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Everett B. Peterson

Jason H. Grant

Sharon Sydow

COLLEGE OF AGRICULTURE AND LIFE SCIENCES
VIRGINIA TECH

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Everett B. Peterson[a]*, Jason Grant[b] and Sharon Sydow[c]

[a] Professor, Department of Agricultural & Applied Economics, Virginia Tech, Blacksburg, VA 24061, Phone: 540-231-6108, Fax: 540-231-7417, email: petrsone@vt.edu

[b] Associate Professor & Director, Center for Agricultural Trade, Department of Agricultural & Applied Economics, Virginia Tech, Blacksburg, VA 24061, Phone: 540-231-7559, Fax: 540-231-7417, email: jhgrant@vt.edu

[c] Senior Economist, Office of the Chief Economist (OCE), Washington DC, Phone: 202-720-6186; Email: ssydow@oce.usda.gov

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Department of Agricultural and Applied Economics
Virginia Tech
250 Drillfield Drive
Blacksburg, VA 24061

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Abstract

In December of 2003, the US Secretary of Agriculture announced the presence of Bovine Spongiform Encephalopathy (BSE) within a cow in the state of Washington. The announcement prompted the stoppage of beef imports by some of the US's largest traditional beef trading partners, resulting in sizeable losses to industry. While this was the first confirmed case of BSE reported in the United States, the international policy response was significant in nearly every major U.S. beef export market. NAFTA partners Mexico and Canada opened their markets to U.S. beef rather quickly following the announcement. However, other markets, including many of the top US export destinations such as Japan, Korea, Taiwan and China, remained closed for much longer periods and China's market remained closed until September 2016. In this paper, a partial equilibrium model of global meat production and trade is developed to conduct a series of historical simulations over the period 2001 to 2013 to capture the observed impacts of the BSE outbreak on global meat trade. Then a set of counter-factual experiments are constructed that adjusts the changes in preferences and technical change in the historical simulation to determine what beef meat trade would have looked like if the BSE outbreak had not occurred. Over the 2004-2013 period, total US beef exports would have been approximately 2 million metric tons higher and the total value of beef exports would have been $6.1 billion higher if the BSE outbreak had not occurred. Canadian beef exports would also have been 350,000 metric tons higher and with the total value of exports increasing by $1.7 billion if the BSE outbreak had not occurred. Conversely, the value of beef exports from Australia, New Zealand, the EU, and South America would have be substantially lower.

Key words: Bovine Spongiform Encephalopathy, historical simulation, import ban, sanitary regulations

JEL Codes: F17, Q17, Q18

1. Introduction

December 23, 2016 marked the 13-year anniversary of the first confirmed case of Bovine Spongiform Encephalopathy (BSE or Mad Cow disease) found in a cow in the State of Washington and originally imported from Canada. This came almost twenty years after BSE was first reported in Great Britain and eight years after a strong link to fatal human Variant Creutzfeldt-Jakob disease (vCJD) was established (Josling, Roberts and Orden 2004). While this was the first confirmed case of BSE reported in the United States, remarkably, the outbreak had virtually no discernable impact on domestic beef purchases other than a small two-week window immediately following the announcement (Kuchler and Tegene 2006).

However, the opposite was true for nearly every major US beef export market. While Mexico and Canada opened their markets to US beef relatively quickly, other markets remained closed for much longer periods. China, who first implemented a beef embargo in 2001 due to BSE outbreaks in Europe, added US beef to that ban after the 2003 case of BSE. China's beef import market remained closed to the US until September 2016 when China announced that it would begin allowing imports of US beef aged less than 30 months provided US exporters comply with China's traceability and quarantine rules. Japan and Korea, who were the largest importers of US beef prior to the outbreak, accounting for over 50 percent of US exports, banned US beef imports for a shorter 3-year period until 2007 when both countries began allowing imports of beef derived from cattle aged 21 months or less. Even after Japan and Korea lifted their bans, US beef exports have been slow to recover to their pre-BSE levels.

Figure 1 and Figure *2* show the impact of the import restrictions on US and Canadian beef in Japan and Korea. Before the export restrictions, the US was the largest exporter of beef to both Japan and Korea, on a weight basis. Australia was the second largest exporter of beef to these markets while Canada and New Zealand have similar levels of beef exports. With the export restrictions in place, US and Canadian beef exports fall to near zero in 2004 and 2005, but begin to recover slowly after the restrictions were eased. During that period, both Australia and New Zealand increased their beef exports to Japan and Korea. By 2013, beef exports by Australia and New Zealand to Japan had diminished somewhat compared to their highs in the 2004-2006 period. Australian beef exports to Japan had returned to the level in 2003 before the BSE outbreak. However, New Zealand beef exports to Japan in 2013 were still above their 2003 level. Neither the US or Canada had regained the 2003 level of beef exports to Japan by 2013. A similar pattern of beef exports to Korea is also observed (Figure 2).

The US Meat Export Federation (USMEF) estimated that the ten-year cumulative loss of US beef trade as a result of the 2003 BSE outbreak was $16 billion, with much of the predicted losses occurring in the first three years. Coffey et al. (2005) estimated that the associated costs to the beef industry due to BSE for the year 2004 alone were $200 million due to lower export sales and a reduction in unit prices. In 2002 and 2003, the US was the largest exporter of beef and offal totaling almost $4 billion (USITC 2008). Besides Japan and Korea, other important destination markets include Canada, Mexico, Taiwan, Hong Kong, Egypt and Russia which collectively imported over $1 billion worth of US beef.

In addition to the direct impacts of import bans by trading partners, there may also be important indirect impacts of the bans. For example, if the countries imposing the ban are large enough to reduce the price of beef from the exporting country, then a lower price could induce higher exports to markets that do not impose the ban. This could include non-traditional markets where little or no trade occurred before the ban was implemented. In addition, consumer preferences may change in countries that impose a ban and may persist longer after the ban is removed. For example, preferences of consumers in Japan and Korea may have shifted away from US beef towards beef from Australia and/or New Zealand who were not affected by the import ban. It also is possible that preferences for consumers in Japan and Korea may shift away from beef entirely because of the food safety shock.

The purpose of this paper is to provide a comprehensive assessment of US and global beef markets prior to, during, and after the US BSE outbreak. To do so, a global, partial equilibrium model of world animal product trade is developed. The model is then used to conduct a historical simulation over the period 2000 to 2013 to match the observed impacts of the BSE outbreak on global meat trade. Next, a set of counter-factual experiments are constructuted that remove the changes in preferences and technical changes due to BSE in the historical simulation in an attempt to determine what meat trade would have looked like if the BSE outbreak had not occurred. While alternative approaches, such as econometric estimations of animal product trade are available, it is difficult to identify the effects of the US BSE outbreak across the many different export destinations across time.

2. Partial Equilibrium Model and Data

A global partial equilibrium model is developed with three meat products: beef, pork, and poultry. Demand in each region is determined by the preferences of a single representative consumer. In this application, the model only includes final demand and abstracts from intermediate input demand for meat products. Preferences of the representative consumer are represented using a three-level utility structure, as depicted in Figure 3. At the top-level, the representative consumer can substitute between the three meat products and an “outside” good, which is an aggregate of all other goods and services consumed. An outside good is included in order to account for increases in the overall price levels in each region in the historical simulations. This is important because the meat prices may be changing relative to price of other goods and services and it allows the specification a complete demand system and the underlying expenditure function. Preferences at the top-level are represented by a Constant Difference of Elasticities (CDE) implicit expenditure function.

In the second-level, the representative consumer can substitute between a domestically produced meat product and a composite imported meat product.[1] At the bottom-level, the representative consumer can substitute between different import sources of a given meat product. Thus, we assume that meat products are differentiated by region, or an Armington style preference structure in the bottom two levels. One justification for this assumption is that regions may utilize different production methods (e.g., grain-fed versus grass-fed beef) as well as trade a different mix of products[2]. A nested Constant Elasticity of Substitution (CES) expenditure function is used to represent preferences in the bottom two levels.[3]

Meat production in each region is represented by a two-level nested Constant Elasticity of Transformation (CET) production possibilities frontier (Figure 4). At the top-level, firms in each region can shift production between either the domestic or export markets as relative prices change. In the bottom-level, firms can shift exports between destinations as relative prices in the destination markets change. The location of the production possibilities frontier is determined by the supply of a single aggregate factor.[4] We assume a linear supply function for this aggregate factor that is a function of the composite producer price for that meat product in each region.[5]

1 We abstract from trade in the outside good in this model.

2 For example, Peterson and Orden (2005) show that the US mainly exports dark-meat poultry. In addition, the unit-values of exports vary widely across destinations for a given meat product.

3 Our representative of preferences for the single consumer in each region is the samiliar to the Global Trade Analysis Project (GTAP) general equilibrium model.

4 One can think of this factor as being comprised of labor, capital, and all other inputs needed to produce meat products.

5 The composite price is a function of prices received in the domestic and export markets.

The supply elasticity of this aggregate factor will determine the overall supply response of a given meat product in each region.

In an equilibrium, all meat markets are assumed to clear. There are market clearing conditions that equate the quantity of domestically produced meat supplied to the quantity of domestically produced meat demanded by the representative household. In addition, the quantity of meat exported by region *o* to destination *d* must equal the quantity of imported meat demanded in region *d* from region *o*. Thus, all meat prices and quantities are endogenously determined in the model. Appendix B contains a complete listing of all model equations.

Twenty individual and composite regions are included in the model. Thirteen individual regions are identified based on their level of exports, imports, and imposition of SPS regulations on US beef imports. The individual countries are: the US, Canada, Mexico, Australia, New Zealand, Japan, Korea, China, Brazil, Argentina, Russia, EU27, and India. We also identify 7 composite geographic regions: Rest of Asia (XAS), Rest of Oceania (XOC), Rest of Central America, Caribbean (XCB), Rest of Middle East (XME), Rest of Africa (XAF), Rest of Europe (XEU), and Rest of South America (XSM).

2.1 Data

Data on bilateral trade are obtained from the United Nations COMTRADE database.[6] The COMTRADE data provide information on trade values ($VXMD_{odk}$) and trade quantities ($LQME_{odk}$) from origin region *o* to destination region *d* from meat product *k*. All trade flows with less than 1,000 kg (or 1.0 metric ton) are eliminated to reduce the dimensions of the historical simulation. Trying to replicate very small trade quantities in the historical simulation can be difficult. The unit-values are determined by dividing value by quantity of trade.

6 The COMTRADE data are available at http://comtrade.un.org/db/.

Data on meat production are obtained from FAOSTAT.[7] The quantity of meat product *k* sold in the domestic market in region *d* ($LQPD_{dk}$) is equal to total production ($QDOM_{dk}$) minus the sum the quantity of product *k* exported from region *d* to all destinations (*LQME*). While FAOSTAT does have some data on producer prices of meat products, the country coverage is not complete. For example, there is no data for beef meat prices (e.g., meat, cattle) for the United States, Canada, or Argentina. Thus, an average export unit-value, an average import unit-value, or an average of the two is used to generate prices of domestically produced meat products (*k)* in region *d* ($LPMD_{dk}$). Average export unit-values are used for countries/regions that mainly export a given meat product and have very little imports. Conversely, the average import unit-values are used for countries/region that are mainly importers, with very little exports of a given meat product. Finally, the average of both export and import-unit values are used countries with significant imports and exports. Table 1 documents which method is used for each commodity and country/region in our model. The producer value of the domestic sales of product *k* in region *d* ($VDOM_{dk}$) is the producer price times the quantity of production sold in the domestic market.

Total expenditure on each meat product by the representative consumer in each region is composed of expenditure on imports plus domestically produced meat products. For imports, we start with the *fob* value of exports from region *o* of meat product *k* ($VXMD_{odk}$). Because data on international transport costs, which would be the difference between the *cif* and *fob* values, tend to have a large level of variability (see Hummels and Lugovskyy, 2006) and would have to be imputed in cases where trade did not occur (for example, if the US stops exporting beef to Japan), we abstract from these costs in our model. However, we do include data on ad valorem equivalent tariff rates, which are obtained from Market Access Maps (MAcMaps).[8] Expenditure

7 Available at http://faostat3.fao.org/faostat-gateway/go/to/home/E.
8 Available at http://www.macmap.org/QuickSearch/FindTariff/FindTariff.aspx?subsite=open_access.

on an imported market product k from region o ($VIMS_{odk}$) is then the *fob* value ($VXMD_{odk}$) times 1.0 plus the ad valorem equivalent tariff rate on product k from region o in destination region d (TMS_{odk}). Note that we do not have data on consumption taxes on imported or domestically produced meat products. The consumer price of imported product k from region o in region d ($LPMS_{odk}$) is computed as the value of expenditure divided by the quantity imported (e.g., *VIMS* divided by *LQME*). Total expenditure on imported meat product k in region d ($VIPA_{dk}$) is the summation of $VIMS_{odk}$ over all origin regions. Expenditure on meat product k that is produced in region d ($VDPA_{dk}$) is equal to the $LQPD_{dk}$ times $LPMD_{dk}$.

Total expenditure on meat product k by the representative consumer in region d (VPA_{dk}) is then equal to the sum of *VIPA* and *VDPA*, and expenditure on the "outside" aggregate good is equal to nominal GDP in region d minus total expenditure on all meat products (e.g., summing VPA_{dk} over k). The price of the outside good in region d is the value of the GDP price deflator, or nominal GDP divided by real GDP. Thus, the quantity of the composite outside good is expenditure on the outside good divided by the GDP price deflator. In our model, changes in nominal GDP and the GDP price deflator are exogenous in both the historical and counter-factual simulations, set equal to the observed changes in our model regions over time. Data on real and nominal GDP and population are obtained from the USDA Economic Research Service International Macroeconomic Database.[9]

While trade and production data are available on an annual basis, we aggregate the data into several distinct time periods in the analysis for two reasons. First, to reduce the chance of choosing an unusual base year for the initial equilibrium, averages of all variables over the 1998-2000 period are used to represent the initial or starting equilibrium. Second, to reduce the scope

9 Available at http://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx.

of the simulation, four aggregate time periods are used in the simulations rather than attempting to simulate all years individually. The first period (P1) corresponds to the pre-BSE period of 2001-2003. The second period (P2) corresponds to the BSE period, 2004-2006, where Japan and Korea imposed import bans on US beef. The third period (P3), 2007-2009, corresponds to a post-BSE period that includes the economic downturn in 2008 and 2009. The final period (P4), 2010-2013, corresponds to a post-BSE and post-Great Recession period.

2.2 Model Calibration

For the representative household in each region, the key model parameters are the substitution and expansion parameters of the CDE implicit expenditure function, the elasticity of substitution between the domestically produced meat product and the composite import (σ_D in Figure 3), and the elasticity of substitution between the different sources of the imported meat product (σ_M in Figure 3). The substitution and expansion parameters are determined to replicate a set of compensated own-price and income elasticities from the GTAP v.9 database. The compensated own-price and income elasticities for the GTAP sector "cmt" is used for beef products in the model. Since the GTAP sector "omt" includes both pork and poultry products, the compensated own-price and income elasticities for this sector is applied to both the pork and chicken products in the model. The compensated own-price and income elasticities for the outside good is determined by aggregating all GTAP sectors, except for cmt and omt, and computing the implied elasticities. Note that the substitution and expansion parameters will differ from those in the GTAP database to the extent that the budget shares for each representative consumer in the model differ from those in the GTAP v.9 database. Finally, the values of σ_D and σ_M for the cmt and omt sectors in the GTAP database are used in the model.

The key parameters for meat production in our model are the elasticity of transformation between the domestic and export markets (σ_{T1} in Figure 4), the elasticity of transformation between export destinations (σ_{T2} in Figure 4), and the supply elasticity of the aggregate factor. Unlike the demand-side parameters, there is less empirical evidence on the values of the supply-side parameters. Based on recent advances in the theoretical and empirical trade literature that emphasize the role of firm-level productivity differences to explain trade patterns (Melitz 2003; Helpman, *et al.* 2008; Chaney 2008; Bernard, *et al.* 2009) where only the most productive firms in an industry are able to enter export markets, the elasticity of transformation between the domestic and export markets is assumed to be inelastic and is assigned a base value of -0.5. However, firms that are able to enter export markets may have a greater ability to shift exports between destinations as relative prices in the destination markets change. Thus, an elastic base value of -5.0 is used for the elasticity of transformation between export destinations. In addition, similar to the elasticities of substitution in the GTAP database, all of the elasticities of transformation are the same across all regions and meat products. This assumption can be relaxed if additional information on these parameter values becomes available. Finally, the supply elasticity of the aggregate factor is assumed equal to 1.0 for all meat products and all regions due to a lack of empirical evidence on these values. These assumptions can be relaxed if additional information on parameter values becomes available.

3. Historical Simulations

Typically, in partial equilibrium models, prices and quantities are endogenous variables while income and changes in preferences and technology are exogenous variables. However, in the historical simulation, one can observe prices and quantities over time. Thus, these variables can be treated as exogenous while changes in preferences and technology to match observed market variables over time can be treated as endogenous (See Van Dijk, et al. (2014), Dixon and Rimmer (2002, 2010), and Beckman and Hertel (2010) for a discussion on historical simulations using CGE models.) For example, consider the demand for composite goods:

$$qp(i,d) - pop(d) = \sum_{k \in DEMD} EP(i,k,d)pp(k,d) + EY(i,d) * y(d) - pop(d) + ap(i,d) - ap\_avg(d) \tag{1}$$

where *qp* is the percentage change in the quantity of the *i*th composite good in region *d; pop* is the percentage change in population in region *d*; *pp* is the percentage change in the consumer price of good *i* in region *d*; *y* is the percentage change in income in region *d*; *ap* is a preference shifter for good *i* in region *d*; *ap_avg* is the budget share weighted average change in preferences for all composite goods in region *d*; and *EP* and *EY* are the uncompensated price and income elasticities.

In the historical simulation, the variable *qp* is observable and treated as an exogenous variable, whereas the preference parameter *ap* is treated as an endogenous variable. Note that to keep the budget constraint from being violated, each demand equation must also include the consumption share weighted average of the preference changes for each good (Dixon and Rimmer, 2002). However, since the expression $ap(i,d) - ap\_avg(d)$ is homogeneous of degree zero in *ap*, its level must be fixed to obtain a unique model solution. To do so, *ap_avg* is treated as an exogenous variable whose value is set equal to zero and one of the quantity changes (*qp*) remains endogenous. In the historical simulation closure, *qp* for each of the three meat products are treated as exogenous while *qp* for the outside good is treated as endogenous. The preference shifter *ap* is endogenous for all products, including the outside good.

