j}\right)_{t-1} + \lambda_{s3}\left(\frac{w_l}{p_j}\right)_{t-1} \\
&+ \lambda_{s4}\left(\frac{w_e}{p_j}\right)_{t-1} + \lambda_{s5}\left(\frac{z_j}{z_{j1}}\right)_{t-1}, \qquad s = d, m \qquad (9)
\end{aligned}
$$

where $\Delta(x_{js}/z_{j1})$ is the first difference of the domestic or imported slaughter quantities per plant, $\Delta(w_{jd}/p_j)$ is the first difference of the ratio of domestic animal price to output price, $\Delta(w_{jm}/p_j)$ is the first difference of the ratio of import animal price to output price, $\Delta(w_l/p_j)$ is the first difference of the ratio of labor price to output price, and $\Delta(w_e/p_j)$ is the first difference of the ratio of energy price to output price, respectively. As indicated previously, the subscript j is used to differentiate the derived demands corresponding to the beef and pork industries.

The bounds tests are based on the Wald or F-statistic. The asymptotic distribution of the F-statistic is non-standard under the null hypothesis of no cointegration relationship between the examined variables. The test is conducted in the following way. The null hypothesis is tested by estimating the UECM for the domestic or imported derived demand function including the lagged variables of the level variables. Formally, a joint significance test needs to be performed, where the null hypothesis is that there exists cointegration versus the alternative hypothesis that there is no cointegration.

$$H_o : \lambda_{s0} = \lambda_{s1} = \lambda_{s2} = \lambda_{s3} = \lambda_{s4} = 0$$

$$H_A : \lambda_{s0} \neq \lambda_{s1} \neq \lambda_{s2} \neq \lambda_{s3} \neq \lambda_{s4} \neq 0$$

For some significance level (say α=5% or 10%), if the calculated F-statistic is lower than the lower bound critical value, we fail to reject null hypothesis of no cointegration. On the other hand, if the calculated F-statistic is higher than the higher bound critical value, the null hypothesis of no cointegration is rejected. The calculated F-statistic lying between the two critical values indicates that no clear decision can be made. The Akaike Information Criterion (AIC) and Schwartz's Criterion (SC) are used to select the number of lags in the UECM models.

3.5 Data and Procedure

Livestock data used in this analysis are quarterly data from 1979:1 to 2002:4, providing a total of 96 observations. The total number of commercial slaughter livestock for cattle and hogs was obtained from the USDA *Red Meat Yearbook* which is available online. The total slaughter livestock figures provided by the USDA overstate the number of domestic slaughter animals in the U.S. because they also include imported slaughter animals from Canada. Hence, the U.S. slaughter livestock quantities are obtained by subtracting the total number of slaughter imported livestock from the total number of commercial slaughter livestock.

Import livestock quantity and expenditure data were obtained from various issues of *Foreign Agricultural Trade of the United States* published by Foreign Agricultural Service (FAS) of the USDA. It is assumed that slaughter imported cattle and hogs are the imported cattle having weights above 700 lb and the imported hogs having weights above 50 lb, respectively. Since slaughter cattle and hogs are mainly imported from Canada to the US, only imports from Canada were considered.

The slaughter domestic cattle price (in cents per pound) was constructed as a weighted average price of the average prices for slaughter domestic steers, slaughter domestic heifers and slaughter domestic cows. The weights are the proportion of each type of cattle with respect to the total number of slaughter cattle. The average price of slaughter domestic steers is the average of the slaughter steer prices in the Nebraska and Texas markets. The average price of slaughter domestic heifers is the average price in the Nebraska market, and the average price of slaughter domestic cows is the average price of this type of cattle at Sioux Falls, South Dakota. The 51-52% lean hog price (live equivalent) in cents per pound was used as the price for slaughter domestic hogs.

Unit values of imported slaughter animals were obtained by dividing imported slaughter values by imported slaughter quantities. Because domestic prices are measured in cents per pound they were transformed to dollars per head to be consistent with the price units of the imported slaughter animals. All import prices include all duties and tariffs.

Prices and weights of domestically produced animals were obtained from the *Red Meat Yearbook*. Producer Price Indexes of beef and pork are used as the selling prices received by processors for their output and they were obtained from the Bureau of Labor Statistics (BLS).

The average wage of meat processing industries was obtained from various issues of various issues of *Employment and Earnings* published by the BLS. The Producer Price Index of fuels and related products and power is used as the energy price and are available in the Producer Price Index Commodity dataset also from the BLS.

The total number of plants slaughtering cattle and hog is from the *Livestock Slaughter Annual Summary* published by the National Agricultural Statistics Service from the USDA (available online). The capacity utilization of food, the industrial production data of beef and pork are from the database *Industrial Production and Capacity Utilization* from the Federal Reserve and is available online. The

U.S. population data are from the Department of Commerce, Bureau of Economic Analysis and is also available online.

The USDA provides only annual data on the number of plants slaughtering cattle and hogs. An interpolation method was utilized to produce quarterly time series of the number of plants from the available annual time series. Interpolation methods allow producing a time series at a higher frequency that is actually available; for example, a quarterly series from yearly data.

A capital index of beef or pork was calculated by dividing the industrial production of beef or pork by the capacity utilization of food. In other words, it is assumed that the capacity utilization of beef and pork is the same as the capacity utilization of food. This variable was constructed in order to take into account the effect of capital on the demand for the inputs.

3.6 The Econometric Model

The supply of slaughter animals is nearly perfectly inelastic in the short run because of the characteristics of livestock production (it takes several months to raise the animals). This implies that in the short run the quantities of slaughter animals may be regarded as predetermined and price is determined as a function of the quantities. Therefore the derived or factor demand equations are estimated as inverse derived demand equations.

We estimate two systems of inverse input demands in this study: one comprising domestic and imported cattle, and another comprising domestic and imported hogs. To take into account the change in the capacity of the industries, the number of slaughter animals per plant is used as the quantity in the models. The models also include output prices, prices of domestic and imported slaughter animals, labor costs and energy costs.

The inverse derived demand functions for domestic and imported livestock based on the general derived demand model of the beef or pork processing industry in equation (12) can be rewritten as follows:

$$-\frac{w_{jst}}{p_{jt}} = -\left[\alpha_s^* + \phi_{s1}^* \frac{x_{jdt}}{z_{j1t}} + \phi_{s2}^* \frac{x_{jmt}}{z_{j1t}} + \phi_{s3}^* \frac{w_{lt}}{p_{jt}} + \phi_{s4}^* \frac{w_{et}}{p_{jt}} + \theta_{s1} \frac{z_{jt}}{z_{j1t}} + \varepsilon_{st}\right],\ s = d, m \qquad (10)$$

The additional explanatory variables for the beef processing industry in equation (10) are seasonal dummy variables, a dummy variable to capture the effect of free trade agreements (1989:1-2002:2), and a dummy variable (1999:3-2000:2) to capture the effect of a countervailing duty which was imposed on the value of live cattle imported from Canada in June 1999 (Wohlgenant and Schmitz, 2005). Free trade agreements signed by the U.S. include CUSTA signed in 1989, NAFTA and the Uruguay Round signed in 1994.

