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

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Abstract

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 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

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I) 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 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).

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 Almost Ideal Demand System (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.

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. 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 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.

II) Model

The Static AIDS Model

The AIDS model proposed by Deaton and Muellbauer (1980) can be used to test homogeneity, symmetry, and separability restrictions and this 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 ith 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 (1), 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 (1) must satisfy adding up, homogeneity and symmetry restrictions.

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

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 in this study.

Based on an ARDL in Harvey (1993), the ARDL model of the general static AIDS model can be written as:

$$w_{it} = \alpha_i + \sum_{k=1}^{r} \varphi_k w_{it-k} + \sum_{m=0}^{s} \sum_{j} \gamma_{ijm}^{*} \ln(p_j)_{t-m} + \sum_{m=0}^{s} \beta_{im}^{*} \ln(E/P^{*})_{t-k} + \tilde{u}_{it}, \qquad (2)$$

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:

$$\begin{aligned}\Delta w_{it} &= \alpha_i + (\varphi_i - 1) w_{it-1} + \sum_{k=1}^{r-1} \varphi'_{ik} \Delta w_{it-k} + \sum_{j} \gamma_{ij0}^{*} \Delta \ln(p_j)_t + \sum_{j} \gamma_{ij}^{*} (\ln p_j)_{t-1} \\ &+ \sum_{m=1}^{s-1} \sum_{j} \gamma'_{ijm} \Delta \ln(p_j)_{t-m} + \beta_{i0}^{*} \Delta \ln(E/P^{*})_t + \beta_i^{*} \ln(E/P^{*})_{t-1} \\ &+ \sum_{m=1}^{s-1} \beta'_{im} \Delta \ln(E/P^{*})_{t-m} + \tilde{u}_{it}, \qquad (3)\end{aligned}$$

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

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

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

If the contributions from the levels variables in (equation 3) are put together we have:

$$\begin{aligned}&(\varphi_i - 1) w_{it-1} + \alpha_i + \sum_{j} \gamma_{ij}^{*} (\ln p_j)_{t-1} + \beta_i^{*} \ln(E/P^{*})_{t-1} \\ &= (\varphi_i - 1)[w_{it-1} - (\alpha_i^{\circ} + \sum_{j} \gamma_{ij}^{\circ} (\ln p_j)_{t-1} + \beta_i^{\circ} \ln(E/P^{*})_{t-1})]\end{aligned} \qquad (4)$$

The model in equation (3) can be rewritten in the following form after substituting the new form derived in equation (4):

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

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

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

Equation (5) 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 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 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. 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: $\sum_{i=1}^{n} \alpha^{\circ}_i = 1$, $\sum_{i=1}^{n} \gamma^{\circ}_{ij} = 0$, $\sum_{i=1}^{n} \beta^{\circ}_i = 0$, $\Delta w_{it} = 0$, $\sum_{k=1}^{r-1} \varphi'_{ik} = 0$

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

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).

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. Engle suggested the autoregressive conditional heteroskedasticity (ARCH) test used to test heteroscedasticity in time series. All the tests are performed in this paper and are done using a multivariate F-test proposed by Rao (1973).

Separability

The unconditional demands are more appropriate used to obtain elasticities for policy and welfare analysis because group expenditures in conditional demand systems are endogenous (LaFrance, 1991). 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), Blackorby, Davidson and Schworm (1991), and Moschini et al. (1994). Based on their work, the separable restrictions are:

$$\frac{\sigma_{ik}}{\sigma_{jm}} = \frac{\eta_i \eta_k}{\eta_j \eta_m}, \tag{6}$$

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 in the LA/AIDS model.

From equation (7), the restrictions for testing separability depend only on the elasticities of the demand system. Hence, the restrictions in the LA/AIDS model are:

$$\frac{\gamma_{ik} + w_i w_k}{\gamma_{jm} + w_j w_m} = \frac{(w_i + \beta_i)(w_k + \beta_k)}{(w_j + \beta_j)(w_m + \beta_{m)}}, \tag{7}$$

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

III) 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).