Similar “swaps” of endogenous/exogenous variables are used in the demand equations in the other two nests of the preference structure for the representative consumer in each region.

The demand equations for the *i*th domestically produced meat product in region *d* and for the composite imported meat product *i* are:

$$qpd(i,d) = qp(i,d) + ESUBD(i)\left[pp(i,d) - ppd(i,d)\right] + \left[1 - ESUBD(i)\right] apd(i,d) \quad \text{and,} \tag{2}$$

$$qpm(i,d) = qp(i,d) + ESUBD(i)\left[pp(i,d) - ppm(i,d)\right] - \left[1 - ESUBD(i)\right]\left(1 - PMSHR(i,d)\right)/PMSHR(i,d)\; apd(i,d) \tag{3}$$

where *qpd* and *qpm* are the percentage change in the demand for domestically produced meat product *i* and the demand for the composite imported meat product *i* in region *d*; *ppd* and *ppm* are the consumer price for the domestically produced meat product *i* and the price index for imported meat product *i* in region *d*; *apd* is the preference shifter for the domestically produced meat product; *ESUBD* is the elasticity of substitution between the domestic and composite goods; and *PMSHR* is the share of imports in total expenditure on meat product *i* in region *d*. Because there are only two "goods" in this nest of the preference structure, one can set the consumption share weighted sum of the preference shifters for the domestic and composite import good equal to zero and solve for the preference shifter for the composite imported good as a function of the preference shifter for the domestic good. Thus, in the historical simulation *qpd* is an exogenous variable and *apd* is an endogenous variable.[10]

Finally, the demand equation for imported meat product *i* by source is:

$$qme(i,o,d) = qpm(i,d) + ESUBM(i)\left[ppm(i,d) - pms(i,o,d)\right] + \left[1 - ESUBM(i)\right]\left[apm(i,o,d) - apm\_avg(i,d)\right] \tag{4}$$

[10] For regions with very small consumption shares of an imported meat product, (1-*PMSHR*)/*PMSHR* could be a relatively large number. This would restrict the value of *apd* in order to keep the percentage change in *qpm* from exceeding -100%. However, this restriction on *apd* may not be compatible with the observed changes in the demand for the domestically produced meat product, prices and income, making it impossible to solve for *apd*.

where *qme* is the percentage change in the quantity demanded of meat product *i* from origin region *o* in destination region *d*; *pms* is the percentage change in the consumer price; *apm* is the preference shifter; and *ESUBM* is the elasticity of substitution between imported products. Since not all destination regions import meat product *i* from all possible origin regions, *apm* is treated as an exogenous variable for origin regions that do not export to region *d*. Because the COMTRADE data contains a significant number of relatively small trade flows, less than 10 metric tons for example, only the principle trade flows are targeted in the historical simulation.[11] Consider beef imports in Japan as an example. The main beef exporting regions to Japan are the United States, Australia, New Zealand, and Canada. However, Japan also imports small quantities (less than 5 metric tons) from Mexico, the EU27, Korea, and the composite regions XSM, XCB, and the XOC. In this case, *qme* is an exogenous variable and *apm* is an endogenous for the United States, Australia, New Zealand, and Canada in the historical simulation. For all other exporters, *apm* is treated as an exogenous variable and *qme* remains endogenous. Because only a subset of *apm* are endogenous for any given meat product and importing region, it is not necessary to fix the scale of *apm_avg* and it is treated as an endogenous variable.

The export supply equation of meat product *i* from region *o* to destination *d* is defined as:

$$qxs(i,o,d) = qom(i,o) + ESUBT2(i)\,pmei(i,o) - pme(i,o,d) - adx(i,o,d) + adx(i,o,d) \tag{5}$$

where *qom* is the percentage change in the composite quantity of exports; *pmei* and *pme* are the percentage changes in the export price index and the producer price of exports to region *o*; *adx* is a technical change shifter, and *ESUBT*2 is the elasticity of transformation between export

[11] Initially, all observed *qme* were treated as exogenous variables and thus all *apm* were endogenous variables. However, the observed changes in export quantities and prices, particularly for the smaller trade flows, were not always compatible with the CES sub-utility structure and it was not possible to find a solution.

destinations. Because of the market clearing conditions, if the import demand *qme*(*i*,*o*,*d*) is an exogenous variable, then the percentage change in export supply *qxs*(*i*,*o*,*d*) will also be "fixed." However, one cannot treat *qxs*(*i*,*o*,*d*) as an exogenous variable because to do so would result in the market clearing condition being a function of only exogenous variables, which would make it redundant. Thus, to endogenize the technical change variable *adx*(*i*,*o*,*d*) requires that it be swapped with another endogenous variable in the export supply equation. The only other variable with the same dimensions as *adx*(*i*,*o*,*d*) is *pme*(*i*,*o*,*d*), the producer price of exports of good *i* from origin region *o* to destination region *d*. For the instances where the technical change shifter *adx*(*i*,*o*,*d*) is treated as an endogenous variable to enable the historical simulation to "match" the observed change in *qxs*(*i*,*o*,*d*), *pme*(*i*,*o*,*d*) is treated as an exogenous variable and set equal to the observed change in unit-value in the COMTRADE data.

As an example of the "swaps" made in the historical simulation, consider the import restrictions imposed by Japan and Korea on US and Canadian beef, as illustrated in Figure 1 and Figure *2*. In period P2, imports of US and Canadian beef in Japan and Korea decreased by over 95% compared with the level of imports in period P1. In contrast, imports of beef Australian and New Zealand beef in Japan and Korea increases dramatically, more than doubling for New Zealand. In the historical simulation, this shift in the source of beef imports is accomplished by fixing the values of *qme* for these 4 exporters and 2 importers and endogenizing the corresponding preference shifter *apm*. In addition, the import restrictions also had the effect to shift beef consumption in Japan and Korea away from imports to domestic production as well as an overall reduction in beef consumption. Thus, the changes in *qpd* and *qp* for beef in Japan and Korea are set equal to their observed changes and the corresponding preference shifters *apd* and *ap* are endogenized.

For beef producers in Australia, Canada, New Zealand, and the US, the trade restrictions also shift the pattern of exports for these countries. The very large observed percentage changes in exports to Japan and Korea along with finite elasticities of transformation would result in very large changes in producer export prices if the technology shifter *adx* remains exogenous. To avoid the potential large price changes, the percentage change in *pme* for beef exports to Japan from the US, Australia, and Canada is set equal to the observed changes in beef export unit-values and the corresponding technology shifter *adx* is endogenized.[12]

The producer export price of beef from New Zealand to Japan is not fixed because the price from the historical simulation was very similar to the observed change in the trade unit-value. For beef exports to Korea, the percentage change in *pme* for the US and Canada is set equal to the observed change in the export unit-value and the corresponding *adx* is endogenized. However, the observed changes in beef export unit-values for Australia and New Zealand to Korea are not used. For New Zealand, beef exports increased by 265.7% to Korea in P2 compared with P1. However, the observed change in the unit-value was only 36.6%. Given a value of -5.0 for the elasticity of transformation between export destinations and the other observed changes in export supply of beef from New Zealand, this observed change in unit-value was too low to be consistent with the CET production possibility frontier and it was not possible to find a solution. A similar problem occurred when attempting to use the observed unit-value change for Australian beef exports to Korea.

The historical simulation also takes into account observed changes in income (GDP), population, overall price level (GDP price deflator), and tariff rates. Thus, the change in

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[12] As is well known, unit-prices are not always a good substitute for "actual" prices, due to changes in quality or the composition of goods within an aggregate over time. Changes in unit-values are not used in the historical simulation when they appear to be counter to the observed change in quantity or much different than the changes in unit-values for other exporters.

preferences in the historical simulation would capture not only changes in tastes of preferences, but also any changes in trade or domestic policies not included in the model. For example, a negative change in preferences for US beef in Japan and Korea when US beef imports are banned would capture not only the change in SPS policies in Japan and Korea, but also any shifts in preferences away from beef towards chicken and/or pork. This is an important distinction because in the counter-factual experiments, the endogenously determined changes in preferences in the historial simulation are adjusted to attempt to determine what meat trade would have looked like if the BSE outbreak had not occurred. So, while the endogenously determined changes in preferences for imported beef by source (*apm*) and between domestic and imported beef (*apd*) in Japan and Korea would likely reflect the change in SPS regulations, it may be less clear how much of changes in preferences for beef (*ap*) were due to the SPS regulations. Similarly, the endogenously determined technical change in beef export destinations for the United States, Australia, Canada, and New Zealand (*adx*) likely reflects the imposition of SPS regulations by Japan and Korea. In the counter-factual experiments, a range of different factors by which the endogenously determined values of *ap*, *apd*, and *adx* are adjusted from the historical simulation are considered.

4. Results

This section is divided into two sub-sections. The first section contains the results from the historical simulation. The focus of this sub-section is a comparison of how well the simulated historical results matched the actual observed changes in trade and production. The second sub-section contains the results for the counter-factual experiments where the endogenously determined values of *ap*, *apd*, and *adx* from the historical simulation are adjusted (partially or totally eliminated) and the simulation model is resolved. The difference in results between these simulations will be our estimate of what global beef trade and production might have been without the BSE outbreak in the US in 2003.

4.1 Historical Simulation

In the historical simulation, the first step is to incorporate observed changes in population, GDP, the GDP price deflator as a measure of prices of non-meat goods and services; quantities of domestically produced and consumed beef, chicken, and pork; and composite quantities of beef, chicken, and pork. Appendix Tables C.1 through C.5 illustrate the values of the exogenous shocks to these variables in the historical simulation. The resulting changes in bilateral beef trade (*qme*) are then compared with the observed changes for each time period as a check to ensure the mode can replicate the historically observed trade flow patterns. When there are significant differences for a given bilateral pair, the change in exports is set equal to the observed change. In some cases, the change in export price (*pme*) is also set equal to the observed change in unit-value. This procedure is implemented in a sequential manner across all four-time periods.

In the first-time period, 2001-2003 (P1), the change in the quantity of beef exports is fixed for 35 bilateral-trade pairs (see Table 2). For the US, the changes in beef exports to Russia, Mexico, Canada, Japan, and the composite XAS (Rest of South Asia) region are fixed. (See Appendix Table C.5 for the exogenous shocks to *qme* in the historial simulation.) However, the change in the beef export price is fixed for 10 of these bilateral pairs. (See Appendix Table C.6 for the exogenous shocks to *pme* in the historical simulation.) These bilateral pairs typically had very large quantity changes, either positive or negative, and fixing the export price eliminated the otherwise large price changes if the price was endogenously determined. For the remaining three-time periods, the number of bilateral pairs with exogenous beef export quantity and price changes increases significantly due to the implementation of trade restrictions from BSE. Approximately 70-75 changes in the quantity of bilateral beef exports are fixed in each of the last three-time periods to match the observed changes in beef exports. This occurs because one would expect a simulation that only incorporates changes in population, income, etc. would not be able to capture the impacts of the BSE-related policy changes. To put these numbers in presceptive, approximately 70% of all bilateral beef export flows of at least 5 metric tons are fixed and approximately 80% of all export flows of at least 10 metric tons are fixed in the last three time periods.

Table 3 and Table 4 report the total quantities of beef imports and exports by region in the historical simulation and compares those values to the observed total imports and exports for each of the four-time periods in the simulation. Overall, the largest overall error for total quantity of global beef trade is 78,100 MT in the first-time period (2001-2003), which represents a 1.3% error. In all other time periods, the overall simulation model error is less than 1% of the observed quantity of global beef trade. For imports, the regions with the largest absolute simulation errors are the EU-27, Russia, and the composite XCB (Rest of Central America and the Caribbean) region. The historical simulation also has a larger absolute error for US beef imports in the first-time period of 41,600 MT (4.2% of observed total imports) and 29,600 MT in the fourth-time period in the composite XAS (Rest of Asia) region (0.1% of observed total imports).

For beef exports, the historical simulation tended to under-estimate exports from Mexico, the composite XSM (Rest of South America) region, and the composite XCB region. It also tended to over-estimate beef exports from Argentina in the last two-time periods. For the US, the largest simulation error occurred in the first-time period where beef exports were underestimated by 13,500 MT, or 1.2%. In the last three-time periods, the simulation error for US beef exports is less than 0.5% of observed total exports. Thus, the simulation model back-casted to the four time periods was able to match quite closely the observed patterns in global beef trade.

Table 5 presents the simulated bilateral beef trade flows for four key exporters - U.S., Canada, Australia, and New Zealand - in the historical simulation and provides a comparison to the actual observed bilateral trade flows. For the US, the historical simulation does match US beef exports to its most important destinations: Mexico, Canada, Japan, Korea (in last three time periods), and the composite region XAS (particularly in the last time period). The largest simulation error for the US in the first-time period was for exports to China (19,100 MT underestimated), the EU-27 (11,400 MT over estimation), and to Korea (20,100 MT over estimation). For all remaining periods, however, the simulation errors on U.S. exports to all countries were small. For Canada, the simulation error in Table 6 is the largest in the second-time period (2004-2006), with beef exports over-estimated by 27,900 MT or 6.5%. The simulation error is between 2.4-2.8% in the first and third time periods and drops to under 1% in the last time period. However, the historical simulation does match Canadian beef exports to their largest destination market, the US, in all time periods with no simulation errors.

For Australia, the simulation error is the largest in the first-time period where beef exports are over-estimated by 11,500 MT, or 1.2%. However, in all subsequent time period, the simulation error is less than 1.0%. We also ensure that the simulation error is zero or very low for the key export destinations for Australian beef: the US, Japan, Korea, and the Rest of Asia (XAS) composite region. Lastly, for New Zealand, the historical simulation over-estimates total beef exports in all periods, with the first and the last time period having the largest errors of approximately 2%. The BSE and post-BSE (second and third) time periods have the lowest simulation error of less than 0.5%. Like Australia, we ensure that the simulation error is zero or very low for the key destinations for New Zealand beef: the US, Japan, Korea, and the Rest of Asia.

Table 6 presents the level of beef production from the historical simulation compared with the observed values for each of the four-time periods. Overall, the simulation error for total production is quite small, ranging from about 40,000 MT to 90,000 MT across all countries, or less than 0.2% of global beef production. Because the percentage change in the quantity of domestically produced beef consumed along with the major bilateral trade flows are fixed in the historical simulation, one would expect that the simulation error for total beef production should be relatively small.

4.2 Counter-factual Simulations

In the counter-factual simulations, the preference and technology shocks determined in the historical simulations for the time periods P2 through P4 are partially or totally removed. For the pre-BSE time period (P1), no adjustments are necessary. In the BSE time-period P2, the changes in the preference shifters for the composite beef product (*ap*) and domestically produced beef (*apd*) for Japan and Korea from the historical simulation are removed. These shifts in preferences in the historical simulation are likely a reflection of the BSE import bans imposed by these countries during this time period. In most of our analysis discussed below changes in *ap* and *apd* for beef in all other regions are maintained in the counter-factual simulation. Another possibility would be to adjust the values of *ap* and *apd* for China during P2-P4 as well, given its policy responses to BSE in Europe in 2001 and the US in 2003 along with other beef animal disease issues. Because the values of *ap* and *apd* are very similar across the last three time-periods and across the three meat products, we choose not to adjust these preference shocks for China from the historical simulation in our base set of results. This allows us to focus the results discussion on Japan and Korea. However, given China's potential market size for U.S. beef and other animal product exports, in addition to the base counterfactual results for Japan and Korea, we also present the results from a scenario that partially removes China's preference shocks in the historical simulation.

To understand the number of preference and technology shocks that are eliminated in the counterfactual simulation, we can refer again to Table 2. The bottom portion of Table 2 gives the number of "shocks" to *apm* and *adx* from the historical simulation that are maintained in the counter-factual experiment. By subtracting these numbers from the corresponding shocks to *qme* and *pme* in the top portion of this table gives the number of preference and technology shocks that are eliminated in the counter-factual experiment. For example, in time period P2, 31 shocks to *apm* (e.g., 75-44) and 21 shocks to *adx* (e.g., 55-34) are eliminated in the counterfactual experiment. Over the last three-time periods, between 25 and 30 preference (*apm*) shocks and between 12 and 21 technology (*adx*) are eliminated.

Table 7 provides a more detailed description of which preference and technology shocks are eliminated. Preference shocks for all US beef imports as well as the corresponding technology shocks for beef exports to the US in the historical simulation are eliminated in the counter-factual experiment. All preference shocks on imports of US beef are eliminated except to Russia, the EU27, and for the XAS composite region in time period P4. The preference shocks for Russia and the EU27 are maintained in the counterfactual experiment due to long-standing trade disputes related to the use of beef hormones. All preference shocks for the XAS region in period P4 are maintained because of significant positive preference shocks for beef from the major exporter countries. Eliminating the US preference shock would have resulted in a large reduction in US exports to the XAS during a period of significant import expansion. Any technology shock for US beef exports that corresponds to a destination market where preference shocks were removed are also eliminated. The elimination of these preference and technology shocks accounts for over one-half of the total number of shocks eliminated in the counter-factual experiment.[13]

4.2.1 Comparisons for Japan and Korea

This section focuses on comparing the historical and counter-factual simulations for Japan and Korea – two key export markets for US beef that imposed SPS import restrictions following the BSE outbreak. Figure 5 compares the composite consumption quantity index (*qp*) for all beef from imports and domestic sources for the Japanese and Korean markets across all model time periods for the historical and counter-factual simulation. Note that all initial values of the index have been normalized to equal 1.0. The solid line represents the values of the index in the historical simulation and the dashed line represents the value of the quantity index in the counter-factual simulation.[14]

For Japan, in the historical simulation, *qp* declines in P1 by approximately 12%. This quantity reduction can be decomposed into a price effect, an income effect, a population effect, and a preference effect.[15] The main drivers of this decrease are shifts in preferences away from all beef in P1 and a reduction in per-capita GDP in Japan. In period P2, *qp* decreases by 30% from P1. The main drivers for this decrease are a price effect, from an increase in the price of

[13] Other preference shocks eliminated in the counter-factual experiement include those related to beef imports to China, Canada, Japan, Korea, and the XCB composite region. In addition, all technology shocks on beef exports to these same regions are eliminated. Two additional technology shocks were eliminated for Canadian exports to Mexcio in period four (P4) and to the XSM composite region in period two (P2).

