# Testing Separability between Import and Domestic Commodities: Application to U.S. Meat Demand in a Dynamic Model

**Tullaya Boonsaeng and Michael Wohlgenant**

Department of Agriculture and Resource Economics

North Carolina State University

Raleigh, North Carolina

## Abstract

This study focuses in two main issues: 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 in U.S. meat consumption data. The results indicate that a dynamic specification of the AIDS model is superior to the static AIDS model. The separability test for both the static and dynamic AIDS models conclude the same thing: that imported meat consumption is non-separable from the U.S. consumption so domestic meat should be included in the analysis of U.S. import meat demand.

***Key words*:** separability, dynamics AIDS model, import meat demand

Tullaya Boonsaeng is a Ph.D. candidate in the Department of Agricultural and Resource Economics, and Michael Wohlgenant is a Professor in the Department of Agricultural and Resource Economics, North Carolina State University.

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## Introduction

The purpose of this study is 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 particular 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 leading importers and producers of beef and pork products. However, previous studies of meat 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 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.

### Dynamic Specification of Demand Systems

The empirical work done using systems of demand equations commonly reject 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). This intercept term will depend on budget shares lagged one period.

Cointegration techniques and non-stationary time series are 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) 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 US 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.

**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 price 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 of all types of meat should estimate 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.

## Model

### 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 $\alpha_i$ 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 ( $\ln P^* = \sum_{i=1}^{n} w_i \ln p_i$ ).

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.

## 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):

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

where $\phi$ and $\omega$ are parameters, $r$ and $s$ are the number of lags. Therefore, the ARDL model of the general static AIDS model is as follows

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

where $\gamma^*_{ijm} = \omega_m \gamma_{ij}$ and $\beta^*_{im} = \omega_m \beta_i$.

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, …, $r-1$

$$\varphi_i = \sum_{n=1}^{r} \varphi_{in}$$

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

$$\gamma^*_{ij} = \sum_{n=1}^{s} \gamma^*_{ijn}$$

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

$$\beta^*_i = \sum_{n=m+1}^{s} \beta^*_{in}$$

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

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

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

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

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

$$+(\varphi_i-1)[w_{it-1}-(\alpha_i^{\circ}+\sum_j\gamma_{ij}^{\circ}(\ln p_j)_{t-1}+\beta_i^{\circ}\ln(E/P^{*})_{t-1})]+\tilde{u}_{it}, \qquad (6)$$

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 variable is given by the error correction term in brackets. In other words, this term captures the influence of the previous period deviation to the long run equilibrium. The lag values of $\Delta w_{it}$ 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 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 variable, 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 : $\gamma_{ij}^{\circ}=\gamma_{ji}^{\circ}$

## 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 explained in terms of this model. All the tests were 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:

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

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

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

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 $\Psi_1 = ... = \Psi_G = 0$. In this study, due to the shortage of degrees of freedom, the specification of (7) only includes a lag value of the independent variable and the predicted errors. In equation (8), the null hypothesis $\alpha_1 = \alpha_2 = ... = \alpha_p = 0$ 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 $\Psi_1^* = \Psi_2^* = ... = \Psi_G^* = 0.$ 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 $\rho_0 = \rho_1 = ... = \rho_p = 0$ in the following equation:

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

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

## 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 conformed by 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 $pq \leq y$ , 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 $d \neq m$:

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

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.

## Data and Procedure

### 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 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 hogs data are divided into three and two weight categories, respectively. In this study, only imported cattle weighting more than 700 pounds and imported hogs weighting 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 to 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 are 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 expenditure on individual meats was obtained by multiplying constant dollar expenditures of individual meats times the CPI 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.

Exchange rate data between U.S. and Canada is from the Federal Reserve Bank of St. Louis and is available online. Food expenditures and the U.S. population were obtained from the Bureau of Economic Analysis (BEA) from the U.S. Department of Commerce. Consumer Price Indexes (CPI) of domestic prices are from the Consumer Price Index Commodity Data (Bureau of Labor Statistics).

## 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.

# Econometric Model

This study considers an unconditional demand system of U.S. food consumption. 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.

## The Static Demand Model

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

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

where i = 1, 2 , … 6 refer to nonmeat, domestic beef, domestic pork, domestic poultry, import beef, and import pork equation respectively, $ex_t$ is the exchange rate between the U.S. and Canada, $D_t$ is a deterministic term including several dummy variables.

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

$$Y_t = \alpha + \Gamma X_t + dD_t + u_t, \qquad (17)$$

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; $X = (\ln P_1, \ln P_2, \ln P_3, \ln P_4, \ln P_5, \ln P_6, \ln(E/P^*), \ln ex)'$ is a (8 × 1) vector of consumer price indexes for nonmeat, domestic beef, domestic pork, domestic poultry, import beef, and import pork, real food expenditures, and the exchange rate between US and Canada; $D = (t, d_1, d_2, d_3, d_{m1}, d_{m2}, d_{m3})'$ is a (7 × 1) vector including a time trend, seasonal dummy variables $(d_1, d_2, d_3)$, a domestic meat dummy $(d_{m1})$, and an imported meat dummy $(d_{m2}, d_{m3})$; $u_t = (u_{1t}, u_{2t}, u_{3t}, u_{4t}, u_{5t}, u_{6t})'$ 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; $\Gamma$ is a (6 × 8) matrix containing the parameters of the exogenous variables; $d$ is a (7 × 7) matrix containing the parameters of the dummy variables.

