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Welfare Impacts of BSE-Driven Trade Bans

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There is often a need to respond quickly to assess the likely implications of policy changes. Here, an equilibrium displacement model is adapted to study international bans on U.S. beef. An equilibrium displacement model offers a convenient way of quickly predicting the effects of supply and demand shocks. The equilibrium displacement model used here has an international sector, which allows the study of issues that past models with only a domestic sector could not. The estimated welfare loss of U.S. beef producers, due to both Japanese and South Korean bans after the discovery of bovine spongiform encephalopathy (BSE) in the United States, is \$565.31 million.

Key Words: equilibrium displacement, international trade, meat, trade ban, welfare

In 2003, Japan and South Korea banned U.S. beef after the discovery of bovine spongiform encephalopathy (BSE) in the United States. Before the ban, about 3 percent of U.S. beef production went to Japan and 2 percent to South Korea. Marsh, Brester, and Smith (2007), as well as Mattson, Jin, and Koo (2005), studied this event by looking backward and determining what happened using econometric methods. Alternatively, Jin, Skripnitchenko, and Koo (2004) tried to predict the effects of the ban immediately after it occurred. We propose an alternative to the Jin, Skripnitchenko, and Koo (2004) approach. The purpose of this paper is to adapt an equilibrium displacement model to consider trade bans. The Japanese and South Korean trade bans are selected for study.

The equilibrium displacement model can consider the possibility of U.S. exports increasing elsewhere as Japan and South Korea purchase from U.S. competitors. The equilibrium displacement model used is source-differentiated so that a ban on

a specific country's imports can be considered. There have been several similar past models of the U.S. meat market (Wohlgenant 1993, Kinnucan, Xiao, and Hsia 1996, Brorsen et al. 2002, Brester, Marsh, and Atwood 2004, Lusk and Anderson 2004). None of the past models differentiated meats by place of origin, and most did not consider international trade. In most of these past studies, imported meats were ignored. If included, these meats were not differentiated by source of origin, and U.S. meat export markets were not considered. As a result, none of these previous models could evaluate the welfare impacts of nontariff trade barriers, such as meat bans, on U.S. producers and retailers.

The Equilibrium Displacement Model

The structural specification of supply and demand relationships of meats (beef, pork, and poultry) provides the framework for an equilibrium displacement model (Wohlgenant 1993). The model used in this study includes U.S. domestically produced meats and U.S. meat imports from major countries [Australia, Canada, New Zealand, and the rest of the world (ROW)] plus U.S. meat exports to major countries (Canada, Japan, Mexico, and South Korea). The meat model specified here includes two distinct sectors: retail (consumer) and farm

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(producer). In addition, on the retail demand side, the model considers relationships (substitution and complementary relationships) between U.S. produced meats and meats from other supply sources in the U.S. domestic and export markets.

An equilibrium displacement model is based on certain theoretical assumptions (Wohlgemant 1993). For this study, these assumptions include: (a) all supply and demand curves are linear; (b) any shifts in supply and demand curves are parallel; (c) fixed proportion production technology exists at the processors-retailers' market level (fixed proportion technology means that the elasticity of substitution between marketing inputs and farm products at the processors-retailers' market level is zero); and (d) substitution and complementary relationships are modeled on the demand side but not on the supply side. The model does not allow for production relationships (substitutes and complements) among the included meats because it assumes that specialized inputs and different production technologies are used in the production of each meat type. MacDonald et al. (1996) find that the meat industry has high specialization in production, so the last assumption seems reasonable.

Our explanation of the equilibrium displacement begins with the meat demand equation with its shifter:

$$(1) \quad Q_{ijk}^{d*} = \eta P_k^{d*} - \varpi_{ik}$$

where Q_{ijk}^{d*} is the percentage change in the quantity of meat of type i from country j demanded in country k . The subscript i denotes meat type and $i = 1, \dots, I$. The subscript j denotes the country of origin of meat type i (the supply source of meat of type i demanded in country k) and $j = 1, \dots, J$. The source-differentiated meat of type i is called a meat product. The subscript k denotes the consuming country (countries in which meat i from country j is demanded). The k destinations are: the United States, Canada, Japan, Mexico, and South Korea. These destinations account for over 90 percent of U.S. produced meat sales. P_k^{d*} is the percentage change in a vector of demand prices for source-differentiated meats in country k ; the star (*) represents the percentage change operator, so that $Q_{ijk}^{d*} = dQ_{ijk}^d / Q_{ijk}^d = d \ln(Q_{ijk}^d)$; η represents a vector of own-price and cross-price demand elasticities for meats demanded in country k ; and ϖ_{ik} is a

vector of demand shifters of meat i demanded in country k .