[14] Recall, for P1, the historical and counter-factual simulations are identical.

[15] The simulation results for a specific equation model can be "decomposed" using the GEMPACK program AnalyseGE (Harrison, *et al.*, 2000) which is the same decomposition program used for GTAP.

imported beef, and a shift in preferences away from beef in P2. The increase in imported beef prices occur in the model because the import ban on US and Canadian beef leads consumers to substitute to imported beef from other suppliers, mainly Australia and New Zealand. Because the supply response of beef exports from Australia and New Zealand is not perfectly elastic and the increase in demand is quite large, the price index for imported beef increases significanty by approximately 50%. In periods P3 and P4, *qp* rebounds, with increases of 6.9% and 11.5% respectively. In both time periods, the main driver is a preference shift back towards beef by the representative household in Japan and small decreases in the composite all beef price due to reductions in the price of imported beef. Note that decreases in GDP of 1.9% in P3 and 3.6% in P4 along with a 0.3% reduction in population in P4 dampens the increases in Japan's composite consumption quantity index (*qp)* in those periods.

In the counter-factual simulation, the consumption quantity index for all beef (*qp*) in Japan declines in each time period, but much less so compared to the historical simulation, decreasing between 3.0% and 7.7%. In P2, the 3.0% reduction in the index (*qp*) is due to an increase in the prices of both domestic and imported beef. Higher global prices for imported beef are the result of a 16.7% increase in global beef trade[16] from P1 to P2 in the counter-factual simulation, a 1.5% larger growth compared to the historical simulation, which is driven by a 20.7% increase in global nominal GDP and a 3.7% increase in global population. An increase in the price of domestically produced beef in Japan occurs because the representative household substitutes away from imported to domestic beef as the price of the former increases. So even though *qp* decreases by 3.0%, consumption of domestic beef (*qpd*) increases by 4.1% in Japan.

[16] This is the percentage change in the global quantity index of beef exports across all exporters and all destinations. The global price index for beef exports increased by 30.4% from P1 to P2 in the counter-factual simulation. In the historical simulation, global beef trade increased by 15.0% in from P1 to P2.

This increase in demand results in an increase in the price of domestically produced beef (*ppd*) in Japan by 4.1%.[17] In periods P3 and P4, *qp* decreases by 3.4% and 7.7%. Increases in prices of domestic and imported beef plus decreases in per-capita GDP are the main drivers of these decreases. The larger decrease in *qp* in P4 is due to larger price increases of imports from the US, Australia, Canada, and New Zealand. For the US, Canada, and New Zealand, there is a decrease in the demand for domestically produced beef in each region while beef exports in these regions increase. Thus, there is a relatively large change in the mix of domestic and export market destinations for beef produced in these regions. Because the elasticity of transformation between beef sold in the domestic market and in exports markets is assumed to be inelastic (-0.5), the relative increase in exports can only be accomplished by an increase in the relative price of exports to the price for the domestic market. The export price index (*pmei*) increases by 17.8%, 11.6%, and 13.2% respectively for the US, Canada, and New Zealand in P4. The increase in *pmei* is smaller for Australia, at 10.6%, because the change in the destination mix is not as large as in the other regions.[18]

Even though the time paths of *qp* for beef in Japan are different in the historical and counter-factual simuations, their values are similar in the last period, P4. In the historical simulation, the composite quantity index is approximately 27% lower than the initial value in P4 while it is approximately 24% lower in the counter-factual simulation. Thus, there would have been only a small increase in overall beef consumption in Japan if the BSE outbreak had not occurred.

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[17] Only a very small portion of Japanese beef production is exported. Thus, the change in domestic demand is essentially the change in Japanese beef production, due to the market clearing conditions. Because a unitary aggregate supply elasticity is assumed for beef in all regions, to meet a 4.1% increase in demand requires a 4.1% price increase for beef production in Japan.

[18] This suggests that the model results may be sensitive to the elasticity of transformation σ_{T1}.

For Korea, the time paths of the composite consumption quantity index (*qp*) are different in both simulations compared to Japan. In the historical simulation, *qp* increases by 11.0% in P1, mainly due to strong income growth in Korea, which offset a shift in preferences away from beef. Similar to Japan, *qp* decreases by 34.1% in P2 due to a shift in preferences away from beef and increases in the price of imports. Note that this decrease would have been larger except for the strong growth in GDP in P2. In periods P3 and P4, similar to Japan, there is a rebound in the composite quantity index. However, this rebound is much stronger than in Japan, with increases in *qp* of 21.5% and 37.5%, respectively, due to stronger income growth in Korea compared to Japan.

In the counter-factual simulation, *qp* for beef in Korea grows steadily, increasing between 9.0% and 10.1% in each period. The main driver of this increase is the strong income growth in Korea, which offsets prices increases of domestic and imported beef. At the end of P4, the quantity index is 19.7% larger in the counter-factual experiment compared with the historical simulation. Thus, while the ending beef quantity index in Japan is similar in the historical and counter-factual simulations, overall beef consumption in Korea would have been much higher if the BSE outbreak in the US had not occurred.

Figure 6 shows the time paths for the composite import quantity index (*qpm*) for beef in Japan and Korea in the historical and counter-factual simulations. The time paths are similar to those for the composite quantity index (*qp*), but with a few differernces. In P1, there is a much larger increase in *qpm* compared with *qp* in Korea (58.6% compared with 11.0%, respectively). This is due to a strong change in preferences toward imported beef by the representative household in Korea in P1. However, in P2 in the historical simulation, the reduction in *qpm* for the representative households in Japan and Korea is much larger than the reduction in *qp*. This occurs because the representative household in both regions substitutes away from imported beef to domestically produced beef due to increases in the price of imported beef. In periods P3 and P4, the rebound effect is a little stronger due to a decrease in the relative price of imported beef and a shift in preferences towards imported beef in P4.

Figure 7 shows the time paths for beef exports by the US and Australia to Japan in the historical and counter-factual simulations. In the historical simulation, US beef exports to Japan drop to essentially zero in P2, due to BSE-related SPS regulations, and then slowly rebound in P3 and P4. However, the level of US exports do not return to the level in P1. For Australia, beef exports to Japan increase in P2 as the SPS regulations cause the representative household in Japan to substitute from US and Canadian imports to other sources (namely Australia and New Zealand). In P3 and P4, Australia beef exports to Japan decline, mainly due to preference changes by the representative household in Japan away from Australian (and New Zealand) beef back towards US and Canadian beef.

In the counter-factual simulation, both US and Australian beef exports to Japan decline from their levels in P1, due to the overall decline in beef consumption in Japan (see Figure 5 and Figure 6). However, US beef exports have a larger decrease, from 343,600 MT in P1 to 232,200 MT in P4, compared with Australian beef exports, which decrease from 290,100 MT in P1 to 255,800 in P4. The larger decrease in US exports is mainly due to larger import price increases for US beef relative to Australian beef in periods P3 and P4, which can be attributed to two factors: relative differences in the growth of import demand and the elasticity of transformation

(σ_{T1}). Had the BSE event not occurred, during periods P3 and P4 there is a larger growth in the import demand for US beef relative to Australian beef, with the export quantity index (*qom*) growing by 13.7% for the US versus 10.8% for Australia. The larger import demand growth, all else constant, leds to stronger growth in export prices for the US relative to Australian beef. In addition, changes in overall beef production in the US and Australia adds to this relative price difference. Beef production in the US remains relatively constant in P3 and P4, but production going to the domestic market decreases by 1.6%, due to an overall reduction in beef consumption in P4 by the US representative household. As noted earlier, the shift in US beef production towards export markets and away from the domestic market requires the export price index (*pmei*) to increase relative to the overall price index (*pm*). With an inelastic elasticity of transformation between the domestic and export markets, a relatively large shift towards exports requires a relatively large increase in the *pmei*. However, because of a 5.4% growth in domestic demand for beef in Australia, due to stronger growth in per-capita GDP, the relative growth in Australian beef exports to domestic sales is much smaller, requiring a smaller increase in *pmei*.

Figure 8 shows the time path of US and Australian beef exports to Korea in the historical and counter-factual simulations. In the historical simulation, US beef exports to Korea follow a similar path of exports to Japan. However, Australian beef exports to Korea, which increase in P2 due to the SPS regulations, continue to grow in P3 and P4 due to the strong growth in beef consumption (*qp*), due to strong income growth. In the counter-factual simulation that eliminates the BSE event, because of the steady growth in beef consumption (*qp*) in Korea, US and Australian beef exports also have a relatively steady growth. From time periods P1 to P4, US beef exports to Korea grows by 47,500 MT while Australian beef exports grow by 37,500 MT. It is also interesting to note the different rank of US beef exports to Korea relative to Australian beef exports. In the historical simulation which matches observed patterns, US beef exports fall well below and never recover to overtake Australian beef exports. However, in the counterfactual simulation the US maintains its number one export position ahead of Australia through period 4.

Figure 9 and Figure 10 show the time path of beef exports from Canada and New Zealand to Japan and Korea in the historical and counter-factual simulations. Because both these countries had shipped smaller quantities of beef to Japan and Korea, the impact of the BSE outbreak on the quantities exported are also smaller. Both Canada and New Zealand shipped approximately 31,500 MT of beef combined to Japan and Korea in P1. In P2 of the historical simulation, those combined shipments drop to approximately zero for Canada and 91,000 MT for New Zealand. In P3 and P4 of the historical simulation, New Zealand beef exports to Japan and Korea declined, while Canadian exports to Japan recovered somewhat, but remain below the level in P1. Canadian beef exports to Korea remained close to zero. In the counter-factual simulations, beef exports to Japan from Canada and New Zealand remain close to their levels in P1 while beef exports to Korea grow by less than 10,000 MT from P1.

4.2.2 Changes in Total Beef Exports

While the BSE outbreak directly led to the beef import restrictions by Japan and Korea, US beef exports to other regions also declined. For example, US beef exports to Canada, Mexico, and the XSM region decrease by approximately 150,000 MT in P2 from their levels in P1 (see Table 5). In the historical simulation, there were negative preference shocks within the import nest (*apm*) for US beef imports in most export destinations.[19] Thus, if the BSE outbreak had not occurred, then these negative preference shocks would also not have occurred and US beef exports to markets other than Japan and Korea could also be higher than in the historical simulation.

[19] Similarly, there are negative preference shocks within the import nest for Canadian beef in most destinations.

Because the model assumes products that are differentiated by market destination, one cannot simply add up the changes in export quantities across destinations to determine a percentage change in overall level of exports. Instead, one can compare the time paths of the export quantity index (*qom*) for these countries. Figure 11 shows the time paths of the normalized beef export quantity index for the US and Australia.[20] In the historical simulation, there is a small increase in the US beef export quantity index in P1 of 1.3%. This is followed be a 35.2% decrease in P2 and then a recovery in periods P3 and P4. At the end of P4, the US beef export quantity index is 10.9% larger than in P1, before the BSE outbreak occurred. For Australia, there is a stronger growth in the beef export quantity index in P1 and P2 of 9.0% and 16.9% respectively. The latter reflecting the shift towards Australian beef due to the BSE outbreak in the US and Canada. However, in P3 and P4, the beef export quantity index remains basically constant. At the end of P4, the Australian beef export quantity index is 16.7% larger than in P1.

In the counter-factual simulation, the beef export quantity index for both the US and Australia increases in each of the last three time periods. As noted earlier, this is a reflection of the growth in income and population globally. If the BSE outbreak had not occurred, the US beef export quantity index would have been 7.3% larger in P4 than in the historical simulation. For Australia, the beef export quantity index in P4 is essentially identical to the index in the historical simulation.

Figure 12 shows the time paths of the normalized beef export quantity index for Canada and New Zealand. The time path for Canada in the historical simulation exhibits a pattern different than for the US, with the drease in the export quantity index in P3 rather than in P2.

[20] Both indices are normalized to equal one in the initial equilibrium which allows a comparison of how the indices changes over time for a given exporter. As such, the normalized values do not indicate the overall level of exports.

During period P2, there is a large preference shift by the representative household in Canada towards domestically produced beef and away from imported beef. The quantity of Canadian beef sold in the domestic market increased by 25.3% in P2 of the historical simulation. The increase in the demand for domestically produced beef leads to a 31.5% increase in the producer price of beef sold in the domestic market. This in turn leads to an increase in the overall producer price index (*pm*) and an outward shift in the production possibilities frontier for beef in Canada by 19.4%. With an inelastic elasticity of transformation between domestic and export markets, the outward shift in the production possibilities frontier leds to larger production going to both the domestic and export markets, with the export quantity index increasing by 9.3%. In P3, there is a 30% reduction in Canadian beef exports to the United States, which accounts for approximately 75% of Canadian beef exports. In addition, there is a preference shift back towards imports by the representative household in Canada, leading to a 4.9% reduction in the quantity of Canadian beef sold in the domestic market. Both of these factors lead to lower producer prices in the domestic and export markets, and a 9.8% inward shift of the production possibilities frontier. The beef export quantity index decreases by 23.4% in P3. In the last period, there is a slight rebound in the export quantity index for Canada.

In the counter-factual simulation, the normalized beef export quantity index for Canada is 4.5% higher in P2 than in the historical simulation, due to larger exports to the US, Japan, and Korea. While this index drops slightly in P3, due to lower beef exports to the US, the drop is much smaller than in the historical simulation. The export index rebounds slightly in P4, due to slightly higher Canadian beef exports to China, Mexico, and the XAS region. Overall, the export quantity index is 25.2% larger in P4 in the counter-factual simulation compared with the historical simulation.

For New Zealand in the historical simulation, there is a sharp increase in the beef export quantity index in P2, similar to the change for Australia, due to the substitution in beef imports away from the US and Canada, and towards New Zealand and Australia. In P3, the beef export quantity index for New Zealand declines by 10.4% as preferences for imported beef switch back towards the US. In P4, there is a slight increase of 2.4% in the export quantity index due to preference shifts towards New Zealand beef in Japan, Korea, XSM, and XAF. If the BSE outbreak had not occurred, the overall growth in New Zealand beef exports would have much lower in P2, by approximately 9%. In periods P3 and P4, New Zealand beef exports to Canada are significantly larger than in the historical simulation, due to the removal of preference shifts towards US and Australian beef. Thus the overall export decline in P3 is less than in the historical simulation and the export growth in P4 is larger than in the historical simulation. This results in the beef export quantity index being 3.4% larger in P4 in the counter-factual simulation than in the historical simulation – or larger beef exports from New Zealand if the BSE outbreak had not occurred.

While one cannot sum the quantity changes across the different destinations, it is possible to compare quantity changes across time for a given exporter-importer pair. Table 8 reports the changes in the quantity of beef exports from the US, Australia, Canada, and New Zealand to select importing regions between the counter-factual and historical simulations in periods P2 through P4. In periods P2 and P3, the largest increases in the quantity of US beef exports are to Japan and Korea, as would be expected given the import restrictions in these countries. Note that because of the rebound in US exports to these regions in the post-BSE periods, the differences between the historical and counter-factual simulations become less over time. The other two regions were the US has substantial gains in beef exports are the XSM (rest of South American) and XAF (rest of Africa). Both of these regions experience significant growth in beef imports in the historical simulation, with the import quantity index nearly tripling for the XSM region and by nearly 8 times for the XAF region. In the counter-factual simulation, there is additional growth in overall beef imports in the both regions due to slightly lower overall prices for beef imports. However, because there are quite large changes in beef imports from some regions, such as Brazil, Argentina, and India in the historical simulation that are not likely related to the BSE outbreak, all changes in preferences imports by source and export technology by destination of exports are maintained in the counter-factual simulation for these regions. Only the preferences changes for US beef and any technology shocks for US beef to these regions are eliminated in the counter-factual simulations. Thus, the increases in beef imports in these two regions can almost entirely be attributed to beef imports from the United States. Thus, it is likely that the gains in US beef exports to these two regions may be overstated.

For Canada, the gains in beef exports to Japan and Korea are relatively small because these markets were not an important destination for Canadian beef before the BSE outbreak. The largest increase in Canadian beef exports are to the US market. The largest gains are in P2 and P3 due to the removal of negative preference shifts for Canadian beef by the US representative household in the historical simulations.

For Australia and New Zealand, beef exports to Japan and Korea would have been lower if the BSE outbreak had not occurred. The reduction in beef exports to Japan by Australia are relatively large, a reduction of over 100,000 MT in P2 and P3. However, the lower exports to Japan and Korea are offset by larger Australian beef exports to the US, Canada, and XAS. The preference shifts in the historical simulation towards Australian beef, leads to higher export and import prices in most destinations. Since this does not happen in the counter-factual simulation, prices for Australian beef are relatively lower, helping to increase exports to these three key destinations. Similarly for New Zealand, the reductions in beef exports to Japan and Korea are offset by increases in exports to Canda, the US, and the XAS.

4.2.3 Changes in Value of Beef Production

In addition to determining the changes in export quantities by exporter-importer pairs, one can also determine the change in the producer value of beef production between the historical and counter-factual simulations. An advantage of using the change in value is that one can sum the changes in dollar values across the different market destinations to obtain an overall change in value. A limitation of using values is that while the the model can "match" the change in trade quantities for the key bilateral pairs in the historical simulation, it is more difficult to match price changes because only unit-values are observed. In addition, the structure of preferences and technology in the model, as well as the assumed parameter values, will also play a key role in determining how the price levels change in the historical and counter-factual simulations. Thus, the price levels from the simulations may be quite different than the observed unit-values.

Table 9 reports the change in the value of exports and the value of production sold in the domestic market for several select regions over the time periods P2 through P4. For the US, the total value of beef production would have been nearly $6.2 billion higher if the BSE outbreak had not occurred. Most of this increase, $6.1 billion, comes from the additional beef exports that would have occurred without the BSE outbreak. There is very little change in the overall US producer value of beef sold domestically, even though the quantity of beef sold domestically is higher in time periods P2 through P4. In periods P2 and P3, lower import prices in the counter-factual simulation leads to lower producer prices for the domestic market, and a lower value of domestic sales. In P4, higher import prices in the counter-factual simulation reduces the level of imported beef and leads to a higher domestic price and value of domestic sales. The increase in value of domestic sales in P4 basically offsets the reductions in P2 and P3.