For the pork processing industry the additional explanatory variables are seasonal dummy variables and a dummy variable (1998:3-1998:4) which was included to capture a supply side shock. In 1998, producers were forced to sell their animals to the market at very low prices (Goodwin and Harper) due to a sharp increase in the price of corn.

The UECM of the inverse derived demand based on equation (14) can be rewritten as follows:

$$\Delta\left(\frac{w_{js}}{p_j}\right)_t = \sum_{k=1}^{n} \xi_s^* \Delta\left(\frac{w_{js}}{p_j}\right)_{t-k} + \sum_{k=1}^{n} \varphi_{s1}^* \Delta\left(\frac{x_{jd}}{z_{j1}}\right)_{t-k} + \sum_{k=1}^{n} \varphi_{s2}^* \Delta\left(\frac{x_{jm}}{z_{j1}}\right)_{t-k}$$

$$+ \sum_{k=1}^{n} \varphi_{s3}^* \Delta\left(\frac{w_l}{p_j}\right)_{t-k} + \sum_{k=1}^{n} \varphi_{s4}^* \Delta\left(\frac{w_e}{p_j}\right)_{t-k} + \sum_{k=1}^{n} \omega_s^* \Delta\left(\frac{z_j}{z_{j1}}\right)_{t-k}$$

$$+ \lambda_{s0}^* \left(\frac{w_{js}}{p_j}\right)_{t-1} + \lambda_{s1}^* \left(\frac{x_{jd}}{z_{j1}}\right)_{t-1} + \lambda_{s2}^* \left(\frac{x_{jm}}{z_{j1}}\right)_{t-1} + \lambda_{s3}^* \left(\frac{w_l}{p_j}\right)_{t-1},$$

$$+\lambda_{s4}^{*}\left(\frac{w_e}{p_j}\right)_{t-1}+\lambda_{s5}^{*}\left(\frac{z_j}{z_{j1}}\right)_{t-1}+\varepsilon_{st}, \quad s=d,m \tag{11}$$

Where again the *j* index is used to differentiate the pork and beef industries and the *s* index is used to differentiate domestic $(s=d)$ and imported $(s=m)$ slaughter animals. The additional explanatory variables included in equation (11) are the same as those included in equation (10). In both models the symmetry restriction corresponding to quantities cross effects between domestic and imported animals was imposed in the estimation. All of the equations were estimated using SUR procedures utilizing the proc MODEL procedure of SAS.

3.7 Results

3.7.1 Results of the Static Inverse Derived Demand Model

Table 1 shows the parameter estimates of the unrestricted static system of inverse derived demand equations. The main parameters of interest are the parameters corresponding to the quantities of animals. The parameters corresponding to domestic and imported quantities (x_d/z_1 and x_m/z_1) in both industries have the correct signs (negative). In the beef processing equations, only the own quantities effects are significant. In the pork industry equations all of these variables have significant parameters. Most of the remaining parameter estimates were significant with the expected signs. Moreover, all of the equations have high R^2's.

Equations in *Table 3.1* were estimated taking into account the autocorrelation of the error terms. Tests of autocorrelation indicated that the errors from the inverse derived demand equations of domestic cattle and hogs were generated by second-order AR processes. The errors from the inverse derived demand equations of imported cattle and hogs were generated by first-order AR processes.

The fact that the DW values in *Table 3.1* are close to 2 in all models indicates that there is no evidence of autocorrelation in the final estimated models.

The free trade agreement dummy variable has the expected negative sign in domestic and import inverse demand for cattle equations since a decrease in tariffs are expected to reduce import prices. This result also causes domestic prices to go down. The dummy variable corresponding to the countervailing duty was not found to be significant.

Diagnostic testing was performed for the static inverse demand model. White's test is used to test for heteroscadasticity and Godfrey's serial correlation test (LM test) is used to test for autocorrelation. We found that the inverse derived demands for domestic and imported live animals show no evidence of the presence of heteroscedasticity and autocorrelation.

Based on the parameter estimates in *Table 3.1,* the calculated own price elasticities (flexibilities) were -2.80 (-0.3675) for domestic cattle, -14.84 (-0.0693) for imported cattle, -2.70 (-0.3984) for domestic hog, and -13.42 (-0.0801) for imported hogs. The own price elasticities for domestic slaughter animals are much lower than the own price elasticities for imported slaughter animals in absolute value. The cross price elasticities for domestic animals with respect to the price of imported animals are 0.16 for domestic cattle and 0.18 for domestic hog. The cross price elasticities for imported animals with respect to the price of domestic animals are 7.34 for imported cattle and 13.96 for imported hogs. All elasticities (flexibilities) were calculated at the mean values.

These results show that the demand for imported livestock by the meat processing industry is very sensitive to the change in the domestic price for livestock, but the demand of domestic slaughter livestock is less sensitive to the change in imported livestock prices. This might be due to the fact than the U.S. livestock market is significantly larger than the Canadian livestock market.

Buhr and Kim (1997) reported an own price elasticity for domestic slaughter cattle of -1.6476, and Marsh (2003) estimated a value of -1.4535. Buhr and Kim (1997) also calculated the own price elasticity for imported Canadian cattle and found a value of -1.5305. In the case of slaughter hogs, Moschini and Meike (1992) estimated the own price elasticity of -0.330, and Parcell et al. (2000) estimated an elasticity of -1.5083. Our own price elasticities for slaughter live animals are much higher than pervious studies.

The compensated cross-price elasticities for imported and domestic livestock (cattle or hogs) are positive. This suggests that imported live animals are substitutes for domestically produced animals. The hypothesis of perfect substitutability between imported livestock and domestic livestock was formally tested in the models. In order to do this, restricted models with the quantity coefficients in the domestic and imported equations were restricted to be in estimation. The hypothesis of perfect substitutability between domestic and imported animals was rejected at the 5% significance level. This implies that imported cattle are not a perfect substitute for domestic cattle, and that imported hogs are not a perfect substitute for domestic hogs.

Cattle imported from Canada are generally different than the U.S. cattle since Canadian producers use different breeds and feed that cause differences in the final quality of the slaughter cattle (Wohlgenant and Schmitz, 2005). The rejection of the hypothesis of perfect substitubility between domestic and imported hogs is more difficult to explain since hogs are more homogeneous in nature.

According to theory, the marginal change in input price with respect to output price must be positive. In equation (10), this marginal effect is $(\partial w_{js} / \partial p_j) = 1/p_j (w_{js} - \phi_{s3}^* w_l - \phi_{s4}^* w_e)$ >0. This marginal effect was positive for both industries and for domestic and imported animals. Another restriction derived from theory that was tested was the symmetry restriction. The null hypothesis that the symmetry restriction is satisfied is not rejected in the static system of inverse derived equations in both industries.

3.7.2 Results of the Dynamic Inverse Derived Demand Model

All the variables included in the demand models were tested for a unit root using the Augmented Dickey-Fuller test. We found that all the variables included in the beef processing industry demand equations were I(1). Most of the variables included in the pork processing industry demand equations were also found to be I(1) except for the ratio of domestic hog prices to output price and the ratio of import hog price to output price which were found to be stationary I(0). Given these results, the bounds test procedure was utilized in this study since not all of the regressors are of the same order of integration in the pork processing industry demand equations. Even in the case where all of the explanatory variables in the beef processing industry demand equations had the same order of integration, the bounds test approach also can be applied.

