Changes in Import Demand Elasticity for Red Meat and Livestock: Measuring the Impacts of Animal Disease and Trade Policy

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Abstract

This paper estimates import demand functions for red meat and live cattle and investigates the impact of BSE and the trade ban on Canadian Cattle and beef on U.S. import demand elasticity using an error correction model (ECM). The results show that beef, pork, and live cattle were price inelastic prior to the BSE case. There has been statistical evidence of the effect of BSE and the trade bans on import demand elasticity in favor of more elastic demand. The effect is, however, quite small in absolute values for pork and beef imports and is relatively more elastic for live cattle. But the import demand elasticities of the three products are still inelastic. The use of ECM model provides efficient and robust estimates of the parameters.

Key words: BSE, elasticity, import demand, red meat and live cattle, trade bans

Introduction

U.S. imports of red meat have steadily increased in recent years and are expected to grow in the future. According to USDA long-term projections, U.S. imports of beef and pork (the two major components of red meat) in 2008 are projected to reach 3.37 billion pounds and 1.04 billion pounds, respectively. Notably, the United States is currently the world's largest importer of beef and is among the top four importers of pork (USDA,; and for several years, the United States has been net importer of red meat. U.S. imports of live cattle have experienced a similar pattern. During the period of 1996 - 2002, U.S. cattle imports increased from 1.97 million to 2.6 million head. The discovery of BSE in 2003 resulted in a trade ban that decreased cattle imports significantly, particularly from Canada. The discovery of BSE not only impacted cattle imports but it also changed the structure of US red meat and livestock trade.

Given the importance of meat and cattle imports in total meat disappearance in the United States, understanding the demand for red meats and livestock and the factors shaping it would clarify the underlying demand parameters affecting this growing market and aid in policy formulation. Understanding the demand and its parameters would be of importance to U.S. meat and livestock producers as well as policy makers in developing effective policies targeted toward increasing producers income and market shares. The main objective of this study is to estimate U.S. import demand functions for red meat (beef and pork) and live cattle and derive elasticities based on the estimated demand functions. The study furthermore aims to measure the impact of animal disease and trade policy on elasticities.

The discovery of bovine spongiform encephalopathy (BSE) has impacted meat and live animal trade and in turn, the structure of meat consumption. Examining the impact of BSE on demand parameters is crucial. Most of previous studies have focused on domestic aggregate consumer demand for red meat (Braschler; Chavas; Moschini and Meilke; Eales and Unnevehr; Brester and a few have investigated U.S. import demand for red meat.

Previous studies strictly assumed that the data used in the analyses were a stationary process such that all traditional econometric theory applied. However, it is argued that not all time series data do exhibit a stationary process. It is argued that performing a regression with these non-stationary data would result in the so-called "spurious regression," which is a serious problem because conventional asymptotic theory cannot be applied (Granger and Newbold, 1974; Maddala and Kim; Banerjee *et al*.). The proposed solution for this problem is to make the non-stationary process into a stationary one through differencing. A number of studies related to demand analysis have used the difference equation (Eales and Unnevehr; Henneberry and Hwang). However, it is also argued that analyzing the data using difference equations alone is not adequate because all information about potential long run relationships between the levels of economic variables is lost (Hendry). Obviously, this approach disregards the potentially important, long run relationships among the levels of the series to which the hypotheses of economic theory are usually taken to apply. The proposed answer to this dilemma is to retain the variables in levels which convey such information. These models are known as error correction models (ECM) (Davidson *et al*.), which is used in this study.

This study contributes significantly to the literature, particularly in import demand analysis for red meat and livestock as it differs from previous studies in several aspects. First, it disaggregates data using HTS-4 digit classification. The use of these data provides relevant parameter estimates since import data are reported in the form of HTS classification. Second, the use of an ECM model has advantages over the models that account only for differences in analyzing non-stationary data and confronts spurious regression. Therefore, the ECM model solves the inference problem when using non-stationary series. Finally, this study uses more recent monthly data from 1992 to 2006, covering the recent discovery of BSE that reshaped red meat and live cattle trade and related policies.