For Canada, the value of beef exports would have been nearly $1.7 billion higher if the BSE outbreak had not occurred. However, unlike the US, a large portion of this increase in export value is offset by lower value of domestic sales in Canada. Lower import prices for Australian and New Zealand beef in Canada lead to much larger levels of imports in the counter-factual simulation. The increased import competition leads to lower quantities of Canadian beef being sold domestically as well as lower producer prices in time periods P2 through P4. In addition, because beef imports comprise a significant share of total beef expenditure in Canada, nearly 30% in P4 in the historical simulation, larger beef imports will have a much larger impact on domestic prices than in regions where imports are a much lower share of total beef expenditure. Overall, the value of domestic sales would have been about $1 billion lower for Canadian beef producers if the BSE outbreak had not occurred. Thus, the net gain in sales for Canadian beef producers would have been about $680 million if the BSE outbreak had not occurred.

The value of beef production for Australia and New Zealand across time periods P2 to P4 is lower in the counter-factual simulation than in the historical simulation. The impact is much larger for Australia, with a $1.45 billion reduction in the value of beef production compared with a $235.4 million reduction for New Zealand. For both regions, this reflect a reduction in the value of exports in time periods P2 and P3. For Australia, the reductions in the value of exports in P2 and P3 range from $775.1 million to $704.6 million. Without the shift in preferences towards Australian beef in P2 of the historical simulation, the level of beef exports (e.g., beef export quantity index) is lower, which also leads to lower export prices (e.g., beef export price index) in the counter-factual simulation. In period P4, there is very little difference in the value of Australia beef exports between the historical and counter-factual simulation because the levels of export price and quantity indices are very similar. For Zealand, the largest decrease in the value of exports, $281.7 million, occurs in time period P2. In time periods P3 and P4, significant increases in beef exports to Canada, due to the removal of a shift in preferences in the import nest for the Canadian representative household, reduces the reduction in the value of exports to $50.2 million in P3 and leads to an increase in the value of exports of $96.5 million in P4. Because both regions import very little beef, and thus little import competiton in the domestic market exists, and with inelastic substitution between the domestic and export markets in production, there are only small differences in the value of domestic beef sales between the historical and counter-factual simulations.

There are also significant changes in the value of beef production in other regions in the model. For Argentina, Brazil and the XSM region, which are important beef exporters and import very little beef, the values of beef exports would have been lower if the BSE outbreak had not occurred. Across the time periods P2 through P4, the value beef exports would have been $134.1 million lower for Argentia, $427.7 million lower for Brazil, and $646.6 million lower for the XSM region. Similar to Australia and New Zealand, the value of domestic beef sales would not be very different for these regions. Conversely, the XAS region is a major beef importer, with large increases in beef imports in the historical simulation. Because Australia and New Zealand are important suppliers of beef imports to the XAS region, the reduction in import prices for beef from these regions in the counter-factual simulation leads to increased beef imports. This in turn leads the representative consumer in the XAS region to substitute away from domestically produced beef, thereby leading to a reduction in the domestic sales of beef. Across the time periods P2 through P4, the value of domestic beef sales in the XSM region decrease by $680.4 million. Finally, the value of beef production in the EU-27 is $693.2 million lower in the counter-factual simulation compared to the historical simulation. About two-thirds of this reduction, or $457.4 million is a reduction in the value of beef exports, due to increased competiton from the US in the XAF market. The loss of exports to the XAF region leads to the EU-27 substituting to other destination markets, mainly intra-EU trade. This shift reduces the price of intra-EU imports, causing the EU representative household to substitute away from beef produced and consumed within a given EU Member State, lower domestic beef prices and thus a lower value of domestic sales.

4.2.4 Eliminating Beef Preference Shifts in China

Because China has maintained a long-standing ban on imported beef from the US and European countries with a history of BSE outbreaks, this counter-factual experiment considers the case of removing the negative preference shocks against imported beef (*apd*) from the historical simulation in periods P2 through P3, as well as reducing the negative preference shocks against all beef (*ap*) in the historical simulation periods P2 through P4. These targeted preference shock eliminations are in addition to all other preference shocks eliminated in the base counter-factual experiment. In this historical simulation, there are preference shifts toward domestic beef and away from imported beef by the representative Chinese household in periods P2 and P3. Because share of total beef expenditures for imported beef in China is very small, approximately 0.005, even a small preference shift towards domestic beef will require a much larger preference shift against imported beef to keep the budget constraint from being violated. In P4, there is a preference shift towards imported beef in China that accounts for the large growth in beef imports in that period in the historical simulation. In the counter-factual experiments, the negative preference shocks to imported beef in P2 and P3 are eliminated, but the positive shock in P4 is maintained.

For overall beef, there is a small preference shift against beef in the pre-BSE time period in the historical simulation. But during and after the BSE outbreak, the negative preference shifts are much larger. This suggests that the BSE outbreak may have affected overall preferences for beef in China. However, there are also larger preference shifts against chicken and pork in periods P2 through P4 compared with P1 as well. Thus, there entire preference shift against beef may not be entirely related to the BSE outbreak, but to overall beef consumption increasing more slowly than would be expected given the demand elasticities and the growth in income in population in China during these time periods. Thus, two alternative values of *ap* are considered in the counter-factual experiments: one that maintains the changes in *ap* for beef in China from the historical simulation and one that reduces this change by one-half.

Figure 13 shows the time path of the normalized composite import quantiy index for China for the historical simulation, the base counter-factual, the counter-factual that eliminates the negative preference changes for imported beef in China (*apd*), and the counter-factual that eliminates the preference change for imported beef and one-half the preference change for overall beef (*ap*). In the historical simulation, the composite import quantity index declines sharply in P2 by approximately 50% and then more modestly, approximately 6% in P3, before sharply rebounding in P4. This reflects the negative preference shift for imported beef in P2 and P3 and the positive shift in P4. In the base counter-factual simulation, which maintains all of the preference changes for beef in China, the reduction in the import quantity index in P2 is much smaller, at 21.3%, due to lower import prices for imported beef from Australia and New Zealand.

In P3, the import quantity index remained virtually unchanged, at a 0.7% increase, because a larger share of imported beef implies a smaller negative preference change in this time period. In P4, the preference shift towards imported beef leads to a sharp increase in beef imports, leaving the import quantity index at a similar level to that of the historical simulation at the end of P4. So in the base counter-factual experiment, Chinese beef imports would be higher than the historical levels in only periods P2 and P3.

In the next counter-factual experiment, the negative preference shifts away from imported beef in China are removed in P2 and P3, but the preference shift away from beef is maintained. Without these shifts, the beef import quantity index for China increases by 3.7% in P2, compared with a 21.3% decrease in the base counter-factual experiment. In period P3, this index increases by an additional 18%, compared with a 0.7% increase in the base counter-factual experiment. By the end of P4, the beef import quantity index for Chinese beef imports would be 7.8% higher compared with the base counter-factual. So while removing the preference shift for imported beef yields larger Chinese beef imports in P2 and P3 compared with historical levels, the difference by the end of P4 is modest.

In the last experiment, one-half of the overall preference shift against beef for China is removed, in addition to the the shift against imported beef. The beef import quantity index increases by 19.8% in P2 and 39.1% in P3, compared with the 3.7% and 18.0% increases if only the shift against imported beef is removed. At the end of P4, the beef import quantity index would be 53.5% higher compared with the base counter-factual experiment.

For the US, the Chinese import ban has essentially precluded the US from exporting beef to China. As shown in Table 10, US beef exports dropped from 16,100 MT in the pre-BSE period, to zero in the remaining time periods in the historical simulation. In the base counter-factual experiment, US beef exports to China totaled almost 80,000 MT over the last three time periods, with the majority being in time period P4. If the negative preference shifts for imported beef in P2 and P3 are also removed, the US would export an additional 15,000 MT of beef to China. If one-half of the negative preference shifts for beef are also removed, US beef exports would be nearly 50,000 MT higher than the base counter-factual experiment. Across all counter-factual experiments, the Chinese market would become the eighth largest beef market for the US behind Mexico, Canada, Japan, Korea, XAS, XSM, and XAF regions. So while the growth in US exports to China is modest in the model, it is important to note that the ending time period of 2010-2013 only picks up the beginning of a large increase in Chinese beef imports.

5. Summary

The discovery of Bovine Spongiform Encephalopathy (BSE) in the US in December of 2003, prompted the stoppage of beef imports by some of the US's largest traditional beef trading partners, resulting in sizeable losses to industry. While a number of economic assessments of BSE on production and trade flows have been undertaken, an important retrospective policy question is: what would U.S. beef exports have looked like had the BSE event not occurred?

In this paper, we developed a partial equilibrium model of global meat production and trade. This model is used to conduct a series of historical simulations over the period 2001 to 2013 to capture the observed impacts of the BSE outbreak on global meat trade. Then a set of counter-factual experiments are constructed that adjusts the changes in preferences and technical change in the historical simulation to determine what meat trade would have looked like if the BSE outbreak had not occurred. Summarizing the implications of this global counter-factual scenario is difficult because predicting future BSE or other animal disease events is challenging and importing countries have different risk perceptions and thus policy reactions to such food safety events. However, several results are noteworthy.

Over the 2004 to 2013 period, US beef exports would have been over 2 million MT higher if the BSE outbreak had not occurred. Higher exports to Japan and Korea, which banned US exports for nearly three years, would have only accounted for a little more than one-half of this increase. Larger exports to Mexico, to South American destinations other than Brazil and Argentina, and to Africa would have accounted for approximately 37% of this increase. The total producer value of US beef exports to all destinations would have been $6.1 billion higher if the BSE outbreak had not occurred, reflecting a higher level of exports as well as export prices.

The impact on quantity of US beef sold domestically would have been much smaller, with an increase of approximately 350,000 MT over this 9 year period if the BSE outbreak had not occurred. The relatively short-lived impacts of the BSE outbreak in the US domestic market as well as greater import competition from Australia and Canada keeps the gain in domestic sales modest. The increased import competiton would place downward pressure on the US producer price of beef sold domestically, leading to only a $84 million increase in the producer value of domestic sales. Overall, the value of US beef production would have been $6.2 billion if the BSE outbreak had not occurred.

Avoiding the major disruptions in the global beef trade from the US BSE outbreak would have also affected other beef exporting regions. Canada, which also faced import bans after the US outbreak, would have exported approximately 350,000 MT more beef if the BSE outbreak had not occurred. Most of the increase in Canadian beef exports would have gone to the US market. The value of the additional exports to all destination for Canadian beef producers would have been $1.7 billion over the 9 year period. However, domestic sales for Canadian beef producers would have been $1.0 billion lower due to increased import competition from Australia and New Zealand in the Canadian market. For Australian and New Zealand, the quantity of total beef exports would not have been substantially affected if the BSE outbreak had not occurred. However, the destination mix would have been greatly affected, with much lower exports to Japan and Korea being offset with increased exports to other destinations, such as the US and Canada. Because the import ban imposed by Japan and Korea greatly enhanced the price of imports from Australia and New Zealand, the prices received by beef producers in Australia and New Zealand would been much lower if the BSE outbreak had not occurred. So even though the quantity of total beef exports would not be affected, the total value of exports would have been $1.5 billion lower for Australian beef producers and $235 million lower for New Zealand producers. The value of beef exports for South American producer would have been $1.2 billon lower if the BSE outbreak had not occurred, due to decreases in export quantity and export prices received. Finally, the value of beef production in the EU-27 would have been $693.2 million lower if the BSE outbreak had not occurred, with about two-thirds of this reduction, or $457.4 million being a reduction in the value of beef exports, due to increased competiton from the US in African markets.

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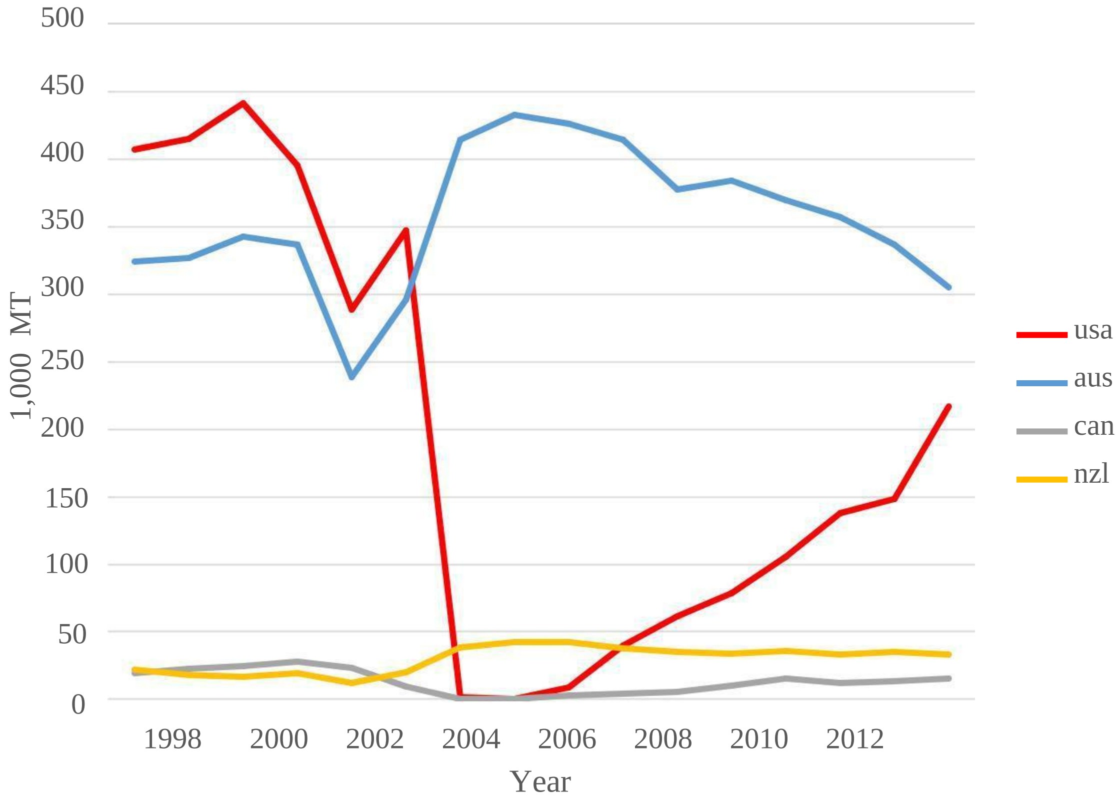