3.7.3 Cointegration and Bound Testing Approach

The null hypothesis for no cointegration among the variables in the UECM of the inverse derived demand models (equation 16) Ho: $\lambda_{io}^{*} = \lambda_{i1}^{*} = \lambda_{i2}^{*} = \lambda_{i3}^{*} = \lambda_{i4}^{*} = 0$ against the alternative Ha: $\lambda_{i0}^{*} \neq \lambda_{i1}^{*} \neq \lambda_{i2}^{*} \neq \lambda_{i3}^{*} \neq \lambda_{i4}^{*} \neq 0$. The null hypothesis corresponds to testing the 'nonexistence of a long-run relationship'. If the computed F-statistics falls outside the critical bounds, a conclusive decision can be made regarding cointegration without knowing the order of integration of the regressors. If the F-statistic is lower than the lower bound critical value, there is no cointegration. A calculated F-statistic lying between the two critical values indicates that no clear decision can be made. The F-statistic was calculated in the usual form:

$$F_{statistic} = \frac{(ESS_R - ESS_U)/q}{ESS_U/(n-k)} ,$$

where ESS_R is the error sum squares of the restricted model and ESS_u is the error sum squares of the unrestricted model.

In order to test the existence of long-run relationship among variables, the UECM inverse derived demand are estimated with lags $n = 1, 2, \ldots, 5$ in both beef and pork processing industries. The results of these tests are showed in *Table 3.5*. In most cases, the results of the tests cannot reject the null hypothesis of nonexistence of a long-run relationship since the calculated F statistics are lower than the lower critical values (at 5 % level of significance). Only in two cases are the calculated F statistics between the two critical values and therefore the results are inconclusive.

The performance of the UECM version of the inverse demand models was also evaluated by analyzing the economic and statistical significance of the parameter estimates of these models. *Table 3.2* shows the parameter estimates of the UECM models using only one lag. The dynamic inverse demand models for domestic and imported cattle model did not perform well as indicated by the low R^2's values and the insignificance and incorrect signs of the parameter estimates.

Table 3.3 presents the parameter estimates of the dynamic inverse derived demand models for the pork processing industry. The parameters of quantity variables were negative but most of them were insignificant. Most of the remaining parameters were also not significant and the equations had low R^2 values.

The result that the static model performs better than the data-based dynamic model contrasts with Buhr and Kim's results based on a theory-based approach. Whereas we do not find evidence of long run relationships in the variables of the derived demand livestock models of the meat processing industry in the U.S., they found evidence of the presence of dynamic adjustments in the processing and wholesale beef sectors as whole. However, the results are not directly comparable since their estimation considers the processing and wholesale beef sectors as one industry, and they also estimated their equations over a different time period.

3.8 Conclusions

The static inverse input demand model performed better than the dynamic inversed input demand models for both the beef and pork processing industries. The results of this study indicate that there is not a long run relationship in the variables of the inverse demand models for livestock.

The static models seem to be appropriate. The reason behind this result might be that meat processing industries cannot store the livestock or the output for a long time. The null hypothesis that imported slaughter animals and U.S. slaughter animals are perfect substitutes (homogeneous) goods was rejected. This implies that the meat processing industry considers imported livestock differently than U.S. produced livestock. This result has implications for the analysis of meat trade policies between the U.S. and other countries.

The calculated own price elasticities (flexibilities) and cross price elasticities (flexibilities) indicate that the demand for imported livestock by the meat processing industry is very sensitive to the change in the price of domestic livestock. The demand for domestic slaughter livestock is less sensitive to the change in the price of imported livestock.

Table 3.1: Parameters of the Static Inverse Livestock Demand Models

Table (3.1a.) Beef processing industry

Parameters	**Domestic Cattle**	**Imported Cattle**
Constant	7.9105 (0.4505)*	4.0779 (1.0068)*
x_d/z_1	-0.00031 (0.000067)*	-0.00015 (0.000139)
x_m/z_1	-0.00015 (0.000139)	-0.00258 (0.000881)*
w_l/p_j	8.424997 (4.9541)**	47.0254 (11.5268)*
w_e/p_j	-0.1309 (0.2921)	-0.1497 (0.7573)
D1	0.0448 (0.0361)	0.340446 (0.0733)*
D2	0.0411 (0.0357)	0.4960 (0.0874)*
D3	0.030714 (0.0376)	0.564449 (0.0746)*
D(Free Trade Agreements)	-0.14268 (0.1503)	-0.80719 (0.3525)*
D(Countervailing duty)	-0.02023 (0.1084)	-0.24604 (0.2593)
DW R^2 Adjusted R^2	2.0870 0.8409 0.8211	1.9264 0.6883 0.6536

Significance levels of 0.05 and 0.10 are indicated by * and * *, respectively

Table (3.1b.) Pork processing industry

Parameters	**Domestic Hogs**	**Imported Hogs**
Constant	1.980437 (0.0695)*	1.487794 (0.1356)*
x_d / z_1	-0.00002 (0.000002695)*	-0.00002 (0.00000672)*
x_m / z_1	-0.00002 (0.00000672)*	-0.00029 (0.00011)*
w_l / p_j	-3.34633 (1.0297)*	4.750218 (2.0633)*
w_e / p_j	0.011957 (0.0723)	-0.22519 (0.1469)
D1	-0.00704 (0.011)	-0.04231 (0.0182)*
D2	0.017075 (0.0104)	-0.03871 (0.0209)**
D3	-0.01573 (0.0113)	-0.02674 (0.0181)
Dummy(Capture Shock)	-0.08865 (0.0322)*	-0.19116 (0.0589)*
DW R^2 Adjusted R^2	1.7624 0.9429 0.9366	1.9035 0.8855 0.8743

Significance levels of 0.05 and 0.10 are indicated by * and * *, respectively

Table 3.2: The Estimated Parameters of the Dynamic Inverse Livestock Derived Demand Model for the U.S. Beef Processing Industry

Parameters	**Domestic Cattle**	**Imported Cattle**
Constant	0.916678 (0.6941)	1.687343 (0.8461)*
$\Delta(w_s/p_j)^a_{t-1}$	-0.3121 (0.1191)*	-0.09513 (0.1212)
$\Delta(x_d/z_1)_{t-1}$	0.000086 (0.000085)	0.000398 (0.000173)*
$\Delta(x_m/z_1)_{t-1}$	-0.00038 (0.000455)	0.000966 (0.00117)
$\Delta(w_l/p_j)_{t-1}$	11.82477 (6.3735)**	6.607102 (15.5827)
$\Delta(w_e/p_j)_{t-1}$	-0.4911 (0.3937)	-0.98163 (0.898)
$(w_s/p_j)^a_{t-1}$	-0.11904 (0.0795)	-0.19555 (0.0879)*
$(x_d/z_1)_{t-1}$	-4.16E-07 (0.000022)	6.75E-06 (0.000067)
$(x_m/z_1)_{t-1}$	6.75E-06 (0.000067)	0.000954 (0.000987)
$(w_l/p_j)_{t-1}$	-0.23066 (4.2774)	-11.6725 (10.1554)
$(w_e/p_j)_{t-1}$	-0.08935 (0.1939)	0.164634 (0.456)
d1	0.112607 (0.0575)**	0.682718 (0.1495)*
d2	-0.04381 (0.0604)	0.501465 (0.1425)*
d3	-0.08774 (0.0555)	0.445544 (0.127)*
D(Free Trade Agreements)	0.016862 (0.0873)	-0.2107 (0.1943)
D(Countervailing Duty)	0.011929 (0.0899)	0.081026 (0.2402)
R^2 Adjusted R^2	0.3812 0.2669	0.4564 0.3560

Significance levels of 0.05 and 0.10 are indicated by * and * *, respectively
[a] If $s=d$ refers to domestic hog and $s=m$ refers to imported hog.