Theoretical and Empirical Models

Error Correction Model

By definition, the term ECM is usually referred to a class of models in which it is explicitly assumed that two or more time series variables stochastically trend together and that deviation from a long run equilibrium condition feed back into short run dynamics so that a long run relation tends to be maintained (Stock).The standard method to derive the error correction model is to show that if x_t and y_t are integrated processes and are co-integrated, the residual of y_t regressed on x_t should be stationary[1]. However, some authors occasionally derive the error correction model from the autoregressive distributed lag (ADL) model through linear transformation. Bårdsen (1989) developed a linear transformation of the ADL for the ECM representation. Following Bårdsen (1989), the general model of the ADL can be written as:

(1) $$y_t = a_0 + Y_{-1}\alpha + \sum_{j=1}^{p} X_j \beta_j + u_t$$

where $Y_{-1} = (y_{t-1}\ y_{t-2}\ ....y_{t-m})$, $\alpha = (\alpha_1\ \alpha_2.......\varepsilon_m)^t$, $X_j = (x_{jt}\ x_{jt-1}.......x_{jt-n})$ and $\beta_j = (\beta_{j0}\ \beta_{j1}.......\beta_{jm})^t$.

Note that the coefficient a_0 represents the constant term, but could also be a vector including other deterministic components such as seasonal dummies and trends. And also note that the number of lags may not be the same, but for the ease of convenience they are treated the same. After performing linear transformations, Bårdsen (1989) comes up with the following equation:

$$(2) \qquad \Delta y_t = \alpha_0 + \sum_{i=1}^{m-1} \alpha_i^* \Delta y_{t-i} + \sum_{j=1}^{p} \sum_{i=0}^{n-1} \beta_{ji}^* \Delta x_{jt-i} + \alpha_m^* y_{t-m} + \sum_{j=1}^{p} \beta_{jn}^* x_{jt-n} + \varepsilon_t$$

where Δ represents the first difference and the number of lags on all x_j are not necessarily equal.

There are no restrictions imposed in (2) such that estimating (1) and (2) will give identical results. However, more is implied in (2) since this equation reveals explicitly the short run dynamics in the form of differenced terms and the long run coefficients. Furthermore, specification (2) may provide a more efficient starting point for conducting a specification search for a parsimonious model under the null hypothesis of an error correction representation of these data generating processes (Bårdsen, 1992).

It is obvious that equation (2) is simply an error correction model (ECM). This can be seen by rewriting (2) in the form of

$$(3) \qquad \Delta y_t = \alpha_0 + \sum_{i=1}^{m-1} \alpha_i^* \Delta y_{t-i} + \sum_{j=1}^{p} \sum_{i=0}^{n-1} \beta_{ji}^* \Delta x_{jt-i} + \alpha_m^* \left[y_{t-m} - \sum_{j=1}^{p} \theta_j x_{jt-n} \right] + \varepsilon_t$$

where the term in brackets is the error correction term and α_m^* is the adjustment coefficient. Bårdsen (1989) further noted that the long run coefficients θ_j are derived from (2) by the following formula

$$(4) \qquad \theta_j = \frac{-\beta_{jn}^*}{\alpha_m^*}.$$

One may notice that the error correction term shown in the brackets does not contain a constant and consequently wonders what if the constant term were inserted into the system. In fact, this is an important point in favor of this model in that the estimated coefficients on the error correction terms are unaffected by the incorporation of any constant (Banerjee *et al*., 1993; p.52).

Equation (2) can be easily and directly estimated using OLS, which gives the short-run dynamics as the coefficients of the differenced terms and the long-run coefficients as the ratios of the level coefficients. It also provides estimated variance of long-run parameters. Given that $\hat{\theta}_j = -\beta^*_{jn} / \alpha^*_m$, the large sample variance of $\hat{\theta}_j$ is given by

$$(5) \qquad \hat{\mathrm{var}}(\hat{\theta}_j) = \left(\frac{\partial \hat{\theta}_j}{\partial \beta^*_{jn}}\right)^2 \hat{\mathrm{var}}(\hat{\beta}^*_{jn}) + \left(\frac{\partial \hat{\theta}_j}{\partial \alpha^*_m}\right)^2 \hat{\mathrm{var}}(\hat{\alpha}^*_m) + 2\left(\frac{\partial \hat{\theta}_j}{\partial \beta^*_{jn}}\right)\left(\frac{\partial \hat{\theta}_j}{\partial \alpha^*_m}\right) \mathrm{cov}(\hat{\beta}^*_{jn}, \hat{\alpha}^*_m)\,.$$

Equation (5) is equivalent to

$$(6) \qquad \hat{\mathrm{var}}(\hat{\theta}_j) = \left(\hat{\alpha}^*_m\right)^{-2}\left[\hat{\mathrm{var}}(\hat{\beta}^*_{jn}) + (\hat{\theta}_j)^2\, \hat{\mathrm{var}}(\hat{\alpha}^*_m) + 2\hat{\theta}_j\, \hat{\mathrm{cov}}(\hat{\beta}^*_{jn}, \hat{\alpha}^*_m)\right].$$

Empirical Model

Three imported products are analyzed in this study: Fresh beef (HTS 0201), Pork (HTS 0203), and live cattle (HTS 0102). The import demand functions are specified based on the common demand theory where quantity demand is hypothesized to be a function of own price, substitute product prices, and other demand shifters such as income. The import demand for pork and beef are expressed as a function of own price, domestic beef price, domestic pork price, chicken price, income, and domestic production of associated products. Cattle imports are specified as a function of own price, prices of imported and domestic beef, cattle on feed, and income. Price of imported beef is included to measure substitutability between imported cattle and imported beef. The models include monthly dummy variables to account for seasonality in consumption, production, and shipping.