Figure 1. Beef Exports to Japan by Exporting Country and Year

Source: UN/COMTRADE

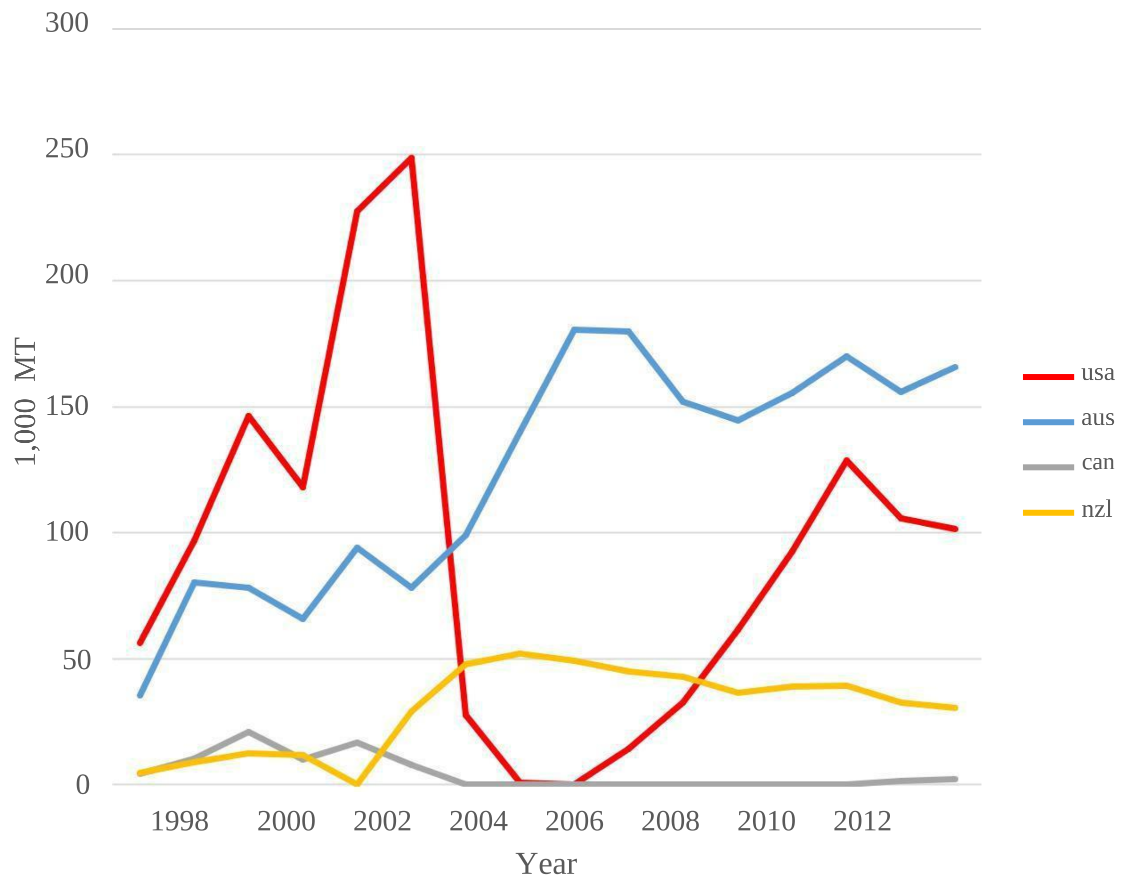

Figure 2. Beef Exports to Korea by Exporting Country and Year

Source: UN/COMTRADE

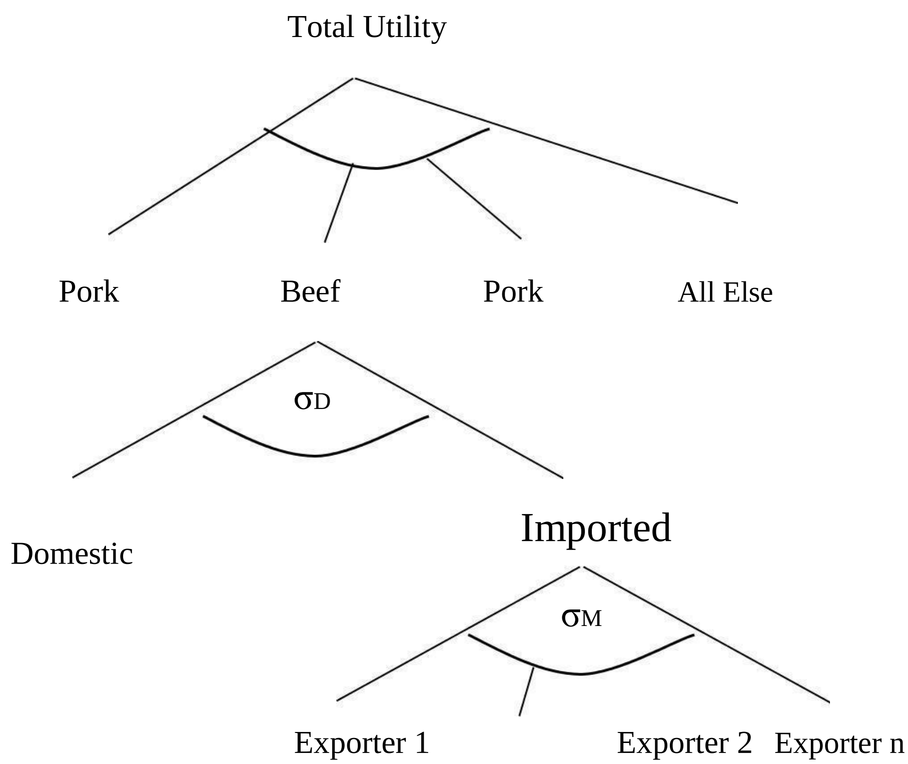

Figure 3. Structure of Preferences for Representative Consumer

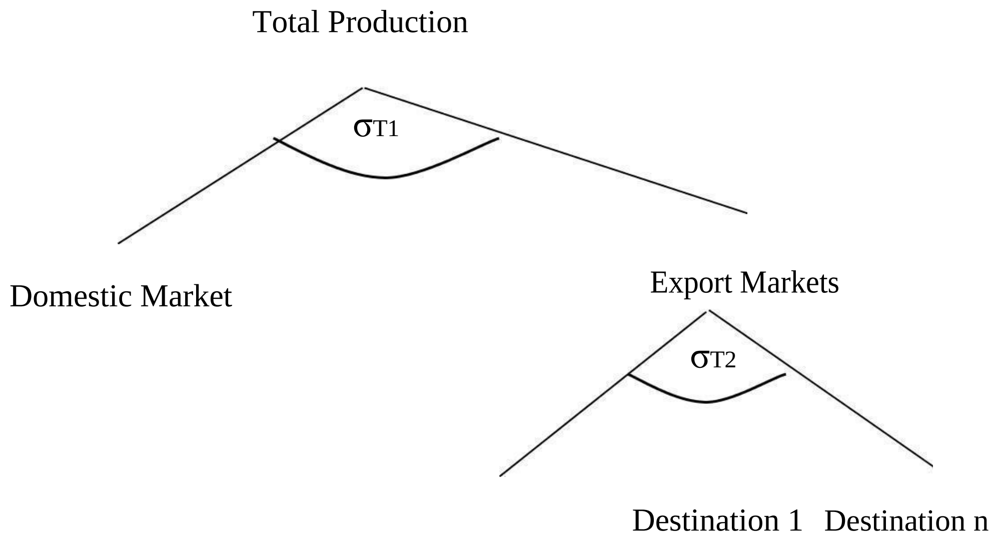

Figure 4. Structure of Nested Constant Elasticity of Transformation Production Possibilities Frontier

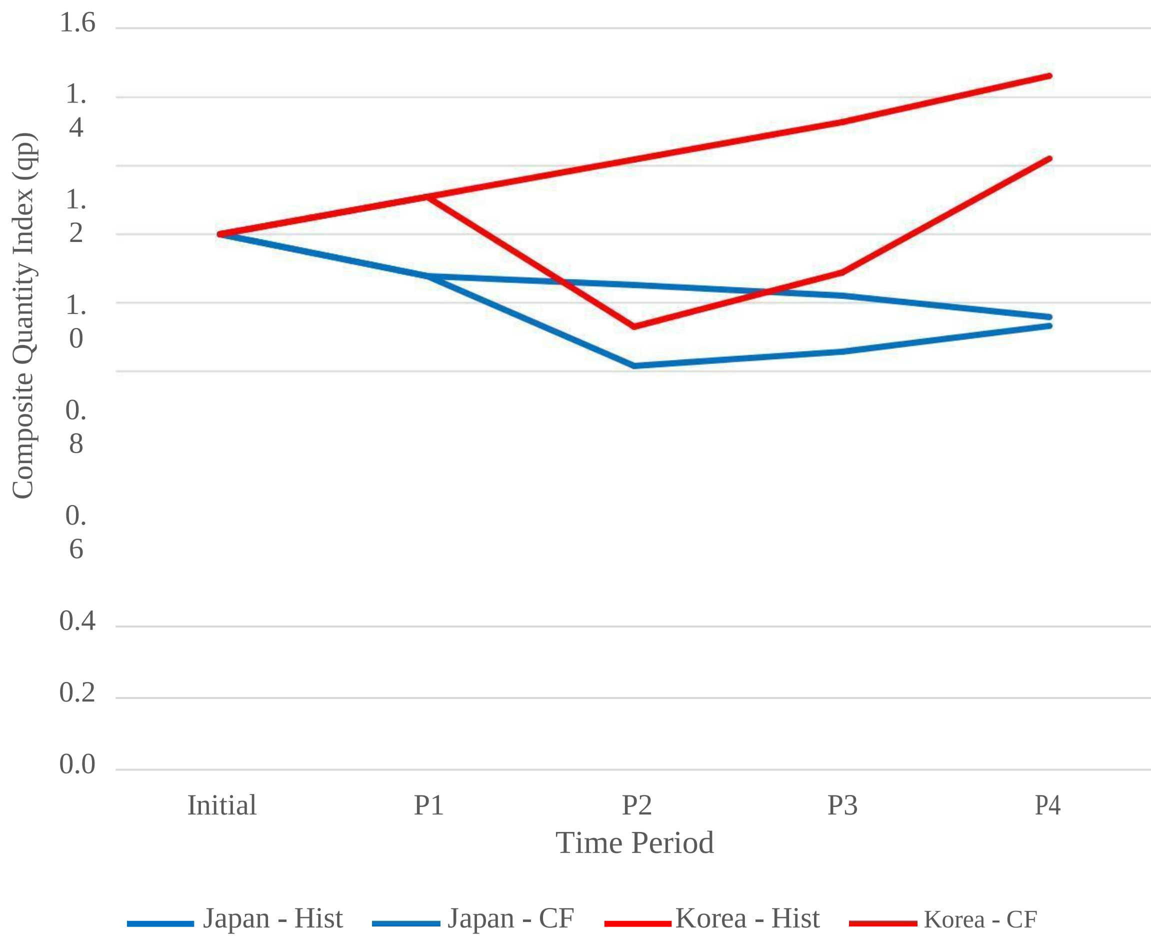

Figure 5. Normalized Composite Beef Consumption Quantity Index for Japan and Korea in the Historial and Counter-factual Simulations

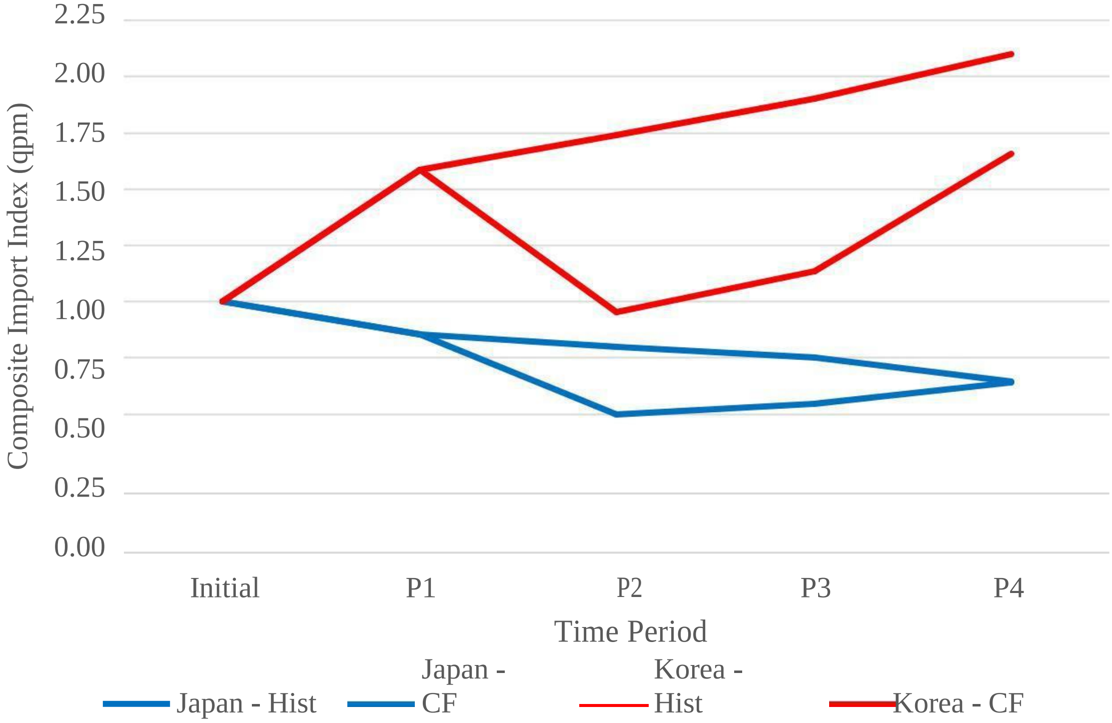

Figure 6. Normalized Composite Beef Import Quantity for Japan and Korea in the Historial and Counter-factual Simulations

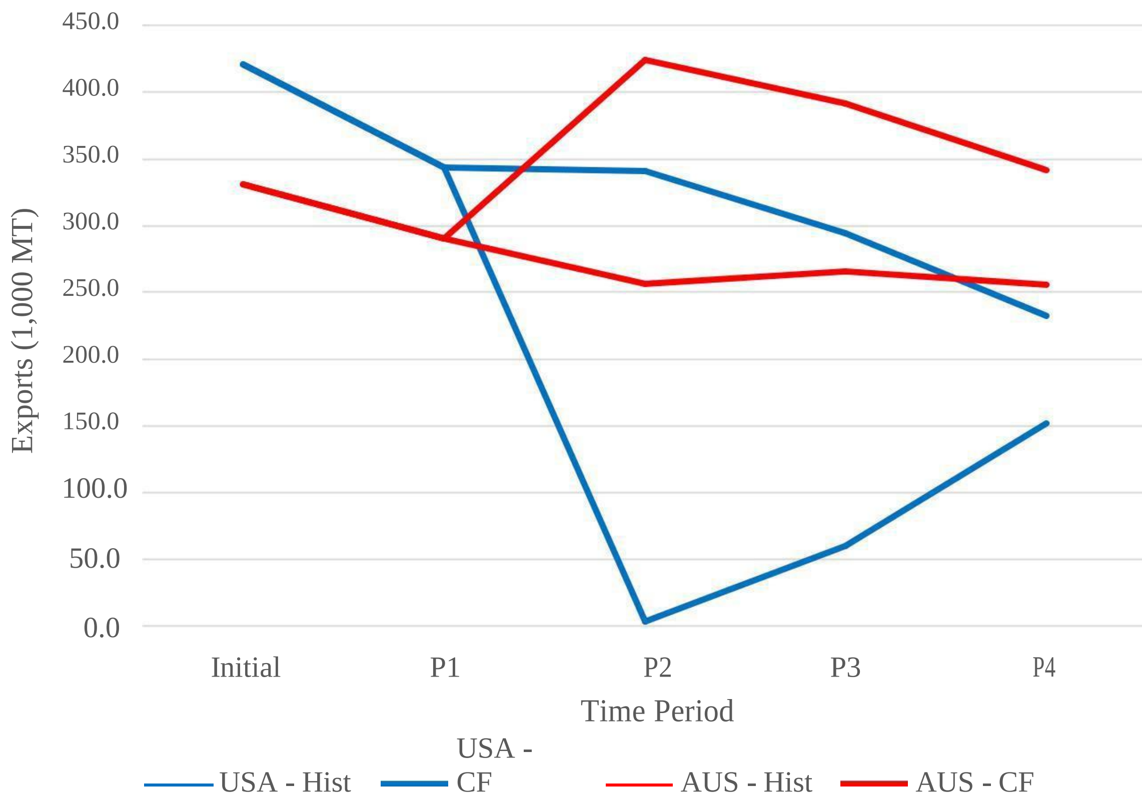

Figure 7. Beef Exports to Japan by United States and Australia in the Historical and Counter-factual Simulations

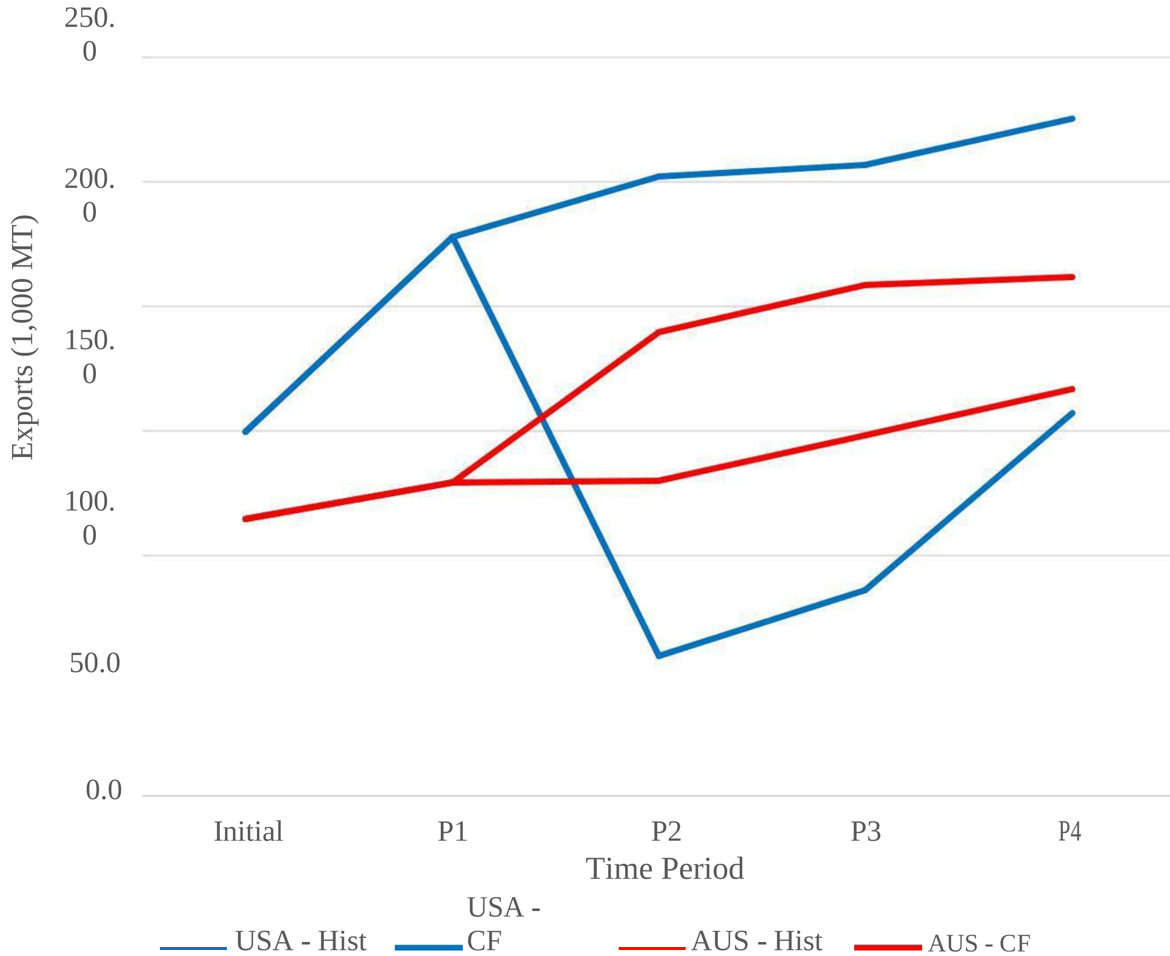

Figure 8. Beef Exports to Korea by United States and Australia in the Historical and Counter-factual Simulations