Table 3.3: The Estimated Parameters of the Dynamic Inverse Livestock Derived Demand Model for the U.S. Pork Processing Industries

Parameter	Domestic Hogs	Imported Hogs
Constant	0.2739 (0.2137)	0.1531 (0.1083)
$\Delta(w_s/p_j)^a_{t-1}$	-0.2104 (0.1407)	0.0319 (0.1145)
$\Delta(x_d/z_1)_{t-1}$	0.0000049 (0.000011)	-0.00000022 (0.000015)
$\Delta(x_m/z_1)_{t-1}$	0.000091 (0.0001)	0.000173 (0.00014)
$\Delta(w_l/p_j)_{t-1}$	-1.3496 (1.8737)	0.0212 (2.5766)
$\Delta(w_e/p_j)_{t-1}$	-0.0721 (0.1204)	-0.1772 (0.1663)
$(w_s/p_j)^a_{t-1}$	-0.3277 (0.1189)*	-0.23929 (0.0739)*
$(x_d/z_1)_{t-1}$	-0.0000066 (0.00000232)*	-0.000002 (0.0000025)
$(x_m/z_1)_{t-1}$	-0.000002 (0.00000253)	-0.00007 (0.000058)
$(w_l/p_j)_{t-1}$	1.5431 (0.9936)	1.2339 (1.2103)
$(w_e/p_j)_{t-1}$	0.0780 (0.0649)	0.0664 (0.0867)
d1	0.065541 (0.0237)*	0.00523 (0.0310)
d2	0.10579 (0.0268)*	0.02065 (0.0375)
d3	0.050464 (0.0203)*	0.011234 (0.0262)
Dummy(Capture Shock)	-0.12685 (0.0486)*	-0.10281 (0.0675)
R^2 Adjusted R^2	0.4831 0.3953	0.2309 0.1003

Significance levels of 0.05 and 0.10 are indicated by * and * *, respectively

[a] If $s=d$ refers to domestic hogs and $s=m$ refers to imported hogs.

Table 3.4: Critical Values for the Bounds of the F Statistic (Unrestricted Intercept and No Trend)

	90% level		95% level		99% level	
obs = 80*						
# of lags	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
1	4.135	4.895	5.060	5.930	7.095	8.260
2	3.260	4.247	3.940	5.043	5.407	6.783
3	2.823	2.885	3.363	4.515	4.568	5.960
4	2.548	3.644	3.010	4.216	4.096	5.512
5	2.355	3.500	2.787	4.015	3.725	5.163
obs = 1,000**						
# of lags	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
1	4.04	4.78	4.94	5.73	6.84	7.84
2	3.17	4.14	3.79	4.85	5.15	6.36
3	2.72	3.77	3.23	4.35	4.29	5.61
4	2.45	3.52	2.86	4.01	3.74	5.06
5	2.26	3.35	2.62	3.79	3.41	4.68

*Critical value bounds of the F-statistic derived by Narayan (2005)
**Critical value bounds of the F-statistic derived by Pesaran et al. (2001)

Table 3.5: Calculated F Statistic for the Tests of Cointegration

Table (3.5a). Beef processing industry

# of lags	Domestic input	Imported input
1	0.841	2.246
2	1.220	1.705
3	0.902	1.731
4	0.846	1.845
5	1.297	2.890

Table (3.5b). Pork processing industry

# of lags	Domestic input	Imported input
1	5.766	2.935
2	3.425	3.363
3	4.740	2.252
4	2.356	0.677
5	2.033	0.809

Chapter 4

Economic Assessment of Import Restrictions on the U.S. Meat and Livestock Markets: An Application to the Case of Discovery of BSE on Canadian Cattle

4.1 Introduction

The markets for meat and livestock products in the United States and Canada are highly integrated. Therefore, a shock occurring in one of the markets will affect the others. For example, changes in imported quantities of Canadian cattle to the U.S. market have impacts not only on the market for domestic livestock but also on the wholesale and retail meat markets.

Prior to the discover of Bovine Spongiform Encephalopathy (BSE) in Canadian cattle in May of 2003, the livestock and meat markets in U.S. and Canada had become almost like a single market due to the several trade liberalization agreements. The Canada-U.S. Free Trade Agreement (CUSTA) in 1989, the North American Free Trade Agreement (NAFTA) in 1994 and the Uruguay Round trade negotiation in 1995 created more open and integrated markets and provided more opportunities for cross-border trade.

The objective of this study is to investigate the effects on the U.S. imported and domestic meat and livestock markets of the discovery of BSE in Canada. To analyze the effects of the discovery of BSE on meat producers and consumers in the United States, this study examines a shift in the supply (reduction) of Canadian cattle imported to the U.S. cattle market.

A multi-market partial equilibrium approach is utilized to analyze these effects. This approach allows computing the changes in quantities and prices in the U.S. meat and livestock markets from a given percentage shift in import supply or shift in import demand. Multi-market partial equilibrium models have been used by several researchers such as Sarwar and Fox (1992) and Shui et al. (1993).

4.1.1 Beef and Cattle Trade between Canada and U.S.

Under the free trade agreements, U.S. cattle and beef imports from Canada had been increased substantially over time. The imports of Canadian slaughter cattle grew and reached a peak of 385,582 heads in 1996:1 and declined over time until 1999 because of the expansion of slaughter capacity in Canada between 1996 and 1999 (Wohlgenant and Schmitz, 2005).

Live cattle imports are a small share of the U.S. cattle market (around 4%), most of which comes from Canada. However, these imports play an important role as an input for the U.S. meat packing industry plants since they usually have excess capacity. These plants with excess capacity rely on imports to reduce average slaughter costs (Brester and Marsh, 1999). Imports from Canada are also important since U.S. prices of livestock, in general, are higher than Canadian prices of livestock.

With exception of a temporary (June 1999- October 1999) countervailing duty (CVD) of 5.57 percent placed on the value of live cattle imported from Canada, the U.S. and Canadian livestock and meat market did not have any restrictions until the discovery in Canada of an animal infected with BSE in May 2003. This discovery prompted the United States to close its border to cattle from

Canada. However, the U.S. allowed imports of Canadian boxed beef from cattle that were under 30 months of age.

In December 2003, another BSE case was found in a dairy cow of Canadian origin located in the state of Washington. Live cattle trade between the U.S. and Canada remained blocked until July 2005 and then the U.S. border was reopened to exports of live Canadian cattle that are under thirty months of age. Currently, trade of beef and cattle between the United States and Canada is still under this regulation.