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

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

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

Quarterly dummy variables were used to capture seasonality effects. The exchange rate between US and Canada was included as an explanatory variable since there is some evidence indicating that this exchange rate affects meat imports. A strong US dollar leads to more imports not only of beef and pork but also of cattle and hogs from Canada. For example, pork and hog imports from Canada rose sharply due to favorable exchange rates with Canada in 1984. The inclusion of the exchange in the demand models is even more important considering the fact that almost half of U.S. meat imports come from Canada.

A dummy variable was used to capture structural change. There is some evidence showing a structural change in the demand for U.S. meat in the mid-1970's (Choi and Sosin, 1990). Changes in trade policy also affect imports. During the late 1980s, the US imposed countervailing duties (CVD) on Canadian live hogs and pork 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 US market, which in turn injured US producers. In 1993, CVD were lowered which caused hog imports from Canada to increase since then. Two dummy variables were included in this analysis to capture change in U.S. meat import policy. The first one is related to the CVD (1993:1-1995:4) and the second one is related to the free trade agreements from the mid-1990s (1996:1-present).

## The Dynamic 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:

$$\Delta y_t = a_0 + by_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + dt + \varepsilon_t \ , \qquad (18)$$

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:

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

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

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

where $\Delta$ represents the first difference, $\lambda$ 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.

## Elasticities

The unconditional price elasticities, the conditional price elasticities and the expenditure elasticities of the complete demand system were calculated by using the following equations (Green and Alston, 1991; Alston et al., 1994):

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

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

$$\eta_i = 1 + \frac{\beta_i}{w_i} \, , \qquad (23)$$

where $\delta$ 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 $\beta_i$ 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.

To identify whether the goods are substitutes or complements, the Morishima elasticities were calculated using the following equation:

$$M_{ij} = \varepsilon_{ij}^* - \varepsilon_{ii}^* \; . \qquad (24)$$

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.

## 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, import beef and import 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.

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

In this study, the nonmeat group is assumed as separable from the meat group. Our focus was 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.

## Results

### Misspecification Tests Results

The results of the single equation and systemwise misspecification tests are presented in *Table 1*. *Table 1a* shows the misspecification tests 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. With regard to the BP tests for homoscedasticity, all of the tests provide evidence of the presence of heteroscedasticity ($p<0.1$). The RESET tests for individual demand equations identified functional form misspecification problems in all of the equations except in the demand equation for imported beef ($p<0.1$). The systemwise test rejects the null hypothesis of correct functional form for the demand system of equations ($P<0.10$). These results provide evidence that the parameters estimates and the standard errors from the LA/AIDS static might not be consistent. Therefore, the elasticities calculated using the results of this model are not reliable for policy analysis.

*Table 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 domestic pork ($p<0.1$). The results from the BP and ARCH(1) tests for homoscedasticity for the single equations show no evidence of the presence of heteroscedasticity ($p<0.5$). The RESET tests for the individual demand equations indicate that there is no functional form misspecification, except the demand for domestic beef ($p<0.5$). All systemwise misspecification tests failed to reject the null hypothesis that there is no misspecification problem.

These results show that the dynamics AIDS model is superior to the static LA/AIDS model. The dynamics AIDS model succeeds in dealing with the problems of autocorrelation, heteroscedasticity, and functional form misspecification and fit the data well. Therefore, elasticities estimates from the dynamic model are more appropriate for policy analysis.

The residuals from the unrestricted dynamic 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 (*Table 8*).

## Results from the Static Demand Model

The results from the restricted LA/AIDS demand model are presented in *Table 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 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 are also shown some problems. For example, according to the imported beef equation, imported beef and domestic beef are complements; however, according to the domestic beef equation, they are substitutes.

## Results of the Dynamic Demand Model

Results for the ADF tests are presented in *Tables 4, 5* and *6*. *Table 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.

*Table 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 except real income (y). Therefore all the variables, except y are I(1).

*Table 6* shows the results of the ADF tests for the residuals of the LA/AIDS static model. The residuals were obtained by subtracting to the observed value of the expenditure shares the fitted values. 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 7*. All equations have high $R^2$'s except imported pork. The parameter estimates corresponding to the exchange rate variable in the demand equations for domestic pork, domestic poultry, and imported beef and pork have the correct sign. If the U.S. currency appreciates, then meat imports from foreign countries will increase. The exchange rate parameter in the domestic beef demand equation has the incorrect sign but it is insignificant.

The variable $\lambda$ 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 $\lambda$ 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 $\lambda$ value, the slower the model moves back to long run equilibrium. The demand for imported beef presents the highest speed of adjustment to equilibrium, followed by the demand for domestic poultry. The demands for imported and domestic pork and the demand for domestic beef have similar speeds of adjustment. To interpret the parameter $\lambda$ consider the error correction term $\lambda$ for domestic beef whose value is -0.2296. This implies that 22.96% 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 $d_{m1}$ which captures the structure change in U.S. meat demand in the mid-1970's was found to have a significant and negative effect in the demand for domestic pork, domestic poultry and imported beef. The parameters corresponding to the variable $d_{m2}$ which captures the countervailing duty events between U.S. and Canada were not significant in any of the demand models. The variable $d_{m3}$, which is intended to captures changes in trade policy after 1996, was found to have a significant and negative effect in the demand for imported beef.

The price and income elasticities for the dynamic demand system of equations are shown in *Table 9*. The income elasticities for all meats are positive except the income elasticity for imported beef. The income elasticity for imported beef is negative and less than one in absolute value. This negative sign could be explained by the fact that most of the beef imported to the United States is low quality beef from Australia and New Zealand. 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 big 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. In line with previous studies, all of the domestic meats have income elasticities that are less than one (necessary goods).