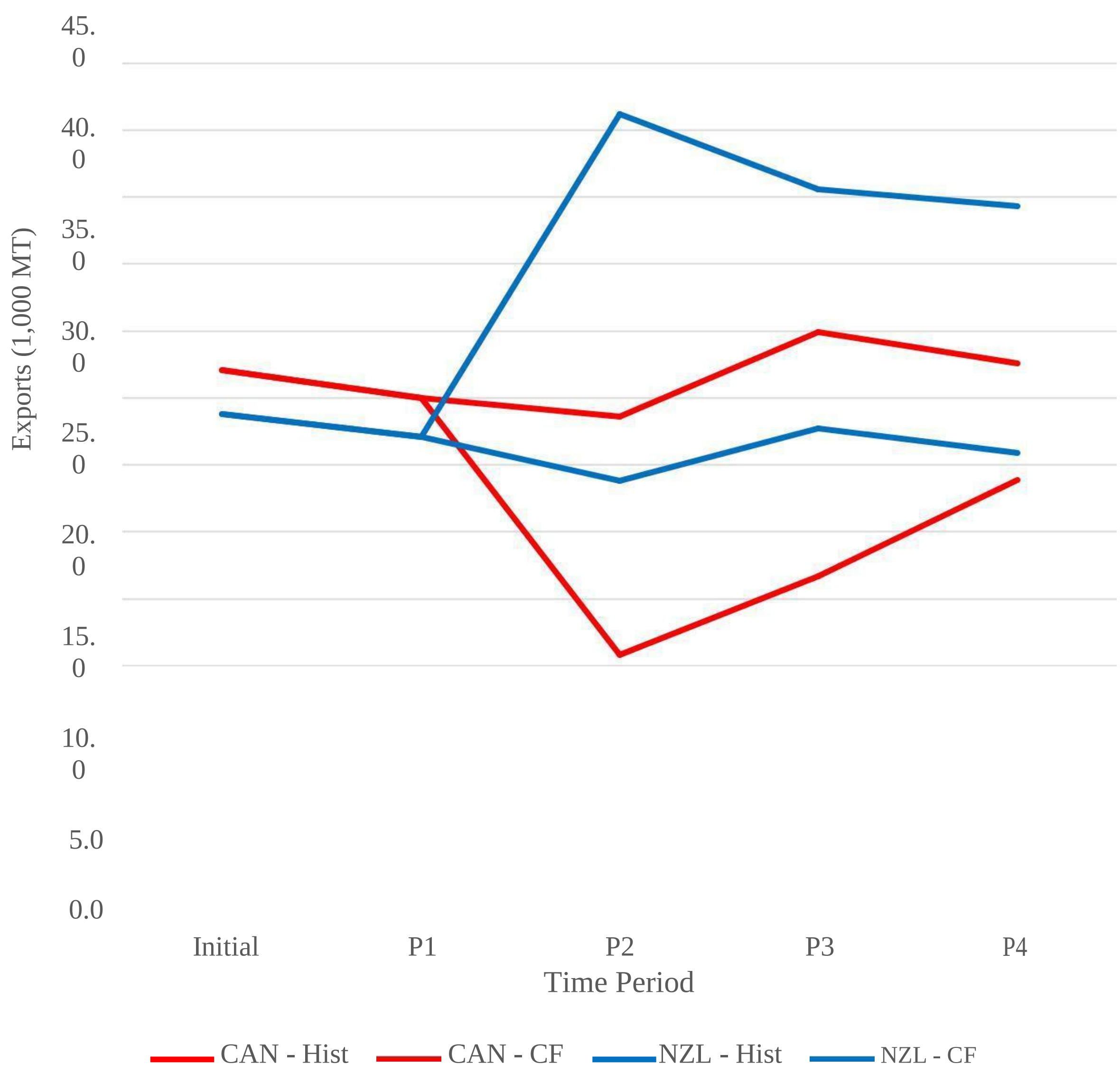

Figure 9. Beef Exports to Japan by Canada and New Zealand in the Historical and Counter-factual Simulations

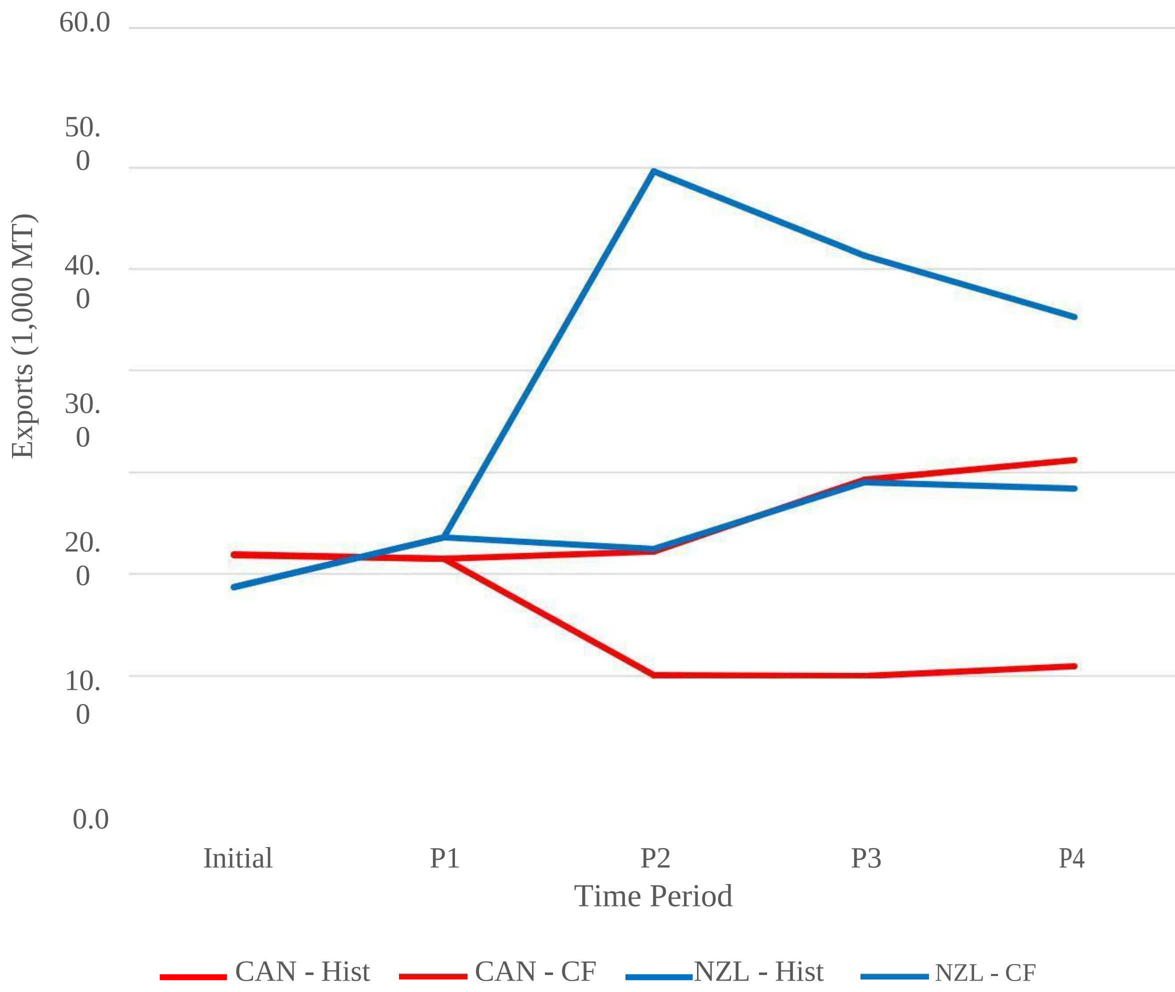

Figure 10. Beef Exports to Korea by Canada and New Zealand in the Historical and Counter-factual Simulations

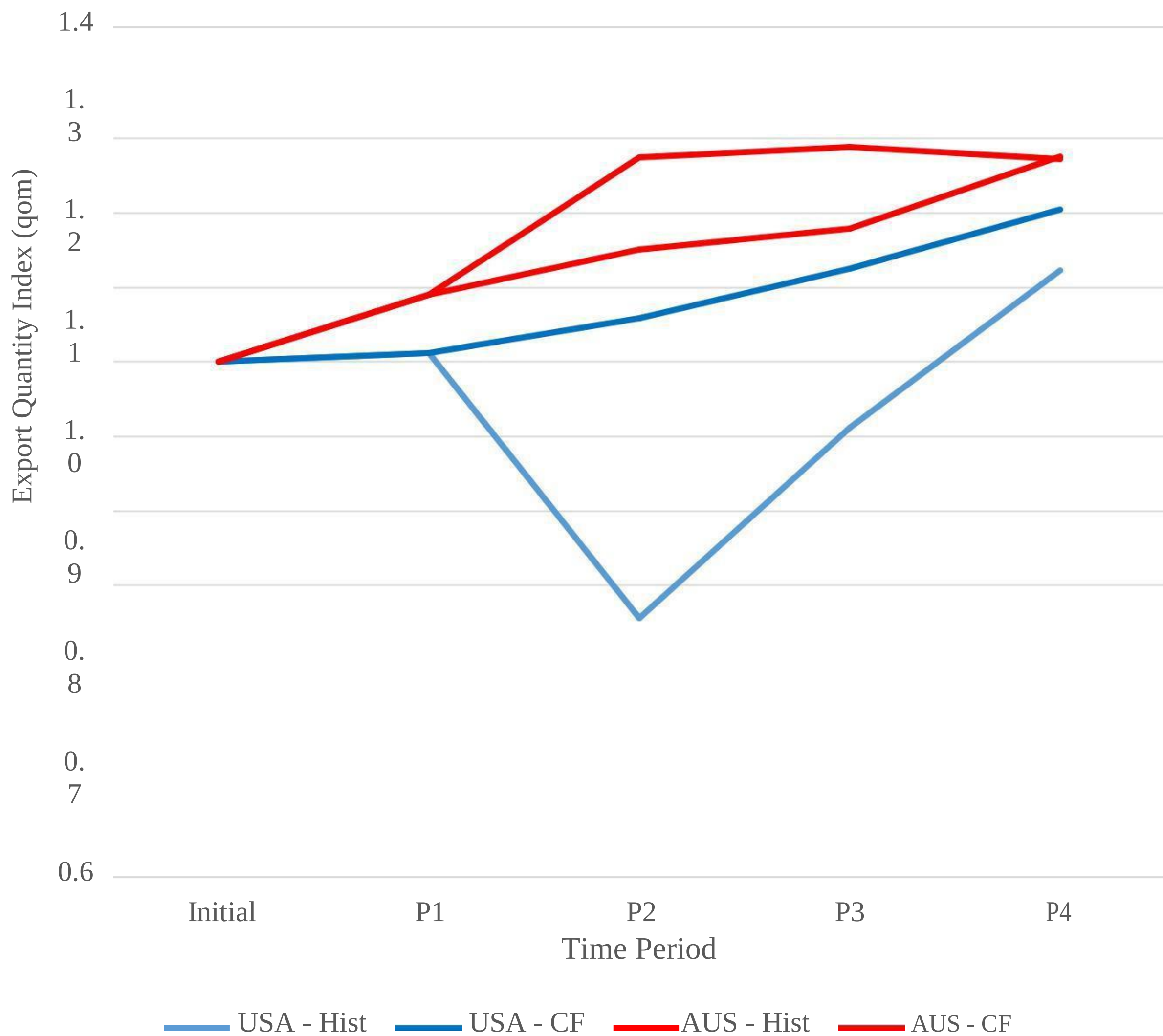

Figure 11. Normalized Beef Export Quantity Index for the US and Australia in the Historical and Counter-factual Simulations

Figure 12. Normalized Beef Export Quantity Index for Canada and New Zealand in the Historical and Counter-factual Simulations

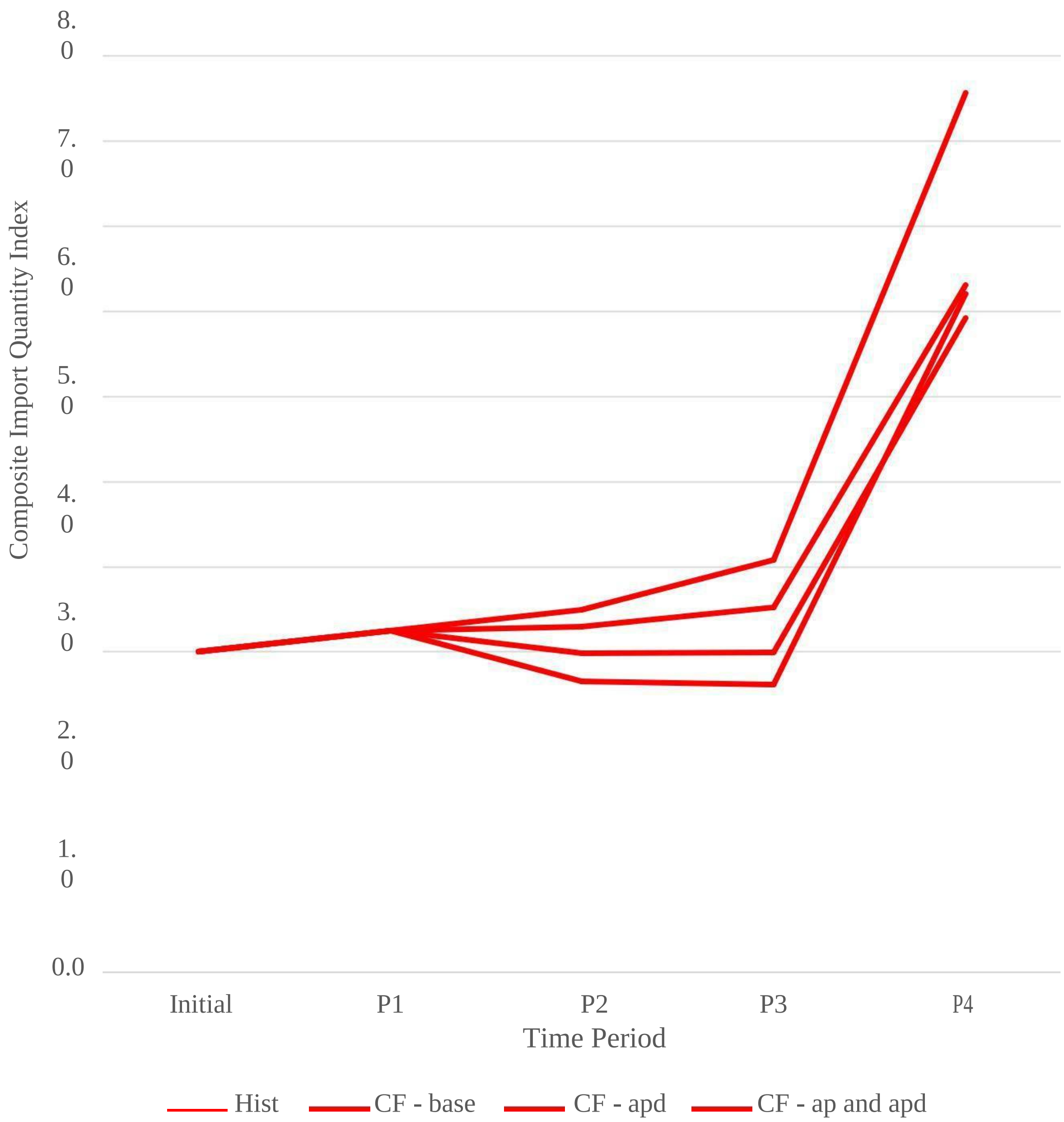

Figure 13. Normalized Composite Import Quantity Index for China Across Historical and Counter-factual Experiments

Table 1. Use of Average Export and Import Unit-Values for Domestic Prices by Region and Commodity

Commodity	Both	Exports	Imports
Beef	Canada	Argentina	China
	EU27	Australia	Japan
	United States	Brazil	Korea
	XSM	India	Mexico
	XCB	New Zealand	Russia
	XEU		XAS
			XAF
			XME
			XOC
Chicken	Canada	Argentina	Japan
	China	Australia	Korea
	EU27	Brazil	Mexico
	India	United States	Russia
	New Zealand		XAS
	XAF		XCB
	XEU		XOC
	XME		
	XSM		
Pork	Australia	United States	Argentina
	Canada	Brazil	Japan
	China		New Zealand
	EU27		Russia
	India		XAF
	Korea		XAS
	Mexico		XCB
	XSM		XEU
			XME
			XOC

Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

Table 2. Number of Bilateral Exogenous Shocks for Beef in Historical and Counter-factual Simulations by Time Period

Variable	P1[a]	P2	P3	P4
Historical Simulation				
Quantity (*qme*)	35	75	77	69
Price (*pme*)	10	55	24	34
Counter-factual Simulation				
Import preference shifter (*apm*)	35	44	46	45
Export supply shifter (*adx*)	10	34	12	21

[a] The four time periods in the simulations are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Table 3. Total Beef Imports by Region in Historical Simulation

Region[a]	Base	Historical Simulation P1[b]	P2	P3	P4	Difference with Actual P1	P2	P3	P4
					1,000 MT				
United States	919.8	1,030.4	1,053.0	810.1	729.4	41.6	1.8	1.2	-6.6
Brazil	66.4	64.6	38.1	30.7	36.1	15.7	1.8	3.9	-2.7
China	25.7	32.0	15.0	14.8	115.1	-15.6	1.3	2.9	4.0
Argentina	18.9	13.0	10.6	10.3	6.9	5.2	7.5	8.5	6.0
Australia	1.3	0.9	3.4	4.4	3.8	-0.4	-0.9	2.8	0.8
Russia	484.9	598.4	676.0	834.5	740.0	29.4	-10.9	-2.3	-12.9
Mexico	346.1	397.4	335.0	334.6	241.5	6.8	1.1	-11.2	0.5
EU-27	1,757.5	1,706.1	2,116.2	2,312.6	2,460.5	31.6	-27.7	-23.4	0.1
Canada	186	219.9	96.5	138.6	173.8	0.4	2.6	-1.4	-3.1
India	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	2.8	1.4	0.6	0.9	0.5	-5.0	-2.4	-3.4	-4.5
Japan	798.7	683.2	482.3	506.1	557.4	11.4	3.4	-0.8	-6.0
Korea	187.3	285.2	208.7	241.5	305.9	-24.7	5.9	1.1	-2.7
XAS	292.6	470.5	550.4	734.9	893.5	-0.3	-8.9	5.5	-29.6
XSM	106.5	102.3	177.9	276.5	275.0	-0.6	10.4	0.4	-0.5
XOC	6.5	14.1	11.2	11.4	14.8	-3.7	-3.3	-1.9	-2.3
XCB	40.3	28.1	39.3	53.4	68.6	-13.4	-16.8	-5.9	-1.8
XME	156.4	226.6	319.0	387.6	516.4	9.7	9.6	-4.7	-1.7
XAF	101.1	73.0	180.8	316.8	585.7	-2.8	4.3	5.5	-4.6
XEU	50	51.6	143.5	115.4	151.9	-7.2	0.7	7.4	6.9
Total	5,548.8	5,998.7	6,457.5	7,135.1	7,876.8	78.1	-20.5	-15.8	-60.7

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Table 4. Total Beef Exports by Region in Historical Simulation