4.1.2 Literature Review on the Effects of BSE on the U.S. Markets

BSE-commonly known as “mad cow disease” was originally found in the United Kingdom (UK) in 1986 and by 1992 more than 1,000 cases had been reported in Europe (Jin et al., 2004). On September 10, 2001, the first case of BSE in Japan was reported by the Japanese government. Canada’s first case of BSE was discovered in 1993 in a cow that had been imported from the UK in 1987. There were no serious trade consequences of the discovery of BSE in 1987. On May 20, 2003, Canada confirmed that BSE was found in a single cow in northern Alberta. By the end of 2003, both beef and cattle prices went up because the United States banned imported beef and live cattle from Canada, which coincided with already tight U.S. supplies and strong demand.

In December 2003, the first case of cattle infected with BSE was found in Washington State (a dairy animal of Canadian origin). After discovery of BSE, the US reduced exports of live cattle and beef to Canada, Mexico, Japan and South Korea. As a result, beef prices declined 29 percent between December 2003 and March 2004 (Almas et al., 2005).

Marsh, Brester and Smith (2005) estimated the effects of BSE on U.S. fed steer prices between 2002 and 2004. They showed that the import share of U.S. beef supplies fell from 15.89 percent in 2002 to 14.39 percent in 2004, corresponding to the ban of live cattle imported from

Canada. The decrease of the import share by 1.5 percentage resulted in an estimated $1.70/cwt increase in fed steer prices (or $20.4 per head for 1200 pound of fed steer).

VanSickle and Hodges (2005) analyzed the economic impact of the discovery of the BSE-infected Canadian cow in the United States. They concluded that the ban on importing Canadian cattle is hurting some U.S. processors because of reducing the number of slaughter cattle in the market, but their impacts are more than offset by the gains to producers by increasing herd size and gains to processors in the long run due to more domestic cattle.

4.2 Cattle/Beef Market Structure

Figure 1 shows the flowchart of the interactions among the farm sector, the processing sector, retail sector and consumer of meat production in the United States. The flowchart ignores exports because we are interested in domestic and imported demand for meat and livestock.

In the farm sector, livestock feedlots demand feeder live cattle either from the cow-calf domestic sector or from foreign countries. The feeder animals are fed until they grow up and are ready for slaughter. Hence, the feedlots supply fed animals to the processing sector. Meat processors buy fed animals from feedlots and also import fed animals from foreign countries.

Meat outputs are the final product from the meat packing industries and are shipped to the wholesale sector (supermarkets). Supermarkets order not only meat products from processors but also imported meat from Canada. Supermarkets sell both domestic meat and imported meat demanded by final consumers in the United States.

4.3 Model Development: Structural Equations

For simplicity, we assume that there are only two countries – the United States and Canada-that trade in cattle/beef. The United States is a net importer of cattle/beef, and Canada is a net exporter of cattle/beef. In order to understand the trade issues in the cattle/beef industry, a multi-market partial equilibrium model is utilized. This model allows us to examine changes in prices and quantities of livestock and meat commodities but price and quantities of other goods are fixed.

The market-level input demands are based on firm optimization (i.e., profit maximization) behavior and the market-level output demands are based on consumer maximization. Assuming perfect competition in the input and output markets, the complete structure for input and output markets of slaughter cattle is:

Input market for slaughter cattle at the processing sector:

(1) $$\frac{w_1^d}{p_1} = f_1\left(\frac{x_1}{z}, \frac{x_2}{z}, \frac{w_3}{p_1}, \frac{w_4}{p_1}\right)$$ Inverse input demand for domestic slaughter cattle

(2) $$\frac{w_2^d}{p_1} = f_2\left(\frac{x_1}{z}, \frac{x_2}{z}, \frac{w_3}{p_1}, \frac{w_4}{p_1}\right)$$ Inverse input demand for imported slaughter cattle

$$\frac{w_1^s}{p_1} = g_1(x_1^s), \ x_1^s \text{ is fixed}$$

$$\frac{w_2^s}{p_1} = g_2(x_2^s), \ x_2^s \text{ is fixed}$$

Output market for wholesale beef at the wholesale sector:

(3) $$q_1^d = D_1(p_1, p_2, p_3, p_4, p_5, p_6, Y)$$ Wholesale demand for domestic beef

(4) $$q_4^d = D_4(p_1, p_2, p_3, p_4, p_5, p_6, Y)$$ Wholesale demand for imported beef

$$q_1^s = S_1(p_1, w_1, w_2)$$ Wholesale supply for domestic beef

$q_4^s = S_2(p_4, w_2)$ Wholesale supply for imported beef

Market clearing condition for input and output market:

$\frac{w_1^d}{p_1} = \frac{w_1^s}{p_1} = \frac{w_1}{p_1}$ Market clearing domestic input price identity

$\frac{w_2^d}{p_1} = \frac{w_2^s}{p_1} = \frac{w_2}{p_1}$ Market clearing imported input price identity

$\frac{x_1^d}{z} = \frac{x_1^s}{z} = \frac{x_1}{z}$ Market clearing domestic input quantity identity

$\frac{x_2^d}{z} = \frac{x_2^s}{z} = \frac{x_2}{z}$ Market clearing imported input quantity identity

$q_1^d = q_1^s = q_1$ Market clearing domestic output quantity identity

$q_4^d = q_4^s = q_4$ Market clearing imported output quantity identity

where x_1^d and x_1^s are the demand and supply of slaughter domestic cattle; x_2^d and x_2^s are the demand and supply of slaughter imported cattle; w_1 and w_2 are the slaughter domestic and imported cattle prices; w_3 is the average wage rate in the meat processing industry; w_4 is the energy price; q_1^d and q_1^s are the demand and supply of domestic beef in the wholesale market; q_4^d and q_4^s are the demand and supply of imported beef in the wholesale market; $p_{1,}$ p_2, p_3, p_4, p_5 and p_6 are the wholesale price of domestic beef, domestic pork, domestic poultry, imported beef, imported pork and non-meat, respectively; and Y is the real food expenditure deflated by Stone's index.

Price linkages between farm and wholesale levels:

(5) $p_1 = h_1(w_1, w_2)$

(6) $p_4 = h_4(w_2)$

With competitive markets and with the assumption of constant returns to scale, the wholesale price of domestic beef and imported beef can be characterized by equation (5) and (6), respectively where the wholesale price of domestic beef is a function of domestic slaughter cattle price and import slaughter cattle price, and the wholesale price of imported beef is a function of imported slaughter cattle price.