The Marshallian own price elasticities for domestic meats are smaller in absolute value than the Marshallian own price elasticities for imported meats. The elasticities of the GAECM model 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.

The results of tests of the homogeneity and symmetry restrictions in the LA/AIDS and GAECM are presented in *Table 10*. In the static LA/AIDS model, the null hypothesis that the homogeneity restrictions are satisfied is rejected in all of the single demand equations ($p<0.05$), except for the demand for domestic beef. In this model, the homogeneity and symmetry restrictions are also rejected for the whole demand system of equations. On the other hand, in the GAECM, the null hypothesis that the homogeneity restrictions are satisfied is not rejected in any of the single demand equations ($p<0.05$), except for the demand for domestic pork. In addition, the homogeneity restriction is not rejected for the complete demand system of equations and the symmetry restrictions for the demand system cannot be rejected neither. Likelihood ratio tests were used to test the restrictions.

## Separability Tests

Separability tests were carried out with the homogeneity and separability restrictions imposed and without these restrictions imposed in both the static and dynamic models. Likelihood ratio tests were used to test the restrictions, therefore a restricted and a restricted model need to be considered. Three cases were considered in this study. In the first case, in the unrestricted model none of the restrictions (homogeneity, symmetry and separability) were imposed whereas than in the restricted model the three restrictions were imposed. In the second case, the unrestricted model was similar to the first case, however the restricted model only imposed the separability restrictions. In the third case, in the unrestricted model only 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 11*. In both models and in the three cases the separability restrictions are rejected. These results imply that imported meats are not separable from domestic meats.

## Summary and Conclusions

The results of this study suggest that the dynamic specification of the AIDS model is 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 passes all the misspecification tests while the static AIDS model fails all the misspecification tests.

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

The separability test for both the static AIDS and dynamic AIDS 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.

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Table 1: Misspecification tests for the LA/AIDS and the GAECM model

Table (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] | 1.3263 | 1.2629 | 1.3160 | 1.7811 | 0.9071 | - |
| BG[2] | 0.0021 | 0.0002 | 0.0053 | 0.0254 | <0.0001 | <0.0001 |
| BP[2] | 0.0004 | 0.0628 | 0.0132 | <0.0001 | 0.0168 | <0.0001 |
| RESET[2] | <0.0001 | 0.0003 | 0.0031 | 0.2857 | 0.0014 | <0.0001 |

Table (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] | 0.2220 | 0.0181 | 0.6143 | 0.5043 | 0.2156 | 0.1244 |
| BP[2] | 0.8919 | 0.1087 | 0.8074 | 0.0766 | 0.3623 | 0.2992 |
| ARCH(1)[2] | 0.6772 | 0.8054 | 0.7804 | 0.4338 | 0.9057 | 0.9414 |
| RESET[2] | 0.0447 | 0.2904 | 0.2151 | 0.9490 | 0.2533 | 0.1439 |

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

[1] Calculated Value
[2] P-values

Table (2): Parameter Estimates for the Restricted Static LA/AIDS Meat Demand Model

| **Variables** | **Domestic Beef** | **Domestic Pork** | **Domestic Poultry** | **Imported Beef** | **Imported Pork** |
|---|---|---|---|---|---|
| Constant | 0.1157* | 0.0624* | 0.0160* | 0.0046* | 0.0021* |
| | (0.0027) | (0.0015) | (0.0009) | (0.0007) | (0.0004) |
| ln(D. Beef Price) | 0.0354* | 0.0064* | 0.0003 | -0.0015 | -0.0013** |
| | (0.0040) | (0.0018) | (0.0015) | (0.0014) | (0.0007) |
| ln(D. Pork Price) | 0.0064* | 0.0021 | -0.0032* | 0.0039* | 0.0030* |
| | (0.0018) | (0.0017) | (0.0010) | (0.0007) | (0.0006) |
| ln(D. Poultry Price) | 0.0003 | -0.0032* | 0.0132* | -0.0023* | 0.0001 |
| | (0.0015) | (0.0010) | (0.0011) | (0.0006) | (0.0004) |
| ln(Im. Beef Price) | -0.0015 | 0.0039* | -0.0023* | 0.0057* | -0.0001 |
| | (0.0014) | (0.0007) | (0.0006) | (0.0007) | (0.0003) |
| ln(Im. Pork Price) | -0.0013** | 0.0030* | 0.0001 | -0.0001 | -0.0010* |
| | (0.0007) | (0.0006) | (0.0004) | (0.0003) | (0.0004) |
| ln(Nonmeat Price) | -0.0393 | -0.0122* | -0.0082* | -0.0057* | -0.0007* |
| | (0.0029) | (0.0015) | (0.0008) | (0.0007) | (0.00035) |
| Exchange Rate | -0.0176* | 0.0086* | 0.0091* | 0.0010 | -0.0023* |
| | (0.0043) | (0.0023) | (0.0012) | (0.0011) | (0.0005) |
| Real Income | -0.0105* | -0.0119* | -0.0032* | -0.0021* | -0.0007 |
| | (0.0038) | (0.0021) | (0.0011) | (0.0010) | (0.0005) |
| Time Trend | -0.0003* | 0.00007* | 0.0002* | 0.00005* | 2.92E-06 |
| | (0.00006) | (0.00003) | (0.00002) | (0.000015) | (7.87E-06) |
| $d_1$ | -0.0012** | -0.0030* | -0.0025* | 0.0003** | 0.000054 |
| | (0.0006) | (0.0003) | (0.0002) | (0.00015) | (0.00007) |
| $d_2$ | -0.0007 | -0.0046* | -0.0015* | 0.0005* | -7.19E-07 |
| | (0.0006) | (0.0003) | (0.0002) | (0.00015) | (0.00007) |
| $d_3$ | 0.0017* | -0.0030* | -0.0011* | 0.00056* | -0.00011 |
| | (0.0006) | (0.0003) | (0.0002) | (0.00015) | (0.00007) |
| $d_{m1}$ | 0.0044* | -0.0013* | -0.0022* | -0.0007* | -0.00043* |
| | (0.0010) | (0.00055) | (0.0003) | (0.00027) | (0.00013) |
| $d_{m2}$ | 0.0024* | 0.0028* | 0.0008* | 0.00041 | -0.0007* |
| | (0.0012) | (0.0006) | (0.0003) | (0.0003) | (0.00015) |
| $d_{m3}$ | 0.0045* | 0.0037* | -0.00012 | 0.00021 | -0.0007* |
| | (0.0017) | (0.0009) | (0.00047) | (0.00043) | (0.00022) |
| $R^2$ | 0.9822 | 0.9517 | 0.9639 | 0.8100 | 0.4815 |
| Adjusted $R^2$ | 0.9803 | 0.9467 | 0.9601 | 0.7902 | 0.4274 |