One of the main features of this study is to measure possible changes in import demand elasticity due to, particularly, animal diseases and trade policy. The discovery of BSE in May

2003 in Canada has reshaped beef and cattle trade. The United States, for example, banned imported cattle from Canada. Although the ban was later eliminated, the impacts of the BSE are hypothesized to carry over for a period of time. Therefore, it is plausible to model the demand function that allows elasticity to vary with the BSE discovery.

This model is represented using a dummy variable and can be illustrated using a simple demand function: $q = \alpha + \beta p$, where q is quantity demand and p is own price. If q and p are in logarithmic values, then β represents demand elasticity. Allowing elasticity to vary over time using a dummy variable, the above demand function can be specified as: $q = \alpha + \beta p + \delta DP$, where DP is a multiplicative variable of dummy variable and own price. In this case, the demand elasticity becomes $\lambda = \beta + \delta D$, where $\lambda = \beta$ indicates demand elasticity prior to the BSE discovery and $\lambda = \beta + \delta D$ represents elasticity after the BSE discovery or the period where D takes the value of 1.

In this study, D is a structural dummy variable which takes a value of zero prior to BSE discovery and one since the BSE discovery. For the pork and beef equations, the cutoff point for the BSE dummy variable is May 2003. Therefore, D takes the value of 1 if observations fall after May 2003 and 0 otherwise. For the cattle equation, the dummy variable is more restrictive in that D takes the value of 1 if observations fall in the period of May 2003 to August 2005. This is because after August 2005, U.S. cattle imports seem to rebound to the level of that prior to the BSE discovery.

Invoking the ECM of the Bårdsen transformation, the three import demand equations can be written as follows (See Table 1 for variable definitions):

Pork Equation

$$
\begin{aligned}
(7)\quad \Delta Q_{pmt} &= \alpha_{pm0} + \sum_{i=1}^{11}\alpha_{d,i}D_{t,i} + \sum_{i=1}^{k-1}\alpha_{pmq,i}\Delta Q_{pm,t-i} + \sum_{i=0}^{k-1}\alpha_{pm,i}\Delta P_{pm,t-i} + \sum_{i=0}^{k-1}\alpha_{bd,i}\Delta P_{bd,t-i} \\
&+ \sum_{i=0}^{k-1}\alpha_{pd,i}\Delta P_{pd,t-i} + \sum_{i=0}^{k-1}\alpha_{cd,i}P_{cd,t-i} + \sum_{i=0}^{k-1}\alpha_{bpm,i}BP_{pm,t-i} + \sum_{i=0}^{k-1}\alpha_{qpd,i}Q_{qpd,t-k} + \sum_{i=0}^{k-1}\alpha_{g,i}G_{t-i} \\
&+ \delta^{*}_{pm}\begin{bmatrix} Q_{pm,t-k} - \theta_{pm}P_{pm,t-k} - \theta_{bd}P_{bd,t-k} - \theta_{pd}P_{pd,t-k} - \theta_{cd}P_{cd,t-k} \\ -\theta_{bpm}BP_{pm,t-k} - \theta_{qpd}Q_{qpd,t-k} - \theta_{g}G_{t-k} \end{bmatrix} + \varepsilon_{pmt}
\end{aligned}
$$

Beef Equation

$$
\begin{aligned}
(8)\quad \Delta Q_{bmt} &= \alpha_{bm0} + \sum_{i=1}^{11}\alpha_{d,i}D_{t,i} + \sum_{i=1}^{k-1}\alpha_{bmq,i}\Delta Q_{bm,t-i} + \sum_{i=0}^{k-1}\alpha_{bm,i}\Delta P_{bm,t-i} + \sum_{i=0}^{k-1}\alpha_{bd,i}\Delta P_{bd,t-i} \\
&+ \sum_{i=0}^{k-1}\alpha_{pd,i}\Delta P_{pd,t-i} + \sum_{i=0}^{k-1}\alpha_{cd,i}P_{cd,t-i} + \sum_{i=0}^{k-1}\alpha_{bbm,i}BP_{bm,t-i} + \sum_{i=0}^{k-1}\alpha_{qbd,i}Q_{qbd,t-i} + \sum_{i=0}^{k-1}\alpha_{g,i}G_{t-i} \\
&+ \delta^{*}_{bm}\begin{bmatrix} Q_{bm,t-k} - \theta_{bm}P_{bm,t-k} - \theta_{bd}P_{bd,t-k} - \theta_{pd}P_{pd,t-k} - \theta_{cd}P_{cd,t-k} - \theta_{bbm}BP_{bm,t-k} \\ -\theta_{qbd}Q_{qbd,t-k} - \theta_{g}G_{t-k} \end{bmatrix} + \varepsilon_{bmt}
\end{aligned}
$$