Region[a]	Base	Historical Simulation P1[b]	P2	P3	P4	Difference with Actual P1	P2	P3	P4
					1,000 MT				
United States	1,057.4	1,109.9	343.8	623.1	950.8	-13.5	1.3	0.2	1.8
Brazil	148	397.8	898.7	997.2	1,057.1	-4.4	6.4	-3.1	-9.6
China	27.1	30.4	20.0	22.2	21.6	18.2	1.1	-0.9	4.9
Argentina	170.7	137.6	368.9	394.2	234.2	6.3	-0.7	20.3	21.3
Australia	885.5	997.2	1,057.7	1,090.2	1,098.2	11.7	-0.1	-4.0	-8.8
Russia	0.6	0.7	0.7	0.7	0.8	0.2	0.4	0.3	-1.4
Mexico	3.4	3.9	6.9	19.1	73.9	-0.1	-13.0	-15.5	-36.2
EU-27	1,933.9	1,805.7	1,998.7	2,226.5	2,551.8	22.5	-32.7	6.9	1.2
Canada	420.2	442.4	458.1	328.8	330.1	-11.1	28.1	8.9	2.5
India	101.8	192.7	312.1	396.5	455.4	0.9	2.5	0.1	0.1
New Zealand	335.2	384.2	436.4	392.3	403.9	7.0	0.6	2.1	8.5
Japan	0.6	0.7	0.5	0.4	0.4	0.3	0.4	-1.0	-0.2
Korea	0.2	0.1	0.2	0.2	0.2	-0.1	0.1	-0.1	-0.3
XAS	15.6	16.6	9.4	17.0	29.7	-0.3	1.3	-1.3	-0.7
XSM	198.4	210.3	373.4	469.3	440.4	26.8	-18.5	-37.5	-12.6
XOC	0.8	0.9	1.1	1.2	1.3	0.1	0.2	0.5	0.8
XCB	37.8	43.1	46.1	65.9	87.4	-10.2	-21.4	-15.6	-36.7
XME	28.5	30.1	18.4	18.4	32.1	12.7	7.7	11.7	2.6
XAF	40.5	49.2	37.9	30.0	44.1	0.1	5.9	1.9	-0.3
XEU	142.5	145.2	68.4	42.0	63.1	11.1	9.9	10.1	1.8
Total	5,548.7	5,998.7	6,457.4	7,135.2	7,876.5	78.2	-20.5	-16.0	-61.3

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Table 5. Bilateral Beef Exports by Select Region in Historical Simulation

Region[a]	Base	Historical Simulation P1[b]	P2	P3	P4	Difference with Actual P1	P2	P3	P4
United States					1,000 MT				
United States	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brazil	3.5	4.3	0.1	0.0	0.0	4.2	0.1	0.0	0.0
China	11.1	16.1	0.1	0.0	0.1	-19.1	-0.1	0.0	0.1
Argentina	2.6	2.5	0.0	0.0	0.0	1.8	0.0	0.0	0.0
Australia	0.0	0.0	0.4	0.1	0.0	-0.1	0.4	0.1	0.0
Russia	60.5	64.3	0.9	20.8	46.1	0.0	0.0	0.0	0.0
Mexico	296.4	317.2	240.2	289.3	207.9	0.0	0.0	0.0	0.0
EU-27	10.0	12.8	1.0	4.0	16.6	11.4	0.0	0.0	-0.3
Canada	85.1	79.1	38.9	97.4	133.4	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Japan	421.3	343.6	3.3	60.1	152.1	0.0	0.0	0.0	0.0
Korea	99.8	178.1	8.5	36.2	107.6	-20.1	-1.0	0.2	0.5
XAS	34.3	54.7	20.1	43.7	106.6	0.0	0.0	0.0	0.0
XSM	9.9	8.8	1.5	5.7	14.0	4.3	0.0	-0.1	-0.2
XOC	0.1	0.2	2.1	0.4	0.2	0.0	1.8	0.2	-0.1
XCB	17.4	15.6	17.0	21.1	37.7	2.3	2.4	0.0	0.0
XME	1.1	1.7	1.5	4.6	11.0	-2.4	-2.3	0.1	0.2
XAF	2.9	9.7	6.9	35.1	113.0	4.3	0.0	0.4	1.2
XEU	1.6	1.3	1.3	4.6	4.5	-0.1	-0.1	-0.7	0.4
Total	1,057.6	1,110.0	343.8	623.1	950.8	-13.5	1.2	0.2	1.7

Table 5. Continued

Region[a]	Base	Historical Simulation[b]				Difference with Actual			
		P1	P2	P3	P4	P1	P2	P3	P4
Canada					1,000 MT				
United States	343.5	347.1	347.7	244.9	237.5	0.0	0.0	0.0	0.0
Brazil	0.5	0.6	1.3	5.4	0.5	0.6	1.3	5.4	0.5
China	1.3	1.6	0.0	0.0	3.9	-3.1	0.0	0.0	-3.0
Argentina	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.3	0.1
Australia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia	2.3	2.9	0.1	4.1	2.8	0.5	0.1	1.3	-3.3
Mexico	27.4	48.7	74.7	42.2	27.9	-3.7	9.0	-0.9	-0.9
EU-27	0.7	0.7	2.2	0.8	3.7	0.1	0.8	0.0	3.2
Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	22.1	20.0	0.8	6.7	13.9	0.0	0.0	0.0	0.0
Korea	11.9	11.5	0.1	0.3	0.1	0.0	0.0	0.3	-0.8
XAS	2.8	2.3	9.2	16.9	25.1	-3.8	0.1	0.3	0.5
XSM	4.0	3.1	7.4	0.4	0.7	-1.2	7.0	0.2	0.1
XOC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XCB	2.8	2.2	6.1	0.3	0.3	-0.6	4.5	0.0	0.0
XME	0.5	0.7	1.5	1.6	5.0	0.4	1.2	1.2	4.4
XAF	0.3	0.9	6.7	3.8	6.5	0.0	4.0	0.0	0.0
XEU	0.0	0.0	0.2	1.1	2.1	-0.3	-0.1	0.9	1.7
Total	420.1	442.3	458.0	328.8	330.1	-11.1	27.9	9.0	2.5

Table 5. Continued

Region[a]	Base	Historical Simulation P1[b]	P2	P3	P4	Difference with Actual P1	P2	P3	P4
Australia					1,000 MT				
United States	312.7	390.4	329.2	277.3	198.9	0.0	0.0	0.0	0.0
Brazil	0.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.2	-1.8
China	7.1	7.7	7.9	8.2	54.0	2.5	1.0	2.6	0.1
Argentina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Australia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia	13.4	15.0	21.7	46.4	57.2	7.8	0.0	-0.2	-0.2
Mexico	8.3	12.9	9.9	1.8	3.4	2.9	3.2	-1.8	1.2
EU-27	11.9	11.4	5.2	10.1	14.0	3.8	-2.7	0.0	0.0
Canada	41.0	66.9	9.6	12.1	13.0	4.2	0.6	0.0	0.1
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	2.7	1.4	0.6	0.9	0.5	-5.0	-2.4	-3.4	-4.4
Japan	331.2	290.1	424.3	391.7	341.9	0.0	0.0	0.0	-0.1
Korea	64.7	79.2	139.8	158.7	159.2	0.0	0.0	0.0	-2.5
XAS	62.6	98.8	85.7	143.4	177.8	0.0	0.0	0.0	0.0
XSM	0.9	0.6	1.2	4.3	15.1	-0.3	0.7	0.1	4.9
XOC	1.3	2.7	2.0	2.0	3.2	-5.6	-1.4	-1.7	-3.2
XCB	1.8	1.2	1.7	2.0	0.6	0.0	0.5	0.6	0.2
XME	6.3	7.2	7.6	11.3	28.0	-1.3	-1.9	-2.9	-7.1
XAF	14.3	8.7	8.4	15.5	25.2	0.0	0.0	0.0	0.0
XEU	5.3	3.0	2.9	4.3	6.0	2.5	2.4	2.9	4.1
Total	885.5	997.2	1,057.7	1,090.1	1,098.1	11.5	0.0	-4.0	-8.7

Table 5. Continued

Region[a]	Base	Historical Simulation[b]				Difference with Actual			
		P1	P2	P3	P4	P1	P2	P3	P4
New Zeland					1,000 MT				
United States	203.9	208.5	200.5	175.3	159.7	0.0	0.0	0.0	0.0
Brazil	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.3	0.2
China	4.6	4.5	2.8	4.3	12.9	2.6	0.0	2.9	0.1
Argentina	0.1	0.0	0.1	0.4	0.2	0.0	0.1	0.4	0.2
Australia	1.3	0.8	2.8	4.1	3.7	-0.5	-1.4	2.6	0.7
Russia	3.6	3.7	2.7	4.2	4.3	3.2	0.0	0.0	-1.1
Mexico	3.2	4.5	3.3	0.9	1.4	-2.1	-4.3	-1.1	0.6
EU-27	8.1	7.0	10.4	2.0	14.0	2.6	5.7	-8.2	1.5
Canada	33.9	52.7	30.3	25.6	23.1	0.0	1.3	6.9	2.6
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	18.8	17.1	41.2	35.6	34.3	0.0	0.0	0.0	0.0
Korea	8.7	13.6	49.6	41.3	35.3	0.0	0.0	0.0	0.0
XAS	35.2	52.1	73.7	80.8	82.9	0.0	0.0	0.0	0.0
XSM	1.6	1.0	2.7	0.8	2.2	-0.4	2.3	0.0	1.9
XOC	4.2	7.8	5.3	8.0	10.5	-1.2	-4.5	0.1	1.5
XCB	0.6	0.3	0.5	1.2	1.1	-0.8	-2.1	-0.1	0.0
XME	2.7	2.8	2.8	1.5	6.6	-0.3	-0.3	-3.0	-1.0
XAF	3.0	6.7	6.7	4.4	9.9	3.3	3.3	0.0	0.1
XEU	1.8	0.9	0.7	1.5	1.6	0.2	0.2	1.1	1.2
Total	335.4	384.1	436.2	392.2	403.9	6.7	0.4	1.9	8.5

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Table 6. Beef Production by Region in Historical Simulation

Region[a]	Base	Historical Simulation[b]				Difference with Actual			
		P1	P2	P3	P4	P1	P2	P3	P4
					1,000 MT				
United States	12,066.7	12,119.8	11,401.3	12,033.5	11,851.8	-13.5	1.3	0.2	1.8
Brazil	6,262.1	7,045.4	8,452.1	9,066.8	9,254.4	-18.8	-9.9	-20.5	-27.4
China	4,286.7	4,921.9	5,350.7	5,883.4	6,259.1	34.6	-12.6	-15.9	-11.1
Argentina	2,635.7	2,537.8	3,054.1	3,256.5	2,652.1	0.5	-8.7	11.8	15.7
Australia	1,984.6	2,085.8	2,091.3	2,152.1	2,160.6	12.5	0.6	-8.6	-10.7
Russia	2,003.2	1,940.0	1,817.0	1,733.3	1,655.5	0.2	0.5	0.3	-1.4
Mexico	1,396.0	1,471.9	1,558.5	1,653.6	1,757.7	-0.1	-13.0	-15.4	-36.3
EU-27	8,559.6	8,248.3	8,106.8	8,084.0	7,845.8	22.4	-32.7	6.8	1.2
Canada	1,236.4	1,242.1	1,459.8	1,281.8	1,174.2	-11.1	28.1	8.9	2.5
India	993.2	959.3	984.6	1,009.8	980.2	0.9	2.5	0.1	0.1
New Zealand	589.1	620.9	671	640.1	619.3	11.9	3.1	5.4	13.1
Japan	533.4	497.4	503.7	512.6	510.3	0.3	0.3	-1.0	-0.2
Korea	341.3	210.4	193.7	249.2	293.4	-0.1	0.0	-0.1	-0.4
XAS	1713	1,719.5	1,907.4	2,242.4	2,605.3	-0.3	1.3	-1.3	-0.8
XSM	2,516.8	2,447.5	2,785.6	2,992.5	3,108.1	26.8	-18.5	-37.5	-12.6
XOC	21.6	21.3	21.2	20.8	20.9	0.2	0.5	0.8	1.1
XCB	518.6	507.4	514.3	596.7	623.1	1.4	-9.7	-2.3	-23.3
XME	1,768.1	1,856.1	2,108.5	2,272.8	2,495.3	12.6	7.6	11.7	2.5
XAF	3,783.9	4,066.9	4,561.8	5,033.0	5,494.3	0.1	5.8	1.9	-0.2
XEU	1,953.1	1,750.6	1,660.5	1,598.9	1,862.8	11.1	9.9	10.2	1.8
Total	55,163.1	56,270.3	59,203.9	62,313.8	63,224.2	91.6	-43.7	-44.5	-84.4

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Table 7. Shocks to *apm* and *adx* Eliminated in Counter-factual Experiment

Shock	P2	P3	P4
apm			
US exports, except Russia and EU-27[a]	14	11	8
US imports	6	12	5
Imports, other than from US			
China	3	0	4
Canada	2	1	1
Japan	3	3	3
Korea	3	2	1
XCB	0	2	2
Total	31	31	24
adx			
US exports, except Russia and EU-27[a]	12	9	7
US imports	2	0	0
Imports, other than from US			
China	1	0	3
Canada	2	0	1
Japan	2	1	1
Korea	1	0	0
XCB	0	2	0
Other Canadian exports			
Mexico	0	0	1
XSM	1	0	0
Total	21	12	13

[a] Also excludes US exports to XAS in P4.

Table 8. Differences in Beef Export Quantities between the Historical and Counter-factual Simulations for Selected Regions

Importer[a]	USA			Australia		
	P2	P3	P4	P2	P3	P4
			1,000 MT			
United States	-	-	-	139.7	43.9	139.7
China	13.7	12.5	53.1	-2.0	-1.8	-17.1
Mexico	81.9	12.4	66.4	1.7	11.3	11.1
Canada	60.0	7.7	-31.5	64.9	82.9	99.5
Japan	337.4	234.3	80.1	-168.0	-125.9	-86.1
Korea	193.7	170.5	118.0	-59.7	-60.4	-42.5
XAS	14.1	19.9	-5.9	23.3	36.9	6.3
XSM	23.8	65.3	127.0	0.3	0.7	-3.1
XAF	46.7	211.3	125.7	3.0	0.2	-3.1
	Canada			New Zealand		
United States	56.6	98.9	105.0	10.0	-3.0	9.2
China	1.3	1.8	4.7	0.3	-0.1	13.7
Mexico	-28.5	25.0	42.5	0.4	4.2	3.9
Canada	-	-	-	23.1	59.1	70.1
Japan	17.8	18.2	8.7	-27.4	-17.9	-18.4
Korea	12.1	19.0	21.1	-37.1	-22.3	-16.9
XAS	-3.0	-12.3	-15.5	14.7	-0.3	-4.3
XSM	0.9	-0.2	-0.3	0.4	-0.1	-0.6
XAF	-1.9	-3.0	-4.4	2.0	-0.8	-2.0

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), and Rest of South America (XSM).

Table 9. Differences in the Value of Beef Production between the Historical and Counter-factual Simulations for Selected Regions by Destination

Regions	Exports	Domestic	Total
		$millions	
United States	6,113.4	83.6	6,197.0
Canada	1,693.6	-1,010.9	682.7
Australia	-1,455.1	19.1	-1,436.0
New Zealand	-235.4	2.9	-232.5
EU-27	-457.4	-235.8	-693.2
Brazil	-427.7	-13.7	-441.4
XAS	-4.9	-680.4	-685.3
XSM	-646.6	55.1	-591.5
All other regions	-2,128.6	-302.9	-2,431.5
Total	2,451.3	-2,083.0	368.3

Table 10. US Beef Exports to China in Historical and Counter-factual Simulations

Experiment[a]	P1[b]	P2	P3	P4
		1,000 MT		
Historical	16.1	0.1	0.0	0.1
Base CF	16.1	13.8	12.5	53.2
Base CF + *apd*	16.1	18.2	19.3	57.3
Base CF + *apd* + *ap*	16.1	21.0	26.2	81.6

[a] The experiments are the historical simulation; the base counter-factual simulation (Base CF); the base counter-factual plus removal of preference shocks for imported beef (*apd*) in China in P2 and P3; and the the base counter-factual plus removal of preference shocks for imported beef (*apd*) in China in P2 and P3 plus one-half of the preference shock for beef (*ap*) in China from historical simulation.

[b] The time periods are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix A. Additional Model Results

This appendix contains model results for the counter-factual simulations that are summarized in the figures and tables of the main body of this report.