Equation (1) to (6) can be totally differentiated and the partial derivatives converted into elasticities as follows:

(1)′ $d \ln w_1 = \varepsilon_{11} d \ln x_1 + \varepsilon_{12} d \ln x_2 + (1 - \phi^*_{13}(w_3/w_1) - \phi^*_{14}(w_4/w_1)) d \ln p_1$

(2)′ $d \ln w_2 = \varepsilon_{21} d \ln x_1 + \varepsilon_{22} d \ln x_2 + (1 - \phi^*_{23}(w_3/w_2) - \phi^*_{24}(w_4/w_2)) d \ln p_1$

(3)′ $d \ln q_1 = \eta_{11} d \ln p_1 + \eta_{14} d \ln p_4$

(4)′ $d \ln q_4 = \eta_{41} d \ln p_1 + \eta_{44} d \ln p_4$

(5)′ $d \ln p_1 = e_{11} d \ln w_1 + e_{12} d \ln w_2$

(6)′ $d \ln p_4 = e_{42} d \ln w_2$

where ε_{11} is the own-price elasticity of demand for domestic slaughter cattle, ε_{12} is the cross-price elasticity of demand for domestic slaughter cattle, ε_{21} is the cross-price elasticity of demand for imported slaughter cattle, ε_{22} is the own price elasticity of demand for imported slaughter cattle, η_{11} is the own-price elasticity of demand for domestic beef, η_{14} is the cross price elasticity of demand for domestic beef, η_{41} is the cross-price elasticity of demand for imported beef, η_{44} is the own-price elasticity of demand for imported beef, e_{11} is the percentage change in the domestic price of beef given a one percent change in the price of domestic slaughter cattle, e_{12} is the percentage change in the domestic price of beef given a one percent change in the imported price of slaughter cattle, e_{42} is the percentage change in the imported price of beef given a one percent change in the imported price of slaughter cattle, ϕ_{13}^{*} and ϕ_{14}^{*} are parameter estimated of (w_3/w_1) and (w_4/w_1) variable, respectively in inverse derived demand functions for domestic slaughter cattle, ϕ_{23}^{*} and ϕ_{24}^{*} are parameter estimated of (w_3/w_2) and (w_4/w_2) variables, respectively in inverse derived demand functions for imported slaughter cattle.

4.3.1 Economic Model of the Impact of Decrease in Supply of Canadian Cattle

We utilized the supply-demand framework to analyze the decrease in supply of Canadian cattle imports to the U.S. market. In this framework, prices and quantities of imported and domestic cattle and beef are determined by the intersection of supply and demand for cattle and beef (Figure 2). This framework contains input and output markets. The relationship between wholesale and farm price is utilized to link input and output markets.

In the Figure 2, the diagram on the left-hand side represents the U.S. market for Canadian slaughter cattle (bottom left) and the U.S. market for import beef (top left). On the U.S. market for Canadian slaughter cattle, D_m denotes the derived demand for Canadian slaughter cattle by U.S. processors and S_m is the supply of imported slaughter cattle from Canada which is assumed to be fixed in the short run. On the U.S. market for imported beef, D_m represents the demand for imported beef from Canada by the retail sector (supermarkets) and S_m is the supply of imported beef supplied by Canadian processors to U.S. beef market.

The diagram on the right-side in Figure 2 represents the U.S. market for domestic slaughter cattle (bottom right) and the U.S. market for domestic beef (top right). On the U.S. market for domestic slaughter cattle, D_d denotes the derived demand for domestic slaughter cattle by U.S.

processors and S_d is the supply of domestic slaughter cattle in the U.S. which is assumed to be fixed in the short run. On the U.S. market for domestic beef, D_d denotes the demand for domestic beef demanded by retail sector (supermarket) and S_d represents the supply of domestic beef from U.S. processors.

Suppose that the supply of cattle imports to United States from Canada decreases due to a restriction on imports of Canadian cattle. This effect is shown by a shift leftward in the Canadian supply of cattle to the United from S_m^0 to S_m^1. As result of this decrease in supply of slaughter cattle from Canada, the new equilibrium of import price and quantity becomes w_2^1 and x_2^1 where the demand of import slaughter cattle (D_m) intersects with the new supply of import slaughter cattle (S_m^1).

In the U.S. market for domestic slaughter cattle, the demand for domestic slaughter cattle will increase due to the increase of price of imported slaughter cattle. The increase in demand of domestic slaughter cattle will shift rightward from D_d^0 to D_d^1. The domestic cattle price will go up from w_1^0 to w_1^1. The supply of domestic slaughter cattle does not change because it is fixed in the short run.

In the U.S. market for domestic beef, the supply of domestic meat shifts upward from S_d^0 to S_d^1 because of increased costs of processing meat due to increase in domestic and imported cattle prices. The demand for domestic meat shifts rightward from D_d^0 to D_d^1 because the price of imported beef goes up. As the result, the domestic price and quantity goes up from p_1^0 to p_1^1 and q_1^0 to q_1^1.

The increase in price of import cattle from Canada drives the beef import price up. In the U.S. market for imported beef, the supply of imported meat shifts upward from S_m^0 to S_m^1 and the demand of imported meat shifts rightward from D_m^0 to D_m^1 due to an increase in price of domestic cattle. As a result, the imported price of meat goes up from p_4^0 to p_4^1 and the quantity of imported meat goes down from q_4^0 to q_4^1 because the increase in imported price of beef has more impact than the shift in demand.

The model outlined in figure 2 is different from models that are based on the assumption of homogeneous goods. In the homogeneous-goods model, there is a single price for both imported and domestic products. In the case of live cattle, we found that imported cattle are not perfect substitutes for domestic cattle. This finding can be explained by the fact that cattle imported from Canada is generally different than the U.S. cattle since Canadian producers use different breeds and feed that cause differences in the final quality of the slaughter cattle (Wohlgenant and Schmitz, 2005).

4.4 Simulation Results of the Effect of Discovery BSE of Canadian Cow

The previous section presented a qualitative analysis of the impact of a decrease in the supply of imports of Canadian cattle to the U.S. market. This section intends to quantify the effect of such a shock. This shock is similar to the effect of discovery of BSE in Canada.

The quantification of the effect of the shocks on prices and quantities requires information on demand elasticities for each commodity in both meat and livestock markets, the price linkage between output and input markets, the output price effect on demand for domestic cattle, and the output price effect on demand for imported cattle.

The output price effect on demand of domestic cattle is $[1-\phi_{13}^*(w_3/w_1)-\phi_{14}^*(w_4/w_1)]$ $= A$ and the output price effect on demand of imported cattle is $[1-\phi_{23}^*(w_3/w_2)-\phi_{24}^*(w_4/w_2)]$ $= B.$ Demand elasticities for the beef market were obtained from the first essay and demand elasticities for the cattle market were obtained from the second essay. To obtain information on the price linkage between the retail and farm prices some equations had to be estimated.

Let $\ln w = k_1 \ln w_1 + k_2 \ln w_2$, where $k_1 = w_1 x_1 / (w_1 x_1 + w_2 x_2)$ and $k_2 = w_2 x_2 / (w_1 x_1 + w_2 x_2)$, then the price linkage equations of domestic and imported retail price were estimated by the log linear function and corrected for autocorrelation. These equations excluded intercept and time trend variables because the parameter results of these variables are insignificant. The estimation results were:

$$d \ln p_1 = \underset{(0.0021)^*}{0.7064} d \ln w$$

$$d \ln p_4 = \underset{(0.0051)}{0.7146} d \ln w_2$$

*Significant at 5 percent level of significant

Based on the results of the parameter estimates, e_{11} = 0.7064* k_1, e_{12} = 0.7064* k_2, and e_{42} = 0.7146. Table 4.1 summarizes the parameter values used in this study. The values in the bracket for beef demand equation are the Marshallian demand elasticities.

In case of the decrease in supply of imports on the U.S. cattle market, the equations $(1')$ to $(6')$ can be solved simultaneously and written in matrix form as R*EN = L*EX, where R is a (6×6) non-singular matrix of parameters, EN is the (6×1) vector of endogenous variables ($d \ln w_1$, $d \ln w_2$, $d \ln p_1$, $d \ln q_1$, $d \ln p_4$, and $d \ln q_4$), L is a (6×1) matrix of parameters, and EN is the exogenous variable ($d \ln x_2$). In the short run, there is no change in domestic cattle supply because x_1 is fixed. The solution of the matrix above can be solved as EN = R^{-1}*L*EX. Based on parameter values in table 4.1, the results of this solution are showed in table 4.2.