Cattle Equation

$$
\begin{aligned}
(9)\quad \Delta Q_{cmt} &= \alpha_{cm0} + \sum_{i=1}^{11}\alpha_{d,i}D_{t,i} + \sum_{i=1}^{k-1}\alpha_{cmq,i}\Delta Q_{cm,t-i} + \sum_{i=0}^{k-1}\alpha_{cm,i}\Delta P_{cm,t-i} + \sum_{i=0}^{k-1}\alpha_{bd,i}\Delta P_{bd,t-i} \\
&+ \sum_{i=0}^{k-1}\alpha_{bm,i}\Delta P_{bm,t-i} + \sum_{i=0}^{k-1}\alpha_{bcm,i}BP_{cm,t-i} + \sum_{i=0}^{k-1}\alpha_{cof,i}Q_{cof,t-i} + \sum_{i=0}^{k-1}\alpha_{g,i}G_{t-i} \\
&+ \delta^{*}_{cm}\begin{bmatrix} Q_{cm,t-k} - \theta_{cm}P_{cm,t-k} - \theta_{bd}P_{bd,t-k} - \theta_{bm}P_{bm,t-k} - \theta_{bcm}BP_{cm,t-k} \\ -\theta_{cof}Q_{cof,t-k} - \theta_{g}G_{t-k} \end{bmatrix} + \varepsilon_{cmt}
\end{aligned}
$$

[Insert Table 1 Approximately Here]

Equations (7), (8), and (9) show the dynamic model of the import demand functions for pork, beef, and cattle, respectively. The summations capture the short-run dynamics and all parameters of the summations indicate the short-run parameters. The inclusion of the lagged dependent variable is to account for habit formation, which is usually important in demand specification. The terms in brackets represent the ECM term, which provides the stationary long-run solution. For example, θ_{pm} in (7) measures the stationary long-run impact of pork import price (P_{pm}) on pork imports (Q_{pmt}). δ^{*}_{pm} is the coefficient of adjustment that measures the impact on ΔQ_{pmt} of being away from the long-run target.

Testing the Order of Integration and Co-integration Relation

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were used for determining the order of integration of the variables under consideration. The lag length was chosen based on Akaike Information Criteria (AIC) and Schwarz Bayesian Criteria (BIC), and the sequential testing of the coefficient of the last lag (general to specific criteria). If two of these comply with each other, the corresponding lag length was chosen. If there is no compliance among them, the choice is made according to the one that gives the longest lag length.

Results of the unit root tests are given in Table 2. For the levels of the series, the ADF test suggests that none rejects the null hypothesis of nonstationarity at a reasonable level of significance. On the other hand, the PP test shows that two of the series reject the null hypothesis of nonstationarity. After first differencing, each series rejects the null hypothesis of nonstationarity at the 1 percent level of significance. Hence, based on the ADF and PP tests, it is concluded that all the variables used in the study are integrated with the order of one, or *I(1)* and thus the summations of first differences capturing the short-run dynamics in equations (7), (8), and (9) are stationary.

[Insert Table 2 Approximately Here]

In order to ensure the existence of long run solutions, the co-integration test was performed using the multivariate co-integration test of Johansen and Juselius (Johansen, 1988; Johansen and Juselius, 1990) on each of the three equations. There are two different test statistics to determine whether co-integration relations exist, namely the trace test (λ_{Trace}) and the maximum eigenvalue test (λ_{Max}). The critical values for co-integration tests are taken from Mackinon *et al*., Table IV for Case III[2]. The results shown in Table 3 suggest a clear indication of co-integration in all cases. The trace and maximum eigenvalue statistics equivocally confirm the existence of one, three, and two co-integration vectors in the pork, beef, and cattle equations, respectively. Hence, the linear combinations in the ECM parentheses in equations (7), (8), and (9) represent co-integration relations and thus can be interpreted as stationary long run solutions.