The meat supply equation with its shifter is presented as:

$$(2) \quad Q_{ij}^{s*} = \varepsilon_{ij} P_{ij}^{s*} + \gamma_{ij}$$

where Q_{ij}^{s*} is the percentage change in the total quantity of meat of type i , supplied by country j . The j suppliers are the United States, Canada, Japan, Mexico, South Korea, Brazil, Australia, New Zealand, Denmark, China, Thailand, and the ROW. The included supply sources have at least 10 percent of the total volume of imports of the selected meats in each of the k destination countries. Note that for each type of meat, the j suppliers vary across the k destinations. Additionally, in our model, certain suppliers are assumed to also be meat consumers (where $j = k$; i.e., the United States, Canada, Mexico, Japan, and South Korea), while other countries are only suppliers (where $j \neq k$; i.e., Brazil, Australia, New Zealand, Denmark, China, Thailand, and the ROW). P_{ij}^{s*} is the percentage change in farm-level supply price of meat i from country j , for countries that are considered as both meat suppliers and meat buyers ($j = k$); while it is the percentage change in export price of meat i from country j , for countries that are only considered as meat suppliers ($j \neq k$). ε_{ij} is the own-price farm supply elasticity of meat i from country j , for the countries that are considered as both meat suppliers and buyers ($j = k$); while it is the excess supply elasticity of meat i from country j , for the countries that are only considered as meat suppliers ($j \neq k$). γ_{ij} is the supply shifter of meat i from country j .

The market-clearing conditions are given by the respective quantity and price equilibrium conditions. For meat exporters, the quantity clearing equation is given as

$$(3) \quad Q_{ij}^{s*} = \tau_{ij} Q_{ij}^{d*} + \sum_{k \neq j}^K \lambda_{ijk} Q_{ijk}^{d*}$$

where Q_{ij}^{s*} is as previously defined; Q_{ij}^{d*} is the percentage change in the quantity of meat i from country j that is demanded in the supplying country j (from its own domestically produced source); Q_{ijk}^{d*}

is the percentage change in the quantity of meat i from country j that is demanded in country k (exported by country j to country k or foreign demand); $\tau_{ijj} = Q_{ijj}^d / Q_{ij}^s$ and it is the ratio between the quantity of meat i from country j that is demanded in the supplying country j (Q_{ijj}^d , demand for own product) and the total quantity supplied of meat i by country j (Q_{ij}^s); $\lambda_{ijk} = Q_{ijk}^d / Q_{ij}^s$, and it is the ratio between the quantity of meat i from country j that is demanded in the importing country k (Q_{ijk}^d , export demand) and the total quantity of meat i supplied by country j (Q_{ij}^s).

For meat importers, the quantity clearing equation is given as:

$$(4) \quad Q_{ijk}^{s*} = Q_{ijk}^{d*}.$$

Q_{ijk}^{s*} is the percentage change in the quantity of meat of type i supplied from country j to the consuming country k . The percentage change in the quantity supplied, Q_{ijk}^{s*} , and the quantity demanded, Q_{ijk}^{d*} , corresponds to the domestically produced meats and foreign-produced meats when $j = k$ and $j \neq k$, respectively.

Given the farm supply and retail demand equations, the retail demand and farm supply equations can be linked with retail-farm price equations to ensure equilibrium across the two vertical channels. The retail-farm price linkage equations are:

$$(5) \quad P_{ijk}^{d*} = P_{ij}^{s*} \delta_{ijk} - v_{ijk}$$

where P_{ijk}^{d*} is the percentage change in the retail consumer price of meat i from country j , demanded in country k ; P_{ij}^{s*} is as previously defined; v_{ijk} is the retailer supply shifter of meat i from country j demanded in country k ; and $\delta_{ijk} = P_{ij}^s / P_{ijk}^d$ is the ratio between the supply price of meat i from country j and the demand price of meat i from country j , demanded in country k .

Model Parameters

An equilibrium displacement model is a synthetic model in that it uses parameter values from previous studies. The model parameters include: own-price and cross-price demand elasticities (η); own-price and excess supply elasticities (ϵ); quantity proportions (τ and λ); and price proportions (δ).

The own-price and cross-price demand elasticities (η) are estimated by Mutondo and Henneberry (2006, 2007) using a restricted source-differentiated almost ideal demand system (RSDAIDS). Their estimates are used except for the cross-price elasticities between U.S. beef and Australian beef and between Australian and U.S. beef, where we used 0.123 and 0.253 instead of their estimates that showed an unlikely complementary relationship. The estimated demand elasticities reflect conditional elasticities since the RSDAIDS model is a complete demand system, which assumes weak separability between meats and other goods. Therefore, following Fan, Wailes, and Cramer (1995) and Edgerton (1997), the own-price and cross-price demand elasticities were converted into unconditional elasticities [see Mutondo (2007), pp. 149-150, for the necessary formulas]. The own-price elasticities for the meat groups are from USDA-ERS (2006). The expenditure elasticities for the meat groups were obtained by regressing meat group expenditures against income.