Table 4.2 shows the effects of a one percent decrease in the supply of imported cattle. This causes the price of imported cattle to increase by 0.0734 percent, the price of domestic cattle to increase by 0.0131, the quantity of domestic beef to increase by 0.0011 (0.0006) percent, the price of domestic beef to increase by 0.0100 percent, the price of imported beef to increase by 0.0525 percent, and the quantity of imported beef to decrease by 0.0120 (0.0124). The values in the bracket are calculated by using the Marshallian demand elasticites.

The analysis can be applied in the case of a Countervailing duty and BSE. Wohlgenant and Schmitz (2005) analyzed the effect of the countervailing duty case. In their study, they found that the increase in the supply of imports by 7.2 percent causes the price of imported cattle to decrease by 2.3 percent and the price of U.S.-produced cattle to fall by 0.14 percent. Using the estimations in table 2, we find that if the supply of imports decreases by 7.2 percent, the price of imported cattle will increase by 0.5285 percent and the price of domestic cattle will increase by 0.0943 percent. Notice that the percentage increase in the U.S. cattle price is less than the percentage increase in the Canadian cattle price. Our results are qualitatively similar to Wohlgenant and Schmitz's results but are smaller in magnitude.

Suppose that the supply of imports decreases by 100 percent because the trade of live cattle between U.S. and Canada is blocked after discovery of BSE in Canada. This causes the price of domestic cattle to increase by 1.31 percent. If the initial price value of domestic cattle was \$809.39 per head in 2002:4, then the expected impact on domestic cattle price would be $(1.31\times\$809.39)/100 =$ \$10.60 per head. Marsh, Brester and Smith (2005) found that fed steer prices would increase by \$20.4 per head for a 1200 pound of fed steer.

4.5 Conclusion

Our empirical analysis of the discovery of BSE on Canadian cattle showed that the impact of the reduction of live animal exports from Canada to the United States is small. This result is similar to Wohlgenant and Schmitz's (2005) study analyzing the effect of the countervailing duty imposed to Canadian cattle in 1998. Wohlgenant and Schmitz analyzed the increase in supply of imported cattle from Canada. They showed that there is little injury to the U.S. cattle producers. We analyzed the decrease in supply of imported cattle from Canada and our result showed that there is little benefit to the U.S. cattle producers.

We found that domestic cattle price increases only 10.60 dollars per head above the price of slaughter cattle in the long run. Marsh, Brester and Smith (2005) estimated the effects of BSE on U.S. fed steer prices between 2002 and 2004. They found that fed steer price increases 20.4 dollar per head for 1200 pound.

Table 4.1: Parameter Values for Beef Demand, Cattle Demand and Price Linkage

	Parameter Values
Beef Demand Equation[1]	
η_{11}	-0.1636 (-0.2077)[3]
η_{14}	0.0527 (0.0496)
η_{41}	0.7582 (0.7336)
η_{44}	-0.3741 (-0.3758)
Inverse Demand Equation for Cattle[2]	
ε_{11}	-0.3675
ε_{12}	-0.0040
ε_{21}	-0.1818
ε_{22}	-0.0693
Output Price Effect on Inverse Demand[2]	
A^*	0.9050
B^*	0.4100
Price Linkage Equation	
e_{11}	0.6939
e_{12}	0.0129
e_{42}	0.7146

[1] Parameter values are obtained from first essay.
[2] Parameter values are obtained from second essay.
[3] Numbers in beef demand equation are Hicksian (Marshaliian) elasticities.
[*] *A* and *B* evaluated at the mean value

Table 4.2: The Effect of Decrease in Canadian Live-Cattle Imports on Prices and Quantities

	$d \ln x_2$ (Hicksian Elasticities)	$d \ln x_2$ (Marshallian Elasticities)
$d \ln w_1$	-0.0131	-0.0131
$d \ln w_2$	-0.0734	-0.0734
$d \ln q_1$	-0.0011	-0.0006
$d \ln q_4$	0.0120	0.0124
$d \ln p_1$	-0.0100	-0.0100
$d \ln p_4$	-0.0525	-0.0525