[Insert Table 3 Approximately Here]

Regression Results

The models in (7), (8), and (9) were estimated using monthly data from 1992 to 2006. The data were obtained from Foreign Agricultural Services and National Agricultural service of USDA, U.S. Bureau of Economics Analysis, and U.S. Bureau of Labor Statistics. Definitions of variables are given in Table 1.

A series of missispecification tests were employed as a check on the validity of the import demand functions, where their parameter estimates and diagnostic statistics are presented in the bottom portion of Tables 4, 5, and 6. The ARCH (q,T-k-2q) is the LM test of the q^{th} order serial correlation and autoregressive conditional heteroscedasticity introduced by Engle (1982). As shown in the bottom of each table, the null hypothesis of no serial correlation and homoscedasticity can not be rejected at the 1% level in each case. Tests for higher orders of q (not reported) also suggest similar conclusions. NORM is the Jarque–Bera normality test (Jarque and Bera) of the residuals. The test is distributed as $\chi^2_{(2)}$. The statistic of NORM shows that the hypothesis of normality can not be rejected at the 5% level. The possibility of autocorrelation was checked using both the D-W statistics. The statistics indicate that autocorrelation is not a problem for the specified model.

A check of the regression (correct) specification developed by Ramsey, called RESET test was also conducted. The procedure is performed by testing the relevance of adding the squared predicted values to the original model. The RESET test shows no evidence of functional form misspecification at the 1% level. The lag length was decided based on the procedure suggested by Bardsen (1989) as well as the information criteria (BIC and AIC). The lags of four in the cattle equation, five in the pork equation, and six in the beef equation were found to be sufficient to account for residual autocorrelation. Based on overall tests, one may conclude that the estimated demand functions for pork, beef, and cattle satisfy all the diagnostic tests and provide generally plausible estimates.

Tables 4, 5, and 6 present empirical estimates for the pork, beef, and cattle equations, respectively. Due to the large number of parameter estimates, estimates for short run dynamics and monthly dummy variables are not presented. Instead, empirical estimates are reported for the long run variables from which economic variables are usually derived and selected short run elasticity estimates that are derived from the short run parameters. In term of short run parameter estimates, in general, the results show that about 40%, 46%, and 52% of short run parameter estimates were significant in the pork, cattle, and beef equations, respectively. All the lagged values of the dependent variables have negative signs and are significant and their values are less than one, as expected.

Concerning economic interpretations, the demand functions as reported in Tables 4, 5, and 6 are basically similar to the regular demand. The difference is that they constitute both long run and short run estimates. The short run parameters are indicated by the variables in differences (not reported) and the long run parameters are represented by the variables in levels. The values can be interpreted directly since the model was estimated assuming m = n in equation (2). That is if there is a change in a particular variable, the effect on quantity demanded is determined by the magnitude of the corresponding parameter.

Pork Equation

As shown in Table 4, all variables in the pork equation are significant at either 1% or 5% significant level, except for domestic pork price, with the coefficient of determination of 0.72. The coefficient of adjustment is -0.698 and significant at the 5% level. This value indicates that there is an adjustment of 70% after deviations from the long run equilibrium.

[Insert Table 4 Approximately Here]

The long run coefficients θ_j show long run elasticity estimates. Prior to the BSE discovery, the own long run price elasticity of pork imports was found to be inelastic with the magnitude of -0.91. The short run elasticity was also inelastic but the magnitude was smaller: -0.50. The interaction term of the BSE dummy variable and pork price shows the effects of the BSE on elasticity. As can be seen in Table 4, the long run parameter estimates of interaction term (θ_{bpm}) is -0.062 and significant. This suggests that the long run elasticity of pork imports after the BSE discovery is more elastic with the magnitude of -0.97. One should note that although the parameter is statistically significant, the absolute impact is quite small. In the short run, the impact of BSE is not significant and the sign is positive and low in magnitude of 0.02.

Domestic beef and chicken were found to be substitute products for pork imports. The parameter estimates are significant with the magnitudes of 1.58 and 0.78 for domestic beef and chicken, respectively. A negative parameter of domestic pork price, which does not necessarily imply the good is not a substitute, is difficult to justify since the parameter is not significant at any reasonable level. The parameter estimate for domestic pork production is negative as expected and significant, suggesting that pork imports adjust in a different direction as there is a change in domestic pork production. The results found that pork imports are income elastic with the magnitude of 3.13.