Regarding meat supply elasticities, rather than attempting to estimate the source-differentiated elasticities (ϵ), this study relies on preexisting estimates of own-price supply elasticities reported in the literature (Sullivan et al. 1989, Tvedt et al. 1991, Wohlgenant 1993, Brester and Wohlgenant 1997, Lusk and Anderson 2004). This approach is taken because the literature has credible estimates of own-price supply elasticities for the meat-supplying countries considered in this study. The quantity proportions (τ) and (λ) and the price proportions (δ) were calculated using the respective 2002 quantities and prices. To save space, the parameter values assigned to the model are not presented here; however, they can be obtained from Mutondo (2007).

Simulation Methods and Welfare Measures

Once the parameters needed in the demand and supply equations (1) and (2) and in the equilibrium condition equations (3) through (5) are assigned, the values of variables with asterisks can be calculated by solving the equations simultaneously. In matrix notation, equations (1-5) can be written as:

$$(6) \quad \mathbf{A} \times \mathbf{Y} = \mathbf{B}$$

where \mathbf{A} is a matrix of the parameters (elasticities and flexibilities) of endogenous variables in equations (1-5); \mathbf{Y} is a vector of changes in endogenous variables (Q_{ijk}^{d*} , Q_{ij}^{s*} , P_{ijk}^{d*} , P_{ij}^{s*} ; $k = 1, \dots, K$; $i = 1, \dots, I$; $j = 1, \dots, J$); and \mathbf{B} is a vector of the exogenous shifters in equations (1), (2), and (5). In this study, \mathbf{A} is 164×164 . Relative changes in endogenous variables \mathbf{Y} caused by relative changes in exogenous supply and demand shifters are calculated by solving the following equation (7):

$$(7) \quad \mathbf{Y} = \mathbf{A}^{-1} \times \mathbf{B}$$

The model was simulated in Excel. An equivalent model was written in SAS software, which was used to verify the accuracy of the Excel simulation. Once the values of \mathbf{Y} have been determined by solving equation (7), the changes in producer surplus can be calculated. Changes in producer surplus at farm and retail levels in the case of parallel shifts are calculated from Wohlgenant (1993) (equation 10, p. 645) as follows:

$$(8) \quad \Delta PS_{ij} = P_{ij}^s Q_{ij}^s (P_{ij}^{s*} + \gamma_{ij}) (1 + 0.5 Q_{ij}^{s*})$$

(producer surplus at farm level)

$$(9) \quad \Delta PS_{ijk} = P_{ijk}^d Q_{ijk}^d (P_{ijk}^{d*} + v_{ijk}) (1 + 0.5 Q_{ijk}^{d*})$$

(producer surplus at retail level)

where ΔPS_{ij} is the change in farm producer surplus of meat i from country j ; ΔPS_{ijk} is the change in retail producer surplus of meat i from country j demanded in country k ; and the other variables are as previously defined.

Methods of Simulating Japanese and South Korean Bans on U.S. Beef

The model described above [equations (1-5)] is used to simulate the welfare impacts of the Japanese and South Korean bans on U.S. beef. The Japanese and South Korean bans on U.S. beef are imposed by shifting the Japanese and South Korean demands for U.S. beef so that the change in quantity demanded for U.S. beef in Japan and South Korea is zero.

Note that some shift in demand would occur without the ban. Kuchler and Tegene (2006) found that U.S. consumers deviated from traditional

purchase patterns for only two weeks after BSE announcements. Peterson and Chen (2005), however, found a substantial response of Japanese consumers to the finding of BSE in Japan in September 2001. Similarly, McCluskey et al. (2005) found that Japan consumers were hypothetically willing to pay a 50 percent premium for BSE-tested beef.

A trade ban represents a large demand shift and so the approach is assuming that elasticities remain constant over the range of the shift. Three ban alternatives are examined: (a) the Japanese ban on U.S. beef; (b) the South Korean ban on U.S. beef; and (c) both the Japanese and South Korean bans on U.S. beef. The model is simulated using 2002 average prices and quantities.

Results

Table 1 presents the results of welfare impacts of Japanese and South Korean bans of U.S. beef on producers and retailers of beef from the United States, Australia, Japan, and South Korea. Concerning the Japanese ban of U.S. beef, the results show that the ban decreases the welfare (as measured by producer surplus) of producers and retailers of U.S. beef and increases the welfare of producers and retailers of Australian and Japanese beef (Table 1).