* Statistically significant at the 0.05 level.
** Statistically significant at the 0.10 level.

Table (3): Elasticities for the Static LA/AIDS Meat Demand Model

| | Income Elasticity |
|---|---|
| Domestic Beef | 0.8785 |
| Domestic Pork | 0.7288 |
| Domestic Poultry | 0.8398 |
| Imported Beef | 0.5358 |
| Imported Pork | 0.6123 |

| | Marshallian Elasticity Matrix | | | | |
|---|---|---|---|---|---|
| | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
| Domestic Beef | -0.5790 | 0.0793 | 0.0062 | -0.0173 | -0.0146 |
| Domestic Pork | 0.1686 | -0.9398 | -0.0672 | 0.0907 | 0.0679 |
| Domestic Poultry | 0.0301 | -0.1521 | -0.3364 | -0.1131 | 0.0073 |
| Imported Beef | -0.3004 | 0.8892 | -0.4947 | 0.2713 | -0.0302 |
| Imported Pork | -0.7300 | 1.7831 | 0.0913 | -0.0818 | -1.5720 |

| | Hicksian Elasticity Matrix | | | | |
|---|---|---|---|---|---|
| | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
| Domestic Beef | -0.5033 | 0.1179 | 0.0238 | -0.0133 | -0.0132 |
| Domestic Pork | 0.2314 | -0.9078 | -0.0526 | 0.0940 | 0.0691 |
| Domestic Poultry | 0.1025 | -0.1153 | -0.9230 | -0.1093 | 0.0087 |
| Imported Beef | -0.2542 | 0.9127 | -0.4840 | 0.2737 | -0.0293 |
| Imported Pork | -0.6772 | 1.8100 | 0.1035 | -0.0790 | -1.5709 |

| | Morishima Elasticity Matrix | | | | |
|---|---|---|---|---|---|
| | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
| Domestic Beef | - | 0.7347 | 0.6058 | 0.2491 | -0.1740 |
| Domestic Pork | 1.0257 | - | 0.7925 | 1.8205 | 2.7178 |
| Domestic Poultry | 0.9468 | 0.8704 | - | 0.4389 | 1.0265 |
| Imported Beef | -0.2870 | -0.1797 | -0.3830 | - | -0.3527 |
| Imported Pork | 1.5577 | 1.6400 | 1.5800 | 1.5416 | - |