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.

IV) Econometric Model

This study considers an unconditional demand system of U.S. food consumption which contains six equations representing the demand for: domestic beef, domestic pork, domestic poultry, imported beef, imported pork, and nonmeat.

The Static Demand Model

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

$$w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln(p_j)_t + \beta_i \ln(E/P^*)_t + e_i \ln ex_t + A_i D_t + u_{it}, \qquad (8)$$

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 which are quarterly dummy, one domestic dummy and two imported dummy variables.

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.

The domestic 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. The two imported 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 with the free trade agreements from the mid-1990s (1996:1-present).

The Dynamic Model

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 and the static AIDS model was estimated and the statistical properties of the residuals analyzed using the ADF test. The ADF of unit root requires estimating the following regression:

$$\Delta y_t = a_0 + by_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + dt + \varepsilon_t \,, \tag{9}$$

where the lag levels (k) are chosen by either AIC or SBC. If all in level-variables are not stationary that would imply that the static AIDS model is inappropriate.

The empirical specification of the GAECM in equation (5) is as follows:

$$\begin{aligned}\Delta w_{it} &= \sum_{k=1}^{r-1} \varphi'_{ik} \Delta w_{it-k} + \sum_j \gamma^*_{ij0} \Delta \ln(p_j)_t + \sum_{m=1}^{s-1} \sum_j \gamma'_{ijm} \Delta \ln(p_j)_{t-m} \\ &+ \beta^*_{i0} \Delta \ln(E/P^*)_t + \sum_{m=1}^{s-1} \beta'_{im} \Delta \ln(E/P^*)_{t-m} + e^*_{i0} \Delta \ln(ex)_t + \sum_{m=1}^{s-1} e'_{im} \Delta \ln(ex)_{t-m} \\ &+ (\varphi_i - 1)[w_{it-1} - (\alpha^\circ_i + \sum_j \gamma^\circ_{ij} (\ln p_j)_{t-1} + \beta^\circ_i \ln(E/P^*)_{t-1} + \\ &\qquad e^\circ_i \ln ex_{t-1} + A^\circ_i D_{t-1})] + \tilde{u}_{it}\end{aligned} \tag{11}$$

Elasticities

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

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

$$U(q) = U^0[q_1, q_2, q_3, q_4, q_5, q_6]. \tag{12}$$

Different types of weakly separable structures can be considered to test against the unrestricted utility function $U(q)$ in equation (12). For example, nonmeat goods can be postulated as weakly separable from meat goods. This structure can be written as:

$$U(q) = U^0[q_1, f(q_2, q_3, q_4, q_5, q_6)]. \tag{13}$$

This structure contains four non-redundant restrictions relative to the unrestricted utility $U(q)$ which follows from our earlier discussion about separability restrictions.

Using eq (7) 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.

V) 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. All systemwise tests rejected the null hypothesis of no misspecification problem ($P<0.10$). 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. 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.

Results from the Static Demand Model

The estimated parameters from the restricted LA/AIDS demand models are utilized to calculate the price, income and Morishima elasticities presented in *Table 2*. 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

The null hypothesis of a unit root in the levels of the variables can not be rejected according to the ADF tests and 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). 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 3*. 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 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. 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 4*. 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.

Tests of Demand and Separability Restriction

The results of tests of the homogeneity and symmetry restrictions in the LA/AIDS and GAECM are presented in *Table 5a* and *Table 5b*. 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 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 5c*. 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.

VI) 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): 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 (3): 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)
λ	-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 (4): 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 5: Tests of demand and separability restrictions in the LA/AIDS and the GAECM Models

Table (5a): 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 (5b): The system tests for symmetry

	The LA/AIDS model		The GAECM model	
	L.R. statistic	Pr>Chisq	L.R. statistic	Pr>Chisq
System tests For symmetry	24.38	0.0066	8.79	0.5523

Table (5c): 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.