Beef Equation

Regression results for the beef equation are provided in Table 5. In terms of parameter estimates, five of the seven coefficients are significant. The adjustment coefficient is negative as expected. This value is –0.49, indicating that in the short-run, agents increase (decrease) their quantity imported by 49% of the last period's excess demand for beef imports. The long run price elasticity prior to the BSE discovery was -0.74 and significant. The short price elasticity, on the other, had a positive sign with the magnitude of 0.26; but it is not significant at any reasonable level. The parameter estimates of the interaction term of the BSE dummy variable and the price of beef imports are significant and negative, suggesting that beef imports are more elastic after the discovery of the BSE. Similar to pork imports, the impact of BSE on elasticity is small in magnitude at 0.04. Thus the long run price elasticity after the BSE discovery for beef imports is -0.78. Parameter estimates for domestic pork and chicken prices are positive and significant, suggesting that these two products are substitutes for beef imports. The cross price elasticities for domestic pork and chicken are 0.97 and 2.04, respectively. Relatively high cross price elasticity of beef imports to chicken indicates consumer's preferences of white meat over red meat.

[Insert Table 5 Approximately Here]

Parameter estimates of domestic beef price and domestic beef production show the expected signs; but they are not significant. As shown in Table 5, cross price elasticity of beef imports to domestic beef price is 0.35 and the elasticity adjustment of beef imports to domestic beef production is -0.23. Beef imports are income elastic at 4.32.

Cattle Equation

The estimated results of the cattle equation, reported in Table 6, show that three out of six long run parameters are significant. The lack of statistical insignificance for imported beef price, cattle on feed, and income is partly due to the dominance effects of BSE on cattle imports. As BSE was discovered in 2003, the United States banned US cattle imports, particularly from Canada. The US government later eliminated the ban and cattle imports resumed in August 2005. This can be observed from the coefficient of the interaction term between BSE dummy variable and cattle price. As can be seen, this coefficient is -0.20, which is far larger in absolute value compared with those given in beef and pork import equations. The long run price elasticity for cattle imports before the BSE discovery is -0.76 and it is -0.96 during the BSE or the ban period. The estimated short run price elasticity before the BSE is -0.11 but the coefficient is not significant.

The coefficient of adjustment is -0.659, indicating that in the short run there is an adjustment of 66% after deviation from the long run equilibrium. Domestic beef is found to be a substitute product for cattle imports with the cross price elasticity of 1.95. The coefficient of beef import price is negative, but it is not significant. Therefore, there is no clear indication what is the relationship between beef imports and cattle imports. Parameter estimates of cattle on feed and income have contrary signs, but they are not significant at any reasonable level.

[Insert Table 6 Approximately Here]

Concluding Remarks

The purpose of this study was to estimate U.S. import demand functions for red meat and live cattle using a dynamic econometric model in the form of error correction model (ECM) and derive elasticities based on the estimated demand functions. The main feature of this study is that it accounts for the properties of the series in the model, which is structured in the ECM framework. By applying an ECM, this study has an advantage over the previous studies because it incorporates the time series properties and hence eliminate the doubt of spurious regression. Therefore, the estimated models provide more efficient and robust estimates. Furthermore, this analysis also accounts for short run deviations from long-run equilibrium and yields estimates of elasticities in both the short run and long run.

Prior to the BSE discovery, estimates of own-price elasticities indicate that pork and beef imports were price inelastic with magnitudes of -0.91 and -0.74, respectively. The results show statistical evidence of the effects of BSE on elasticities, but the magnitudes are quite small. After BSE, import demand elasticities for pork and beef were found to be -0.97 and -0.82, respectively. Cattle imports are also found to be price inelastic at-0.66, before the BSE discovery. The effect of BSE and the trade ban seems to be higher than the previous cases. After BSE, import demand for live cattle was found to be -0.86, a 0.20 point increase in absolute value. It is worth pointing that the more elastic import demand after the BSE discovery may not be affected by BSE or trade ban alone. There might be other factors contributing to the change in elasticity estimates. Disentangling such factors from each other requires more detailed analysis.

The results suggest that domestic beef and chicken are substitutes for pork imports. Similarly, domestic pork and chicken are also substitutes for beef imports. There is no statistical evidence to determine the relationships between domestic pork and pork imports and domestic beef and beef imports. Domestic beef appears to be a substitute product cattle imports. But such a conclusion should be cautioned considering the nature of the two products. Both beef and pork imports are income elastic. The income parameter for cattle imports is not significant and negative.

Endnotes

[1] The basic idea behind co-integration is that if each element of a vector time series X_t achieves stationary after differencing, and if a linear combination $\alpha' X_t$ is stationary, then X_t is said to be co-integrated with co-integrating vector α . Since $\alpha' X_t$ is stationary, it will always manifest a tendency to revert to its (zero) mean, that is $\alpha' X_t = 0$; therefore there will exist a tendency to return to long run equilibrium. Engle and Granger interpret $\alpha' X_t = 0$ as the long run equilibrium relationship between the elements of X_t (Granger, 1981; Engle and Granger, 1987).