Table (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) | | W1 | w2 | w3 | w4 | w5 | lnp1 | lnp2 | lnp3 | lnp4 | lnp5 | lnp6 | lnex | y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | parameter | -0.07 | -0.10 | -0.12 | -0.26 | -0.13 | -0.16 | -0.11 | -0.09 | -0.19 | -0.15 | -0.15 | -0.06 | -0.02 |
| | ADF stat | -1.06 | -1.68 | -1.89 | -2.52 | -2.03 | -3.38 | -2.33 | -1.66 | -3.24 | -2.62 | -2.57 | -2.44 | -2.63 |
| | AIC | -9.02 | -9.96 | -10.96 | -11.35 | -13.99 | -4.51 | -3.68 | -3.32 | -2.51 | -2.58 | -6.42 | -5.44 | -6.70 |
| | SC | -8.76 | -9.70 | -10.70 | -11.09 | -13.73 | -4.26 | -3.42 | -3.06 | -2.26 | -2.33 | -6.16 | -5.18 | -6.45 |
| 7 | parameter | -0.07 | -0.08 | -0.10 | -0.29 | -0.11 | -0.16 | -0.12 | -0.08 | -0.17 | -0.14 | -0.16 | -0.06 | -0.03 |
| | ADF stat | -1.17 | -1.41 | -1.46 | -2.97 | -1.75 | -3.31 | -2.53 | -1.50 | -3.04 | -2.53 | -2.71 | -2.41 | -3.09 |
| | AIC | -9.04 | -9.95 | -10.86 | -11.36 | -13.99 | -4.39 | -3.68 | -3.23 | -2.53 | -2.57 | -6.37 | -5.46 | -6.71 |
| | SC | -8.81 | -9.71 | -10.62 | -11.13 | -13.76 | -4.16 | -3.45 | -3.00 | -2.30 | -2.34 | -6.13 | -5.23 | -6.48 |
| 6 | parameter | -0.06 | -0.11 | -0.14 | -0.34 | -0.13 | -0.17 | -0.12 | -0.09 | -0.15 | -0.14 | -0.14 | -0.06 | -0.02 |
| | ADF stat | -1.06 | -1.83 | -1.90 | -3.68 | -2.06 | -3.68 | -2.54 | -1.73 | -2.78 | -2.74 | -2.58 | -2.31 | -2.90 |
| | AIC | -9.03 | -9.83 | -10.68 | -11.37 | -13.99 | -4.39 | -3.70 | -3.25 | -2.54 | -2.60 | -6.39 | -5.48 | -6.72 |
| | SC | -8.83 | -9.62 | -10.48 | -11.16 | -13.78 | -4.18 | -3.49 | -3.04 | -2.33 | -2.39 | -6.18 | -5.27 | -6.51 |
| 5 | parameter | -0.09 | -0.13 | -0.17 | -0.31 | -0.14 | -0.14 | -0.12 | -0.09 | -0.14 | -0.14 | -0.13 | -0.06 | -0.02 |
| | ADF stat | -1.54 | -2.29 | -2.37 | -3.42 | -2.35 | -3.27 | -2.61 | -1.73 | -2.78 | -2.86 | -2.52 | -2.37 | -2.77 |
| | AIC | -9.03 | -9.82 | -10.67 | -11.33 | -14.00 | -4.37 | -3.71 | -3.27 | -2.55 | -2.61 | -6.39 | -5.51 | -6.74 |
| | SC | -8.85 | -9.64 | -10.48 | -11.15 | -13.82 | -4.19 | -3.52 | -3.09 | -2.36 | -2.42 | -6.20 | -5.32 | -6.55 |
| 4 | parameter | -0.13 | -0.16 | -0.21 | -0.32 | -0.18 | -0.16 | -0.19 | -0.13 | -0.20 | -0.18 | -0.19 | -0.05 | -0.02 |
| | ADF stat | -2.23 | -2.85 | -2.95 | -3.81 | -2.92 | -4.09 | -4.05 | -2.49 | -4.06 | -3.75 | -3.58 | -2.24 | -3.12 |
| | AIC | -9.00 | -9.82 | -10.65 | -11.36 | -13.95 | -4.37 | -3.46 | -3.20 | -2.50 | -2.59 | -6.31 | -5.51 | -6.76 |
| | SC | -8.84 | -9.66 | -10.49 | -11.20 | -13.79 | -4.21 | -3.30 | -3.04 | -2.34 | -2.43 | -6.15 | -5.35 | -6.60 |

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 (5): Augmented Dickey Fuller test 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) | | Dw1 | dw2 | dw3 | dw4 | dw5 | dlnp1 | dlnp2 | dlnp3 | dlnp4 | dlnp5 | dlnp6 | dlnex | dy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | parameter | -1.15 | -1.65 | -2.19 | -2.16 | -1.73 | -0.87 | -1.22 | -1.66 | -0.92 | -1.21 | -1.31 | -0.44 | -0.09 |
| | ADF stat | -3.31 | -4.03 | -4.58 | -4.98 | -4.52 | -4.31 | -4.70 | -4.71 | -3.67 | -4.20 | -4.89 | -2.58 | -1.66 |
| | AIC | -8.95 | -9.95 | -10.99 | -11.32 | -14.12 | -4.43 | -3.67 | -3.38 | -2.48 | -2.55 | -6.43 | -5.40 | -6.60 |
| | SC | -8.74 | -9.74 | -10.78 | -11.11 | -13.91 | -4.22 | -3.46 | -3.17 | -2.27 | -2.34 | -6.22 | -5.19 | -6.39 |
| 7 | parameter | -1.26 | -1.73 | -2.05 | -2.21 | -1.78 | -0.80 | -1.13 | -1.53 | -0.95 | -1.10 | -1.20 | -0.49 | -0.08 |
| | ADF stat | -3.87 | -4.58 | -4.55 | -5.87 | -4.78 | -4.32 | -4.74 | -4.57 | -4.03 | -4.11 | -4.80 | -3.04 | -1.55 |
| | AIC | -8.97 | -9.94 | -10.95 | -11.34 | -14.00 | -4.44 | -3.67 | -3.32 | -2.46 | -2.55 | -6.39 | -5.42 | -6.62 |
| | SC | -8.78 | -9.75 | -10.76 | -11.15 | -13.82 | -4.26 | -3.49 | -3.13 | -2.27 | -2.36 | -6.21 | -5.23 | -6.44 |
| 6 | parameter | -1.28 | -2.20 | -3.20 | -1.93 | -2.05 | -0.81 | -1.12 | -1.83 | -0.98 | -1.26 | -1.16 | -0.50 | -0.07 |
| | ADF stat | -4.31 | -6.83 | -8.64 | -5.80 | -6.45 | -4.53 | -5.20 | -6.03 | -4.54 | -5.19 | -5.00 | -3.25 | -1.28 |
| | AIC | -9.00 | -9.92 | -10.83 | -11.33 | -14.01 | -4.34 | -3.67 | -3.25 | -2.48 | -2.55 | -6.35 | -5.44 | -6.61 |
| | SC | -8.83 | -9.76 | -10.67 | -11.17 | -13.85 | -4.18 | -3.51 | -3.09 | -2.32 | -2.38 | -6.18 | -5.28 | -6.44 |
| 5 | parameter | -1.46 | -1.71 | -2.28 | -1.58 | -1.81 | -0.72 | -1.12 | -1.62 | -1.04 | -1.22 | -1.19 | -0.53 | -0.07 |
| | ADF stat | -5.49 | -5.74 | -6.75 | -5.19 | -6.62 | -4.23 | -6.01 | -6.19 | -5.43 | -5.72 | -5.86 | -3.62 | -1.35 |
| | AIC | -8.99 | -9.83 | -10.68 | -11.30 | -14.00 | -4.32 | -3.69 | -3.26 | -2.51 | -2.56 | -6.37 | -5.46 | -6.62 |
| | SC | -8.86 | -9.69 | -10.54 | -11.16 | -13.86 | -4.18 | -3.55 | -3.12 | -2.37 | -2.42 | -6.23 | -5.32 | -6.48 |
| 4 | parameter | -1.30 | -1.45 | -1.88 | -1.59 | -1.57 | -0.77 | -1.21 | -1.65 | -1.03 | -1.10 | -1.25 | -0.52 | -0.08 |
| | ADF stat | -5.48 | -5.34 | -6.36 | -5.83 | -6.74 | -5.02 | -8.09 | -7.86 | -6.28 | -5.91 | -7.58 | -3.81 | -1.46 |
| | AIC | -9.00 | -9.81 | -10.65 | -11.28 | -14.00 | -4.32 | -3.69 | -3.28 | -2.52 | -2.57 | -6.38 | -5.49 | -6.63 |
| | SC | -8.89 | -9.69 | -10.54 | -11.17 | -13.89 | -4.21 | -3.58 | -3.17 | -2.41 | -2.46 | -6.26 | -5.37 | -6.51 |