The welfare of producers and retailers of U.S. beef decreases with the Japanese ban because as this major U.S. beef importer stops importing U.S. beef, the quantities of U.S. beef available in the U.S. domestic market and in other U.S. export markets increase. The increase in quantities of U.S. beef is expected to decrease the U.S. beef price, which leads to a decrease in the welfare of producers and retailers of U.S. beef. The welfare of producers and retailers of Japanese and Australian beef increases because the shares of beef from these sources in the Japanese market increase as Japanese consumers substitute the nonexistent U.S. beef with Japanese and Australian beef.

Regarding the South Korean ban of U.S. beef, the simulation results indicate that, similar to the Japanese ban on U.S. beef, the South Korean ban on U.S. beef decreases the welfare of producers and retailers of U.S. beef and increases the welfare of producers and retailers of Australian and South Korean beef (Table 1).

Table 1. Results of Welfare Impacts of Japanese and South Korean Bans on U.S. Beef (\$ in millions)

| Description | Japanese Ban | South Korean Ban | Both Japanese and South Korean Ban |
|--|--------------|------------------|------------------------------------|
| Farm Level | | | |
| Change in U.S. fed beef producer surplus | -217.03 | -351.23 | -565.31 |
| Change in U.S. nonfed beef producer surplus | 91.12 | 0.58 | 91.74 |
| Change in Australian beef producer surplus | 195.79 | 204.77 | 415.62 |
| Change in Japanese beef producer surplus | 2,681.93 | | 2,703.79 |
| Change in South Korean beef producer surplus | | 14.45 | 60.59 |
| Retail Level | | | |
| Change in U.S. beef producer surplus in the U.S. | -195.97 | -317.84 | -514.96 |
| Change in U.S. beef producer surplus in Canada | -1.46 | -2.42 | -3.84 |
| Change in U.S. beef producer surplus in Japan | -2.33 | -7.60 | -6.17 |
| Change in U.S. beef producer surplus in Mexico | -6.67 | -9.74 | -17.91 |
| Change in U.S. beef producer surplus in South Korea | -4.24 | -3.38 | -5.73 |
| Change in Australian beef producer surplus in Japan | 25.96 | | 52.84 |
| Change in Australian beef producer surplus in S. Korea | | 16.48 | 32.14 |
| Change in Japanese beef producer surplus in Japan | 2,682.79 | | 2,704.65 |
| Change in producer surplus of South Korean beef | | 14.45 | 60.59 |
| Consumers | | | |
| Change in U.S. beef consumer surplus | 33.86 | 267.66 | 297.92 |
| Change in Japanese beef consumer surplus | -4,393.09 | 1.61 | 4,406.39 |
| Change in South Korean beef consumer surplus | -49.36 | -2,560.71 | -2,746.14 |

Note: The table only contains the key welfare impacts.

Finally, as expected, when both Japan and South Korea ban U.S. beef simultaneously, producers and retailers of U.S. beef lose more compared to a single-ban scenario either by Japan or by South Korea. For U.S. beef producers, the results of this study show that, under a multiple-ban scenario, the welfare loss is increased by 160.5 percent compared to a scenario with only a single ban by Japan (welfare changes from -\$217.03 million under a single ban to -\$565.31 million under a multiple ban) (Table 1). Moreover, the loss in producers' welfare is increased by 70 percent under a multiple-ban scenario, compared to a scenario involving a single ban by South Korea (from -\$351.23 million to -\$565.31 million). On the other hand, the producers and retailers of Australian, Japanese, and South Korean beef gain more under a multiple-ban scenario, compared to a single ban by either Japan or South Korea (Table 1).

Summary and Conclusions

This research suggests an equilibrium displacement model as a way to quickly estimate impacts of demand and supply shocks on U.S. meat prices, quantities, and industry welfare. Previous models did not include the U.S. meat trade (imports and exports), with meats differentiated by supply source, and so were limited in the changes that could be studied. This study constructs an equilibrium displacement model, which includes U.S. produced meats, U.S. meat imports from major partners, and U.S. meat exports to major partners, with meats differentiated by source of origin. Additionally, the model is unique since it can estimate the welfare impacts of disease-driven international meat bans on meat producers and retailers.

Regarding the Japanese and South Korean bans of U.S. beef, as expected, the results indicate that

the bans reduce the welfare of producers and retailers of U.S. beef and increase the welfare of producers and retailers of other competing beef products. For example, for U.S. beef producers, the results show that the negative impact of banning U.S. beef is greater under multiple bans (-\$565.31 millions) compared to a single ban (-\$217.03 million for the Japanese ban and -\$351.23 million for the South Korean ban).

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