[2] Table of critical values of these two tests have been computed, in particular Johansen and Juselius (1990), Osterwald-Lenum, Johansen (1995), Mackinon, Haug, and Michelis, and Pesaran, Shin, and Smith. The Mackinon's critical values that are based on response surface regression are confirmed to be much more accurate than any published previously. Note that Pesaran's Tables were previously appeared in working paper's edition in 1999.

Table 1. Variable Definitions for the Import Demand Models

Symbol	Definition	Mean	Standard Deviation
Q_{pm}	Quantity of pork imports – HTS 0203 (million pounds)	50.79	15.37
Q_{bm}	Quantity of beef imports – HTS 0201 (million pounds)	52.58	18.69
Q_{cm}	Quantity of cattle imports – HTS 0102 (heads)	177800	60459
Q_{qpd}	U.S. domestic pork production (million pounds)	1453	110
Q_{qbd}	U.S. domestic beef production (million pounds)	1112	100
Q_{cof}	U.S. number of cattle on feed (thousand heads)	9975	1334
P_{pm}	Price of pork imports (cents per pound)	60.75	7.78
P_{bm}	Price of beef imports (cents per pound)	78.09	11.67
P_{cm}	Price of cattle imports (US $ per head)	330.77	70.63
P_{bd}	Price of domestic beef (cents per pound)	190.49	14.69
P_{pd}	Price of domestic pork (cents per pound)	146.14	5.50
P_{cd}	Price of young composite chicken (cents per pound)	92.37	5.72
G	U.S. personal consumption expenditures (billion dollars)	3757	502

Prices for imported products are unit values. All prices and income are in real values, deflated using CPI. Data are monthly series from 1992 to 2006.

Table 2. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests for Integration Order

Variable	ADF		PP	
	I(0)	I(1)	I(0)	I(1)
Imported products				
Q_{pm} : Pork imports	-1.749	-23.122***	-2.898	-23.122***
Q_{bm} : Beef Imports	-2.109	-11.373***	-2.992	-14.479***
Q_{cm} : Cattle Imports	-3.127	-5.919***	-2.272	-13.887***
Q_{cof} : Cattle on Feed	-1.104	-4.055***	-1.347	-9.808***
Prices				
P_{pm} : Pork imports	-2.115	-15.596***	-2.351	-15.596***
P_{bm} : Beef imports	-2.680	-15.809***	-2.680	-15.809***
P_{cm} : Cattle Imports	-2.239	-4.133***	-2.262	-14.825***
P_{bd} : Domestic beef	-1.765	-10.894***	-1.713	-11.325***
P_{pd} : Domestic pork	-1.557	-12.875***	-2.093	-12.875***
P_{cd} : Chicken	-1.247	-17.875***	-1.312	-18.102***
Other Variables				
Q_{qpd} : Pork Production	-1.076	-3.467**	-4.962**	-24.615***
Q_{qbd} : Beef Production	-2.336	-5.484***	-7.291**	-29.047***
G : Income	1.440	-18.29***	1.376	-18.292***

Note: 1. All prices and income are in real values and all variables are in log values.
2. Test statistics for PP test are for estimated *rho*.
3. ** and *** indicates significant at 5% and 1%, respectively.

Table 3. Multivariate Co-integration Tests of the Variables in the Import Demand Functions

Hypothesis	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r \leq 4$	$r \leq 5$
95% Quantiles						
$\lambda Trace$	160.87	127.05	97.26	71.44	49.64	31.88
$\lambda \max$	52.41	46.31	40.19	34.03	27.80	21.49
Pork Import Equation						
Eigenvalue	0.327	0.190	0.181	0.095	0.076	0.041
$\lambda Trace$ statistics	**184.8**	115.6	78.72	43.84	26.35	12.47
$\lambda \max$ Statistics	**69.2**	36.9	34.88	17.49	13.87	7.35
Beef Import Equation						
Eigenvalue	0.563	0.312	0.276	0.141	0.094	0.044
$\lambda Trace$ statistics	**319.9**	**175.9**	**110.8**	54.68	28.33	11.20
$\lambda \max$ Statistics	**144.0**	**65.1**	**56.1**	26.35	17.12	7.92
Cattle Import Equation						
Eigenvalue	0.349	0.223	0.175	0.111	0.044	0.031
$\lambda Trace$ statistics	**188.7**	**113.1**	68.65	34.84	14.21	6.23
$\lambda \max$ Statistics	**75.7**	**44.5**	33.82	20.63	7.97	5.61

The Statistics of trace and $\lambda \max$ (maximum eigenvalue) are defined in Johansen (1988) and Johansen and Juselius (1990). The number of variables in pork and beef equations is 8 and in the cattle equation 7. Therefore the right critical values for $r = 0$ in the cattle equation should be replaced by $r \leq 1$, and so forth. The statistics in bold are significant at the 5% level.