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

Table (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 | -0.81 | -1.00 | -0.86 | -0.99 | -0.44 |
| | ADF stat | -3.62 | -4.72 | -3.99 | -4.03 | -3.06 |
| | AIC | -9.62 | -10.86 | -12.11 | -12.27 | -14.02 |
| | SC | -9.41 | -10.65 | -11.90 | -12.06 | -13.81 |
| 7 | Parameter | -0.80 | -0.87 | -0.85 | -1.10 | -0.42 |
| | ADF stat | -3.84 | -4.45 | -4.24 | -4.96 | -3.06 |
| | AIC | -9.64 | -10.86 | -12.09 | -12.28 | -14.03 |
| | SC | -9.46 | -10.68 | -11.90 | -12.10 | -13.85 |
| 6 | Parameter | -0.74 | -0.90 | -0.92 | -0.94 | -0.47 |
| | ADF stat | -3.80 | -5.15 | -5.07 | -4.55 | -3.56 |
| | AIC | -9.64 | -10.88 | -12.08 | -12.28 | -14.04 |
| | SC | -9.48 | -10.72 | -11.92 | -12.11 | -13.88 |
| 5 | Parameter | -1.00 | -0.87 | -0.81 | -0.81 | -0.57 |
| | ADF stat | -5.63 | -5.53 | -4.85 | -4.18 | -4.67 |
| | AIC | -9.58 | -10.84 | -12.08 | -12.26 | -14.03 |
| | SC | -9.44 | -10.70 | -11.94 | -12.12 | -13.90 |
| 4 | Parameter | -0.98 | -0.80 | -0.77 | -0.79 | -0.59 |
| | ADF stat | -6.53 | -5.62 | -5.17 | -4.43 | -5.46 |
| | AIC | -9.60 | -10.81 | -12.10 | -12.27 | -14.06 |
| | SC | -9.48 | -10.70 | -11.98 | -12.16 | -13.94 |
| 3 | Parameter | -0.72 | -0.66 | -0.69 | -0.72 | -0.48 |
| | ADF stat | -4.91 | -5.01 | -5.05 | -4.35 | -4.69 |
| | AIC | -9.44 | -10.79 | -12.09 | -12.28 | -13.98 |
| | SC | -9.35 | -10.70 | -12.00 | -12.19 | -13.89 |
| 2 | Parameter | -0.76 | -0.61 | -0.70 | -0.99 | -0.45 |
| | ADF stat | -5.94 | -5.15 | -5.75 | -6.72 | -4.84 |
| | AIC | -9.46 | -10.80 | -12.08 | -12.23 | -13.99 |
| | SC | -9.39 | -10.73 | -12.01 | -12.16 | -13.93 |
| 1 | Parameter | -0.81 | -0.77 | -0.73 | -1.07 | -0.42 |
| | ADF stat | -7.89 | -7.76 | -7.09 | -9.15 | -4.89 |
| | AIC | -9.48 | -10.76 | -12.07 | -12.17 | -14.01 |
| | SC | -9.43 | -10.72 | -12.02 | -12.12 | -13.97 |