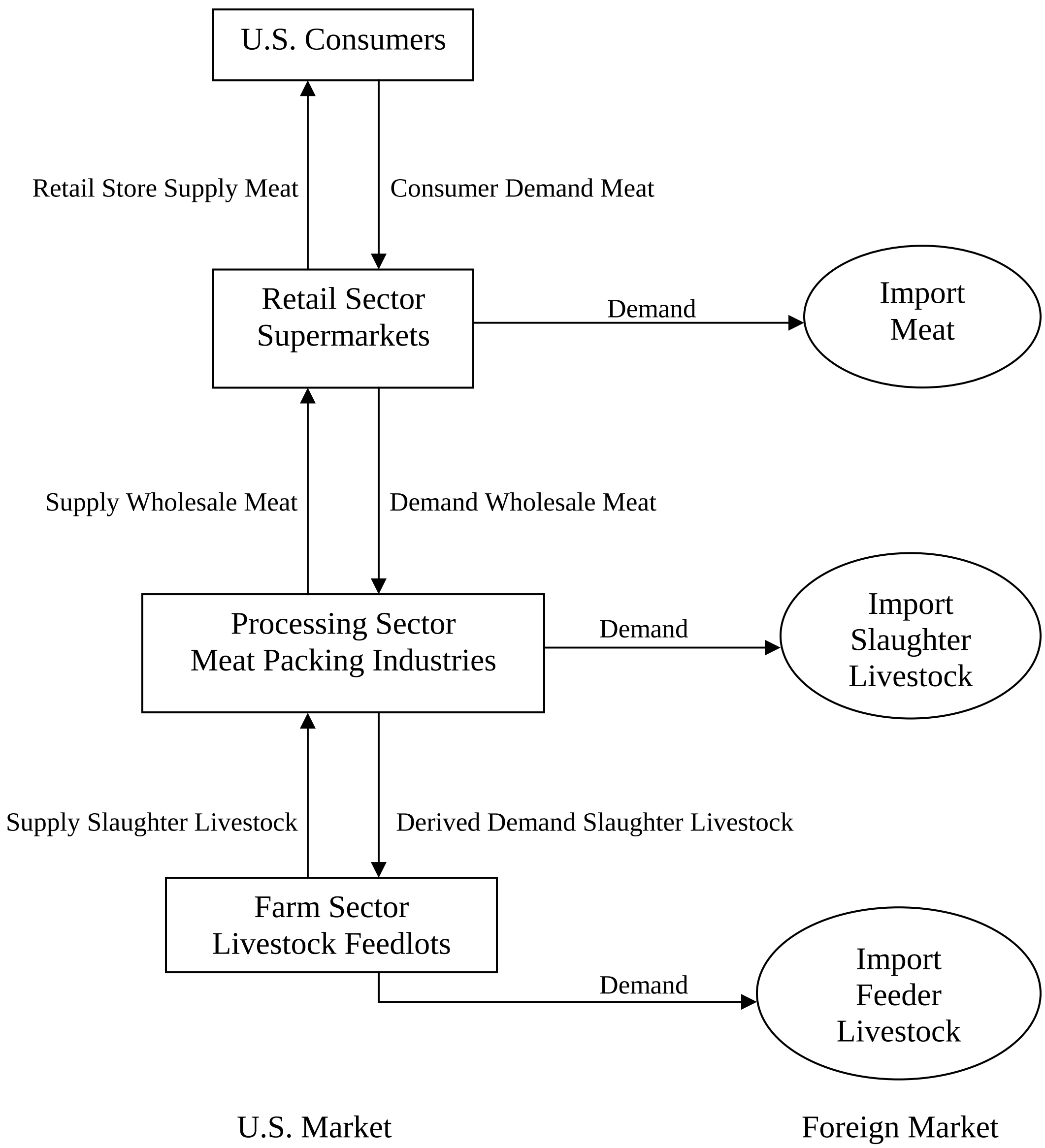

Figure 1: Flowchart of Farm Level to Consumer

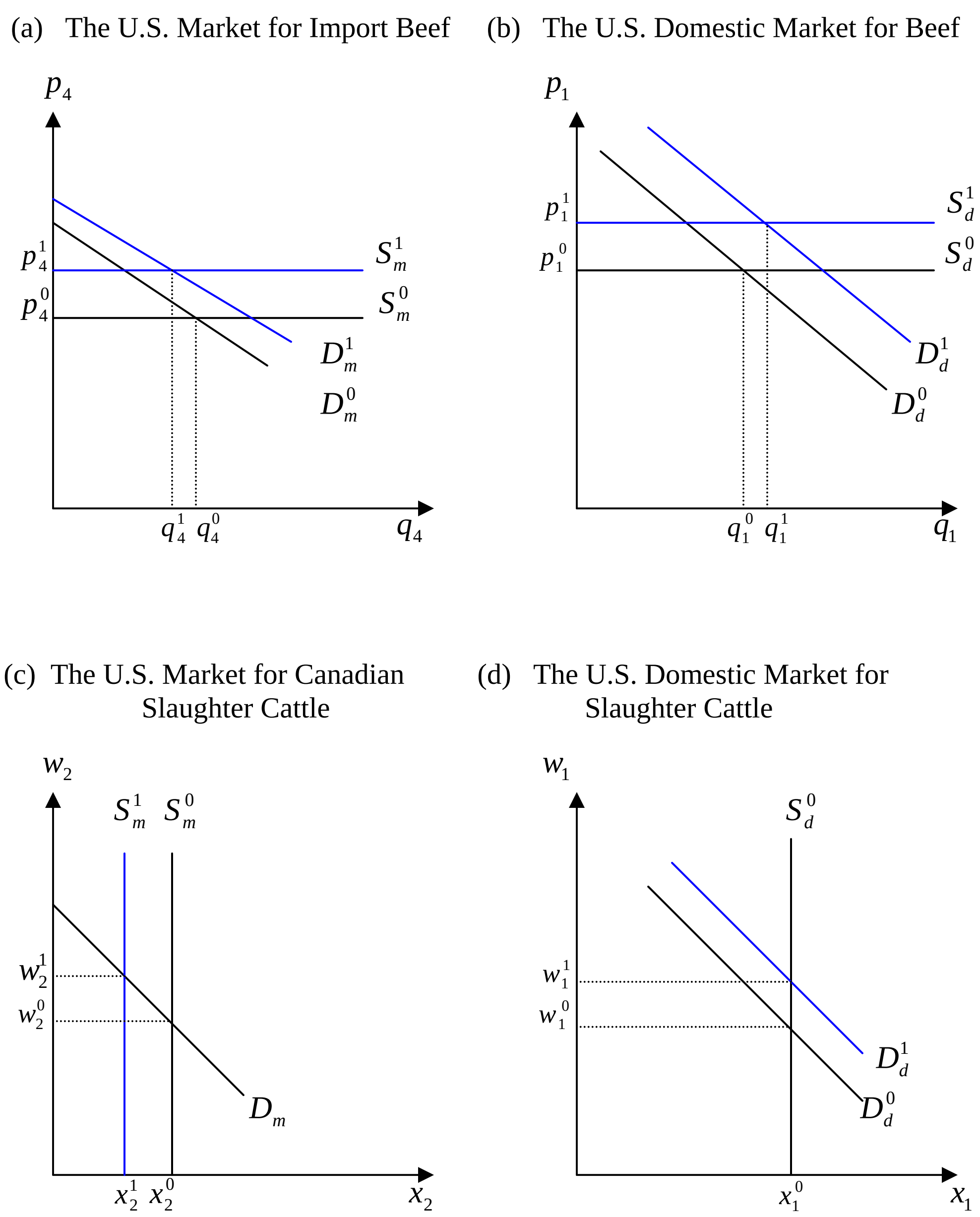

Figure 2: U.S. Markets for Canadian and U.S. Cattle and Beef

Summary and Conclusion

This dissertation studies domestic versus imported demand of meat and livestock in the United States. The first essay focuses on the separability between domestic and imported beef. The separability test concludes that imported meat is a part of U.S. consumption so imported meat should be included in the analysis of U.S. consumer demand for meat. Moreover, researchers estimating import demand for beef or pork should take into account the influence of domestic demand on imports. The separability assumption of demand between foreign and domestic sources maintained in trade models such as the Armington trade model should not be considered.

In the long run, domestic beef and domestic pork are found to be price inelastic and domestic poultry to be elastic, in line with previously published estimates. Demand for imported beef is found to be inelastic but imported demand for pork is elastic. The expenditure elasticities indicate that domestic beef, domestic pork, and imported beef may be considered as necessities. Imported pork may be considered a luxury. In addition, our results of elasticities and separabiltiy tests are robust to endogeneity because the elasticities and separability test results from the GAECM and DSUR models are not different.

The dynamic GAECM and DSUR models performed better than the static model because homogeneity and symmetry restrictions of consumer theory are found to be reasonable descriptions of aggregate behavior in the dynamics demand model, but these demand properties all fail in the static demand model. On the other hand, the static inverse input demand model performed better than the dynamic inverse input demand model for both the beef and pork processing industries.

The results in the second essay showed that there is not a long run relationship in the variables of the inverse demand models for livestock. The static demand models for meat processing industries seem to be appropriate. The reason behind this result might be that meat processing industries cannot store the livestock or the output for a long time. The null hypothesis that imported slaughter animals and U.S. slaughter animals are perfect substitutes (homogeneous) goods was rejected. This implies that the meat processing industry considers imported meat differently than U.S. meat production. The result has implications for the analysis of meat trade policies between the U.S. and other countries which usually assume that meats are homogenous.

The calculated own price elasticities (flexibilities) and cross price elasticities (flexibilities) indicate that the demand for imported livestock by the meat processing industry is very sensitive to changes in the price of domestic livestock. The demand for domestic slaughter livestock is less sensitive to the change in the price of imported livestock.

Our empirical analysis on the case of the discovery of BSE on Canadian cattle showed that the impact of the reduction of live animal exports from Canada to the United States is small. This result implies that there was little injury to the U.S. cattle producers probably because of the small import share. We found that domestic cattle price increases only 10.60 dollars per head based on $809.39 per head in 2002:4.

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