Table 4. OLS Estimates of Import Demand Function for Pork

Variable	Parameter Estimates	Standard Error
Quantity: $Q_{pm,t-5}$	-0.6975	0.1154***
Pork Price: $P_{pm,t-5}$	-0.6379	0.1423***
Beef Price: $P_{bd,t-5}$	1.1047	0.2403***
Pork Price: $P_{pd,t-5}$	-0.1863	0.3185
Chicken Price: $P_{cd,t-5}$	0.5464	0.2711**
Pork Price x D: $BP_{pm,t-5}$	-0.0432	0.0133***
Dom. Pork Prod.: $Q_{qpd,t-5}$	-1.1815	0.4794**
Income: G_{t-5}	2.1834	0.4654***
Long Run Parameters		
θ_{pm}	-0.9145	0.1509***
θ_{bd}	1.5837	0.2066***
θ_{pd}	-0.2671	0.4543
θ_{cd}	0.7834	0.3689**
θ_{bpm}	-0.0619	0.0163***
θ_{qpd}	-1.6939	0.6251***
θ_{g}	3.1303	0.4205***
Diagnostic Statistics[a]		
R^2 = 0.7176; RESET = 1.9184(0.1687); D-W = 1.9193 (0.1929)		
NORM: $\chi^2(2)$ = 5.4634 (0.0651); ARCH = 0.1444 (0.7039)		

** and *** are significant at 5% and 1%, respectively. [a]Numbers in parentheses are probability of rejecting the null hypothesis.

Table 5. OLS Estimates of Import Demand Function for Beef

Variable	Parameter Estimates	Standard Error
Quantity: $Q_{bm,t-6}$	-0.4908	0.1173***
Beef Import Price: $P_{bm,t-6}$	-0.3656	0.1383**
Beef Domestic Price: $P_{bd,t-6}$	0.1699	0.3102
Pork Domestic Price: $P_{pd,t-6}$	0.4782	0.2672*
Chicken Price: $P_{cd,t-6}$	1.0001	0.3831*
Beef Import Price x D: $BP_{bm,t-6}$	-0.0390	0.0192**
Dom. Beef Prod.: $Q_{qbd,t-6}$	-0.1121	0.6030
Income: G_t	2.1221	0.6703**
Long Run Parameters		
θ_{bm}	-0.7449	0.2725***
θ_{bd}	0.3462	0.6591
θ_{pd}	0.9743	0.5756*
θ_{cd}	2.0376	0.5576***
θ_{bbm}	-0.0795	0.0309**
θ_{qbd}	-0.2284	1.2135
θ_{g}	4.3237	0.6503***
Diagnostic Statistics[a]		
R^2 = 0.9350; RESET = 0.0250(0.8748); D-W = 1.9950 (0.3372);		
NORM: χ^2 (2) = 2.1741 (0.3372); ARCH = 0.4867 (0.4854)		

*, **, and *** are significant at 10%, 5%, and 1%, respectively. [a]Numbers in parentheses are probability of rejecting the null hypothesis.

Table 6. OLS Estimates of Import Demand Function for Cattle

Variable	Parameter Estimates	Standard Error
Quantity: $Q_{cm,t-4}$	-0.6592	0.1051***
Cattle Price: $P_{cm,t-4}$	-0.5014	0.2392**
Domestic Beef Price: $P_{bd,t-4}$	1.2868	0.4631***
Imported Beef Price: $P_{bm,t-4}$	-0.2354	0.2084
Cattle Price x D: $BP_{cm,t-4}$	-0.1324	0.0307***
Cattle on Feed: $Q_{cof,t-4}$	0.2422	0.3410
Income: G_{t-4}	-0.2760	0.3250
Long Run Parameters		
θ_{cm}	-0.7606	0.3538***
θ_{bd}	1.9521	0.6117***
θ_{bm}	-0.3571	0.3055
θ_{bpm}	-0.2008	0.0368***
θ_{cof}	0.3674	0.5113
θ_{g}	-0.4186	0.4885
Diagnostic Statistics[a]		
R^2 = 0.7919; RESET = 1.9826(0.1615); D-W = 1.9290 (0.1987);		
NORM: $\chi^2(2)$ = 0.5025 (0.7778); ARCH = 0.0064 (0.9361)		

** and *** are significant at 5% and 1%, respectively. [a]Numbers in parentheses are probability of rejecting the null hypothesis.

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