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

Table (7): Parameter Estimates of the Restricted GAECM model of U.S. meat demand

| Variables | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
|---|---|---|---|---|---|
| Constant | 0.1175* | 0.0476* | 0.01095* | 0.0071* | 0.00133 |
| | (0.0124) | (0.0076) | (0.0018) | (0.0010) | (0.00118) |
| ln(D. Beef Price) | 0.0469* | 0.0114** | 0.0074* | 0.0056* | -0.0029 |
| | (0.0203) | (0.00647) | (0.0028) | (0.0025) | (0.0021) |
| ln(D. Pork Price) | 0.0114** | 0.02007** | -0.00185 | 0.0026 | 0.0075 |
| | (0.00647) | (0.0114) | (0.00267) | (0.0019) | (0.0023) |
| ln(D. Poultry Price) | 0.0074* | -0.00185 | 0.0157* | -0.0058* | -0.0021 |
| | (0.0028) | (0.00267) | (0.0025) | (0.0013) | (0.0013) |
| ln(Im. Beef Price) | 0.0056* | 0.0026 | -0.0058* | 0.0020 | 0.0016 |
| | (0.0025) | (0.0019) | (0.0013) | (0.0014) | (0.0010) |
| ln(Im. Pork Price) | -0.0029 | 0.0075* | -0.0021 | 0.0016 | -0.0027 |
| | (0.0021) | (0.0023) | (0.0013) | (0.0010) | (0.0014) |
| ln(Nonmeat Price) | -0.0683* | -0.0398* | -0.0134* | -0.0060* | -0.0014 |
| | (0.0202) | (0.0123) | (0.0020) | (0.00126) | (0.0014) |
| Exchange Rate | -0.0221 | 0.0040 | 0.0081* | -0.00004 | -0.0028** |
| | (0.0164) | (0.0065) | (0.0019) | (0.0012) | (0.0016) |
| Real Income | -0.0190 | -0.0079 | -0.0005 | -0.0057* | 0.0021 |
| | (0.0177) | (0.0071) | (0.0021) | (0.0014) | (0.0017) |
| Time Trend | -0.00013 | 0.000124 | 0.00013* | 0.000104* | -0.00005** |
| | (0.00027) | (0.000096) | (0.00003) | (0.000022) | (0.00003) |
| $d_1$ | 0.0046 | -0.00035 | 0.0030* | 0.00005 | -0.00035 |
| | (0.0038) | (0.00217) | (0.0008) | (0.00022) | (0.00028) |
| $d_2$ | 0.0048 | 0.0044 | 0.0017* | 0.00033 | -0.00083* |
| | (0.0039) | (0.0031) | (0.0006) | (0.00024) | (0.00035) |
| $d_3$ | -0.0035 | 0.0110* | 0.0041* | -0.00018 | -0.00005 |
| | (0.0040) | (0.0047) | (0.0009) | (0.00024) | (0.0003) |
| $d_{m1}$ | 0.0009 | -0.0070* | -0.0025* | -0.00069** | -0.00041 |
| | (0.0046) | (0.0030) | (0.0005) | (0.00038) | (0.00045) |
| $d_{m2}$ | 0.0066 | 0.0021 | 0.0004 | -0.0006 | 0.00017 |
| | (0.0048) | (0.0018) | (0.0005) | (0.0004) | (0.00046) |
| $d_{m3}$ | 0.0036 | 0.0010 | -0.0003 | -0.0015* | 0.0009 |
| | (0.0071) | (0.0029) | (0.0008) | (0.0006) | (0.0008) |
| $\lambda$ | -0.2296* | -0.2924* | -0.6100* | -0.8891* | -0.2725* |
| | (0.1109) | (0.1067) | (0.1080) | (0.1915) | (0.0830) |
| $R^2$ | 0.7571 | 0.9307 | 0.9367 | 0.8033 | 0.5942 |
| Adjusted $R^2$ | 0.6401 | 0.8972 | 0.9062 | 0.7085 | 0.3986 |

* Statistically significant at the 0.05 level.
** Statistically significant at the 0.10 level.

Table (8): 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 | -1.27 | -1.37 | -1.06 | -1.09 | -1.60 |
| | ADF stat | -4.11 | -3.11 | -3.75 | -3.53 | -4.99 |
| | AIC | -10.13 | -11.59 | -12.66 | -12.70 | -14.80 |
| | SC | -9.91 | -11.37 | -12.45 | -12.49 | -14.59 |
| 7 | Parameter | -1.44 | -1.47 | -1.04 | -1.20 | -1.48 |
| | ADF stat | -5.25 | -3.61 | -4.02 | -4.23 | -5.15 |
| | AIC | -10.14 | -11.61 | -12.68 | -12.72 | -14.82 |
| | SC | -9.95 | -11.42 | -12.49 | -12.53 | -14.63 |
| 6 | Parameter | -1.34 | -1.81 | -1.09 | -1.08 | -1.49 |
| | ADF stat | -5.59 | -4.93 | -4.63 | -4.08 | -6.03 |
| | AIC | -10.16 | -11.59 | -12.70 | -12.73 | -14.84 |
| | SC | -9.99 | -11.42 | -12.54 | -12.57 | -14.68 |
| 5 | Parameter | -1.24 | -1.91 | -0.93 | -1.24 | -1.28 |
| | ADF stat | -5.92 | -6.20 | -4.20 | -5.26 | -5.89 |
| | AIC | -10.16 | -11.60 | -12.68 | -12.74 | -14.84 |
| | SC | -10.02 | -11.46 | -12.54 | -12.60 | -14.70 |
| 4 | Parameter | -1.15 | -1.73 | -0.94 | -1.23 | -1.06 |
| | ADF stat | -6.33 | -6.82 | -4.70 | -6.05 | -5.24 |
| | AIC | -10.15 | -11.62 | -12.70 | -12.77 | -14.76 |
| | SC | -10.04 | -11.50 | -12.59 | -12.65 | -14.65 |
| 3 | Parameter | -0.92 | -1.48 | -1.06 | -1.13 | -1.03 |
| | ADF stat | -5.51 | -7.00 | -5.98 | -6.42 | -5.79 |
| | AIC | -10.10 | -11.60 | -12.67 | -12.76 | -14.78 |
| | SC | -10.01 | -11.51 | -12.58 | -12.67 | -14.69 |
| 2 | Parameter | -0.93 | -1.26 | -0.93 | -0.99 | -0.98 |
| | ADF stat | -6.53 | -7.20 | -5.94 | -6.55 | -6.43 |
| | AIC | -10.13 | -11.59 | -12.66 | -12.76 | -14.80 |
| | SC | -10.06 | -11.53 | -12.59 | -12.69 | -14.73 |
| 1 | Parameter | -0.86 | -1.22 | -0.96 | -0.95 | -0.98 |
| | ADF stat | -7.25 | -8.77 | -7.50 | -7.68 | -8.14 |
| | AIC | -10.14 | -11.57 | -12.69 | -12.77 | -14.83 |
| | SC | -10.09 | -11.52 | -12.64 | -12.73 | -14.78 |

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

Table (9): Elasticities from the Generalized AIDS Error Correction Model

| | Income Elasticity |
|---|---|
| Domestic Beef | 0.7800 |
| Domestic Pork | 0.8213 |
| Domestic Poultry | 0.9766 |
| Imported Beef | -0.2491 |
| Imported Pork | 2.2776 |

| | Marshallian Elasticities | | | | |
|---|---|---|---|---|---|
| | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
| Domestic Beef | -0.4377 | 0.1419 | 0.0899 | 0.0661 | -0.0334 |
| Domestic Pork | 0.2750 | -0.5352 | -0.0385 | 0.0604 | 0.1718 |
| Domestic Poultry | 0.3700 | -0.0913 | -0.2157 | -0.2888 | -0.1038 |
| Imported Beef | 1.3492 | 0.6334 | -1.2550 | -0.5458 | 0.3487 |
| Imported Pork | -1.8458 | 4.4357 | -1.2662 | 0.9295 | -2.6364 |

| | Hicksian Elasticities | | | | |
|---|---|---|---|---|---|
| | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
| Domestic Beef | -0.3704 | 0.1761 | 0.1055 | 0.0697 | -0.0321 |
| Domestic Pork | 0.3458 | -0.4992 | -0.0221 | 0.0641 | 0.1731 |
| Domestic Poultry | 0.4539 | -0.0484 | -0.5157 | -0.2844 | -0.1021 |
| Imported Beef | 1.3278 | 0.6225 | -1.2600 | -0.5469 | 0.3483 |
| Imported Pork | -1.6494 | 4.5358 | -1.2206 | 0.9398 | -2.6326 |

| | Morishima Elasticities | | | | |
|---|---|---|---|---|---|
| | Domestic Beef | Domestic Pork | Domestic Poultry | Imported Beef | Imported Pork |
| Domestic Beef | - | 0.7162 | 0.8243 | 1.6982 | -1.2790 |
| Domestic Pork | 0.6753 | - | 0.4508 | 1.1216 | 5.0349 |
| Domestic Poultry | 0.6211 | 0.4936 | - | -0.7443 | -0.7049 |
| Import Beef | 0.6166 | 0.6110 | 0.2625 | - | 1.4867 |
| Import Pork | 2.6005 | 2.8057 | 2.5305 | 2.9809 | - |

Table 10: Test of demand restrictions in the LA/AIDS and the GAECM Models

Table (10a): 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 | 2.66 | 27.27 | 23.12 | 3.95 | 10.80 | 63.07 |
| Pr>ChiSq | 0.1030 | <0.0001 | <0.0001 | 0.0470 | 0.0010 | <.0001 |
| | | | | | | |
| **The GAECM model** | | | | | | |
| L.R. statistic | 0.13 | 5.19 | 0.85 | 0.11 | 0.08 | 5.82 |
| Pr>ChiSq | 0.7172 | 0.0227 | 0.3562 | 0.7353 | 0.7824 | 0.3239 |

Table (10b): Paired and system tests for symmetry

| | The LA/AIDS model | | The GAECM model | |
|---|---|---|---|---|
| | L.R. statistic | Pr>Chisq | L.R. statistic | Pr>Chisq |
| B23 = b32 | 1.56 | 0.2118 | 2.48 | 0.1150 |
| B24 = b42 | 5.26 | 0.0219 | <0.01 | 0.9600 |
| B25 = b52 | 0.02 | 0.9017 | 2.89 | 0.0891 |
| B26 = b62 | 0.67 | 0.4118 | 0.29 | 0.5927 |
| B34 = b43 | 5.97 | 0.0146 | 0.29 | 0.5930 |
| B35 = b53 | 0.24 | 0.6214 | 0.84 | 0.3596 |
| B36 = b63 | 0.76 | 0.3838 | 0.22 | 0.6367 |
| B45 = b54 | 0.51 | 0.4769 | 0.37 | 0.5455 |
| B46 = b64 | 0.13 | 0.7200 | 0.07 | 0.7956 |
| B56 = b65 | 3.11 | 0.0777 | 0.22 | 0.6398 |
| System tests For symmetry | 24.38 | 0.0066 | 8.79 | 0.5523 |

Table (11): P-value of the separability tests

| | L.R. statistic | P-value |
|---|---|---|
| **The LA/AIDS Model** | | |
| Separability test in case 1 | 166.3235 | <0.0001 |
| Separability test in case 2 | 20.4685 | 0.0010 |
| Separability test in case 3 | 76.3724 | <0.0001 |
| | | |
| **The GAECM Model** | | |
| Separability test in case 1 | 45.6029 | <0.0001 |
| Separability test in case 2 | 16.8050 | 0.0049 |
| Separability test in case 3 | 30.6787 | <0.0001 |

Case 1: Unrestricted model: No restrictions imposed. Restricted model: homogeneity, symmetry and separability imposed

Case 2: Unrestricted model: No restrictions imposed. Restricted model: separability imposed.

Case 3: Unrestricted model: Homogeneity and symmetry imposed. Restricted model: Homogeneity, symmetry and separability imposed.