Appendix Table A.1. Normalized Beef Consumption Quantity Indices in Historical and Counter-factual Simulation

Region[a]	Historical Simulation				Counter-factual Simulation			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
Composite Quantity (*qp*)								
United States	1.008	1.017	1.030	1.003	1.008	1.033	1.037	0.999
Brazil	1.087	1.230	1.312	1.335	1.087	1.230	1.312	1.334
China	1.149	1.248	1.371	1.492	1.149	1.248	1.372	1.491
Argentina	0.973	1.087	1.158	0.978	0.973	1.087	1.158	0.977
Australia	0.990	0.944	0.973	0.972	0.990	0.923	0.953	0.971
Russia	1.026	1.062	1.144	1.127	1.026	1.069	1.144	1.128
Mexico	1.073	1.087	1.143	1.100	1.073	1.097	1.146	1.107
EU-27	0.977	1.000	1.022	1.003	0.977	1.003	1.025	1.003
Canada	1.015	1.068	1.089	1.054	1.015	1.182	1.212	1.156
India	0.860	0.754	0.688	0.589	0.860	0.754	0.686	0.588
New Zealand	0.928	0.916	0.970	0.841	0.928	0.896	0.966	0.848
Japan	0.877	0.615	0.657	0.733	0.877	0.851	0.822	0.759
Korea	1.110	0.731	0.888	1.221	1.110	1.217	1.327	1.462
XAS	1.103	1.225	1.513	1.816	1.103	1.242	1.534	1.826
XSM	0.967	1.088	1.211	1.292	0.967	1.087	1.207	1.290
XOC	1.335	1.277	1.211	1.357	1.335	1.268	1.211	1.348
XCB	0.941	0.975	1.133	1.178	0.941	0.979	1.131	1.154
XME	1.076	1.248	1.369	1.561	1.076	1.252	1.373	1.561
XAF	1.067	1.270	1.479	1.745	1.067	1.273	1.481	1.738
XEU	0.905	1.159	1.014	1.124	0.905	1.174	1.025	1.150

Appendix Table A.1. Continued

Region	Historical Simulation				Counter-factual Simulation			
	P1	P2	P3	P4	P1	P2	P3	P4
Composite Imports (*qpm*)								
United States	1.118	1.181	0.966	1.166	1.118	1.235	0.952	1.001
Brazil	1.021	0.596	0.471	0.633	1.021	0.724	0.533	0.647
China	1.248	0.651	0.613	5.210	1.248	0.983	0.990	4.928
Argentina	0.696	0.594	0.578	0.391	0.696	0.783	0.850	0.454
Australia	0.639	2.430	3.247	2.877	0.639	2.609	3.198	2.457
Russia	1.226	1.538	1.904	1.925	1.226	1.579	1.893	1.926
Mexico	1.146	0.989	1.031	0.739	1.146	1.133	1.142	1.077
EU-27	0.992	1.226	1.369	1.436	0.992	1.250	1.390	1.449
Canada	1.168	0.503	0.789	1.018	1.168	1.278	1.542	1.668
India	0.437	0.250	0.090	0.019	0.437	0.198	0.088	0.018
New Zealand	0.500	0.217	0.329	0.175	0.500	0.291	0.410	0.170
Japan	0.852	0.496	0.545	0.643	0.852	0.798	0.750	0.644
Korea	1.586	0.954	1.136	1.659	1.586	1.740	1.902	2.100
XAS	1.577	1.732	2.394	3.081	1.577	1.965	2.679	3.247
XSM	1.011	1.739	2.517	2.755	1.011	1.882	2.631	2.909
XOC	2.168	2.019	1.860	2.299	2.168	1.968	1.888	2.275
XCB	0.700	0.955	1.316	1.624	0.700	1.030	1.472	1.259
XME	1.376	1.775	2.159	3.019	1.376	1.894	2.307	3.081
XAF	0.879	2.710	4.598	7.783	0.879	2.999	4.861	7.440
XEU	1.238	5.132	3.333	3.199	1.238	5.362	3.520	3.725

Appendix Table A.1. Continued

Region	Historical Simulation				Counter-factual Simulation			
	P1	P2	P3	P4	P1	P2	P3	P4
Composite Domestic (*qpd*)								
United States	1.000	1.004	1.036	0.990	1.000	1.016	1.046	1.000
Brazil	1.087	1.235	1.320	1.341	1.087	1.234	1.319	1.340
China	1.148	1.251	1.376	1.464	1.148	1.250	1.374	1.466
Argentina	0.974	1.089	1.161	0.981	0.974	1.088	1.159	0.980
Australia	0.990	0.940	0.966	0.967	0.990	0.919	0.947	0.968
Russia	0.968	0.907	0.865	0.826	0.968	0.895	0.866	0.824
Mexico	1.054	1.114	1.174	1.209	1.054	1.088	1.147	1.116
EU-27	0.972	0.922	0.884	0.799	0.972	0.918	0.881	0.798
Canada	0.980	1.227	1.167	1.034	0.980	1.161	1.135	1.025
India	0.860	0.755	0.688	0.589	0.860	0.754	0.686	0.588
New Zealand	0.932	0.924	0.976	0.848	0.932	0.903	0.972	0.856
Japan	0.932	0.945	0.961	0.957	0.932	0.971	0.988	1.030
Korea	0.616	0.567	0.730	0.859	0.616	0.676	0.729	0.796
XAS	1.003	1.118	1.311	1.517	1.003	1.084	1.273	1.500
XSM	0.965	1.040	1.088	1.151	0.965	1.032	1.088	1.149
XOC	0.976	0.962	0.940	0.940	0.976	0.974	0.927	0.939
XCB	0.966	0.974	1.104	1.114	0.966	0.969	1.085	1.138
XME	1.050	1.201	1.296	1.416	1.050	1.195	1.288	1.415
XAF	1.073	1.209	1.336	1.456	1.073	1.199	1.330	1.474
XEU	0.887	0.879	0.860	0.994	0.887	0.867	0.849	0.970

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.2. Normalized Beef Production Quantity Indices in Historical and Counter-factual Simulation

Region[a]	Historical Simulation				Counter-factual Simulation			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
Composite Quantity (*vo*)								
United States	1.001	0.979	1.025	1.005	1.001	1.021	1.055	1.025
Brazil	1.095	1.272	1.343	1.384	1.095	1.269	1.340	1.381
China	1.148	1.250	1.375	1.463	1.148	1.248	1.373	1.464
Argentina	0.975	1.122	1.197	1.011	0.975	1.119	1.193	1.009
Australia	1.037	1.115	1.133	1.124	1.037	1.036	1.063	1.127
Russia	0.968	0.907	0.865	0.827	0.968	0.896	0.866	0.824
Mexico	1.055	1.125	1.204	1.334	1.055	1.089	1.151	1.131
EU-27	0.965	0.968	0.993	1.000	0.965	0.963	0.988	0.997
Canada	1.003	1.197	1.080	0.998	1.003	1.172	1.131	1.077
India	0.902	0.938	1.079	1.215	0.902	0.930	1.058	1.209
New Zealand	1.042	1.219	1.134	1.119	1.042	1.125	1.116	1.152
Japan	0.933	0.949	0.967	0.965	0.933	0.971	0.990	1.032
Korea	0.617	0.568	0.731	0.861	0.617	0.676	0.730	0.797
XAS	1.004	1.118	1.314	1.522	1.004	1.084	1.275	1.505
XSM	0.975	1.094	1.217	1.262	0.975	1.069	1.204	1.251
XOC	0.983	0.980	0.966	0.975	0.983	0.983	0.937	0.952
XCB	0.982	0.996	1.154	1.190	0.982	0.996	1.103	1.171
XME	1.051	1.200	1.294	1.416	1.051	1.193	1.286	1.415
XAF	1.074	1.205	1.326	1.453	1.074	1.195	1.319	1.470
XEU	0.895	0.881	0.858	0.994	0.895	0.868	0.845	0.969

Appendix Table A.2. Continued

Region	Historical Simulation				Counter-factual Simulation			
	P1	P2	P3	P4	P1	P2	P3	P4
Composite Exports (*qom*)								
United States	1.013	0.656	0.911	1.123	1.013	1.059	1.126	1.204
Brazil	1.342	2.109	1.963	2.345	1.342	2.082	1.927	2.305
China	1.117	1.101	1.277	1.303	1.117	1.080	1.255	1.295
Argentina	0.998	1.465	1.570	1.327	0.998	1.450	1.551	1.314
Australia	1.090	1.274	1.289	1.273	1.090	1.151	1.179	1.276
Russia	1.012	1.239	1.260	1.459	1.012	1.200	1.228	1.412
Mexico	1.255	2.313	3.314	5.467	1.255	1.360	1.729	2.537
EU-27	0.934	1.113	1.275	1.419	0.934	1.104	1.267	1.412
Canada	1.042	1.139	0.872	0.925	1.042	1.191	1.124	1.159
India	1.168	1.626	2.111	2.507	1.168	1.601	2.060	2.492
New Zealand	1.111	1.371	1.228	1.259	1.111	1.247	1.205	1.302
Japan	1.051	1.733	1.871	2.013	1.051	1.197	1.473	1.551
Korea	0.948	1.101	1.433	1.653	0.948	1.070	1.297	1.438
XAS	1.073	1.094	1.676	2.159	1.073	1.062	1.629	2.145
XSM	1.076	1.489	1.950	1.942	1.076	1.372	1.888	1.895
XOC	1.199	1.422	1.531	1.669	1.199	1.235	1.229	1.288
XCB	1.154	1.219	1.586	1.769	1.154	1.257	1.298	1.483
XME	1.131	1.007	1.061	1.419	1.131	0.992	1.028	1.408
XAF	1.092	1.098	0.965	1.375	1.092	1.088	0.947	1.365
XEU	1.017	0.906	0.821	0.996	1.017	0.881	0.774	0.957

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.3. Normalized Beef Consumption Price Indices in Historical and Counter-factual Simulation

Region[a]	Historical Simulation				Counter-factual Simulation			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
Composite Price (*pp*)								
United States	1.009	1.052	1.059	0.995	1.009	1.032	1.049	0.999
Brazil	1.080	1.202	1.300	1.301	1.080	1.202	1.300	1.302
China	1.148	1.253	1.377	1.471	1.148	1.251	1.374	1.473
Argentina	0.972	1.059	1.129	0.954	0.972	1.059	1.129	0.954
Australia	0.946	0.796	0.825	0.833	0.946	0.817	0.845	0.834
Russia	0.986	1.037	1.066	1.070	0.986	1.018	1.067	1.066
Mexico	1.055	1.124	1.163	1.174	1.055	1.097	1.156	1.154
EU-27	0.967	0.990	1.012	1.032	0.967	0.984	1.008	1.032
Canada	0.987	1.334	1.356	1.245	0.987	1.171	1.181	1.105
India	0.820	0.607	0.439	0.285	0.820	0.611	0.445	0.286
New Zealand	0.835	0.702	0.842	0.645	0.835	0.726	0.847	0.637
Japan	0.995	1.314	1.303	1.290	0.995	1.055	1.087	1.169
Korea	0.915	1.098	1.206	1.196	0.915	1.003	1.079	1.175
XAS	1.010	1.222	1.399	1.618	1.010	1.171	1.342	1.591
XSM	0.961	1.055	1.110	1.236	0.961	1.059	1.122	1.242
XOC	1.086	1.066	1.026	1.088	1.086	1.095	1.024	1.116
XCB	0.956	0.976	1.083	1.064	0.956	0.965	1.089	1.141
XME	1.039	1.211	1.320	1.465	1.039	1.201	1.309	1.463
XAF	1.083	1.240	1.394	1.512	1.083	1.227	1.386	1.538
XEU	0.896	0.948	0.900	1.085	0.896	0.929	0.884	1.047

Appendix Table A.3. Continued

	Historical Simulation				Counter-factual Simulation			
Region	P1	P2	P3	P4	P1	P2	P3	P4
Import Price (*ppm*)								
United States	1.149	1.334	1.192	1.238	1.149	1.297	1.188	1.308
Brazil	1.098	1.587	1.780	1.719	1.098	1.522	1.752	1.730
China	1.124	1.273	1.305	1.831	1.124	1.171	1.223	1.860
Argentina	1.061	1.539	2.177	1.949	1.061	1.404	1.836	1.748
Australia	1.060	1.658	1.607	1.674	1.060	1.595	1.578	1.674
Russia	1.041	1.369	1.534	1.606	1.041	1.346	1.542	1.605
Mexico	1.062	1.204	1.240	1.567	1.062	1.137	1.200	1.362
EU-27	0.922	1.307	1.599	1.965	0.922	1.293	1.581	1.949
Canada	1.116	1.715	1.897	2.233	1.116	1.263	1.358	1.547
India	0.978	0.808	0.745	0.696	0.978	0.864	0.758	0.703
New Zealand	0.980	1.021	1.115	0.969	0.980	0.972	1.058	0.967
Japan	1.027	1.549	1.516	1.498	1.027	1.099	1.140	1.250
Korea	1.151	1.486	1.547	1.435	1.151	1.262	1.357	1.476
XAS	1.037	1.551	1.693	1.962	1.037	1.427	1.567	1.884
XSM	1.078	2.086	2.921	3.560	1.078	1.994	2.796	3.383
XOC	1.291	1.277	1.219	1.373	1.291	1.318	1.213	1.409
XCB	1.032	1.267	1.412	1.356	1.032	1.220	1.363	1.522
XME	0.947	1.250	1.461	1.760	0.947	1.216	1.414	1.729
XAF	1.502	2.115	2.601	2.847	1.502	2.032	2.513	2.885
XEU	1.213	1.602	1.392	1.959	1.213	1.583	1.389	1.858

Appendix Table A.3. Continued

Region	Historical Simulation				Counter-factual Simulation			
	P1	P2	P3	P4	P1	P2	P3	P4
Domestic Price (*ppd*)								
United States	0.999	1.030	1.048	0.975	0.999	1.012	1.037	0.976
Brazil	1.080	1.200	1.297	1.299	1.080	1.200	1.298	1.300
China	1.149	1.253	1.377	1.466	1.149	1.251	1.375	1.468
Argentina	0.972	1.058	1.127	0.952	0.972	1.058	1.127	0.952
Australia	0.946	0.793	0.824	0.831	0.946	0.815	0.844	0.831
Russia	0.968	0.907	0.865	0.826	0.968	0.895	0.865	0.824
Mexico	1.053	1.103	1.144	1.096	1.053	1.086	1.144	1.102
EU-27	0.980	0.878	0.787	0.638	0.980	0.875	0.785	0.638
Canada	0.957	1.258	1.262	1.072	0.957	1.150	1.139	0.976
India	0.820	0.607	0.439	0.285	0.820	0.611	0.445	0.286
New Zealand	0.834	0.700	0.841	0.643	0.834	0.724	0.846	0.635
Japan	0.932	0.940	0.956	0.950	0.932	0.970	0.986	1.027
Korea	0.616	0.566	0.729	0.858	0.616	0.675	0.729	0.795
XAS	1.003	1.118	1.309	1.512	1.003	1.084	1.270	1.495
XSM	0.955	0.990	0.973	1.049	0.955	0.995	0.983	1.055
XOC	0.969	0.945	0.915	0.905	0.969	0.966	0.916	0.927
XCB	0.950	0.952	1.056	1.043	0.950	0.943	1.066	1.106
XME	1.049	1.203	1.298	1.416	1.049	1.197	1.290	1.415
XAF	1.073	1.212	1.347	1.459	1.073	1.203	1.341	1.478
XEU	0.879	0.878	0.862	0.994	0.879	0.866	0.852	0.970

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.4. Normalized Beef Production Price Indices in Historical and Counter-factual Simulation

Region[a]	Historical Simulation				Counter-factual Simulation			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
Composite Price (*pm*)								
United States	1.001	0.979	1.025	1.005	1.001	1.021	1.055	1.025
Brazil	1.095	1.272	1.343	1.384	1.095	1.269	1.340	1.381
China	1.148	1.250	1.375	1.463	1.148	1.248	1.373	1.464
Argentina	0.975	1.122	1.197	1.011	0.975	1.119	1.193	1.009
Australia	1.037	1.115	1.133	1.124	1.037	1.036	1.063	1.127
Russia	0.968	0.907	0.865	0.827	0.968	0.896	0.866	0.824
Mexico	1.055	1.125	1.204	1.334	1.055	1.089	1.151	1.131
EU-27	0.965	0.968	0.993	1.000	0.965	0.963	0.988	0.997
Canada	1.003	1.197	1.080	0.998	1.003	1.172	1.131	1.077
India	0.902	0.938	1.079	1.215	0.902	0.930	1.058	1.209
New Zealand	1.042	1.219	1.134	1.119	1.042	1.125	1.116	1.152
Japan	0.933	0.949	0.967	0.965	0.933	0.971	0.990	1.032
Korea	0.617	0.568	0.731	0.861	0.617	0.676	0.730	0.797
XAS	1.004	1.118	1.314	1.522	1.004	1.084	1.275	1.505
XSM	0.975	1.094	1.217	1.262	0.975	1.069	1.204	1.251
XOC	0.983	0.980	0.966	0.975	0.983	0.983	0.937	0.952
XCB	0.982	0.996	1.154	1.190	0.982	0.996	1.103	1.170
XME	1.051	1.200	1.294	1.416	1.051	1.193	1.286	1.415
XAF	1.074	1.205	1.326	1.453	1.074	1.195	1.319	1.470
XEU	0.895	0.881	0.858	0.994	0.895	0.868	0.845	0.969

Appendix Table A.4. Continued

	Historical Simulation				Counter-factual Simulation			
Region	P1	P2	P3	P4	P1	P2	P3	P4
Composite Exports (*pmei*)								
United States	1.024	0.439	0.810	1.254	1.024	1.099	1.201	1.415
Brazil	1.646	3.498	2.871	3.971	1.646	3.415	2.771	3.847
China	1.087	0.970	1.185	1.160	1.087	0.935	1.148	1.145
Argentina	1.022	1.914	2.059	1.743	1.022	1.879	2.017	1.711
Australia	1.146	1.457	1.466	1.441	1.146	1.280	1.308	1.446
Russia	1.057	1.692	1.835	2.575	1.057	1.608	1.741	2.418
Mexico	1.493	4.755	9.119	22.408	1.493	1.698	2.598	5.693
EU-27	0.904	1.279	1.636	2.012	0.904	1.266	1.623	1.999
Canada	1.083	1.084	0.704	0.857	1.083	1.210	1.118	1.247
India	1.513	2.818	4.132	5.170	1.513	2.756	4.010	5.137
New Zealand	1.185	1.543	1.331	1.416	1.185	1.383	1.300	1.471
Japan	1.185	3.164	3.621	4.200	1.185	1.474	2.192	2.332
Korea	1.457	2.133	2.810	3.176	1.457	1.694	2.303	2.595
XAS	1.147	1.070	2.138	3.063	1.147	1.041	2.082	3.057
XSM	1.187	2.028	3.126	2.987	1.187	1.761	2.963	2.870
XOC	1.462	2.062	2.427	2.858	1.462	1.553	1.612	1.742
XCB	1.356	1.493	2.180	2.630	1.356	1.585	1.527	1.878
XME	1.219	0.846	0.870	1.423	1.219	0.826	0.822	1.402
XAF	1.111	1.001	0.703	1.301	1.111	0.990	0.679	1.267
XEU	1.157	0.931	0.786	0.997	1.157	0.894	0.708	0.945

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.5. Total Beef Imports by Region in Counter-factual Simulation

Region[a]	Base	Counter-factual Simulation[b]				Difference with Historical Simulation			
		P1	P2	P3	P4	P1	P2	P3	P4
					1,000 MT				
United States	919.8	1,030.4	1,148.3	881.6	915.5	0.0	95.3	71.5	186.1
Brazil	66.4	64.6	47.5	32.7	38.1	0.0	9.4	2.0	2.0
China	25.7	32.0	25.2	25.8	128.9	0.0	10.2	11.0	13.8
Argentina	18.9	13.0	14.2	15.1	8.1	0.0	3.6	4.8	1.2
Australia	1.3	0.9	3.6	4.3	3.3	0.0	0.2	-0.1	-0.5
Russia	484.9	598.4	694.5	856.4	758.1	0.0	18.5	21.9	18.1
Mexico	346.1	397.4	390.8	391.3	369.9	0.0	55.8	56.7	128.4
EU-27	1,757.5	1,706.1	2,141.1	2,328.4	2,469.4	0.0	24.9	15.8	8.9
Canada	186	219.9	237.7	288.9	314.7	0.0	141.2	150.3	140.9
India	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	2.8	1.4	0.8	1.1	0.5	0.0	0.2	0.2	0.0
Japan	798.7	683.2	635.9	607.2	530.4	0.0	153.6	101.1	-27.0
Korea	187.3	285.2	308.5	344.2	382.8	0.0	99.8	102.7	76.9
XAS	292.6	470.5	589.0	787.9	929.3	0.0	38.6	53.0	35.8
XSM	106.5	102.3	209.4	330.9	391.6	0.0	31.5	54.4	116.6
XOC	6.5	14.1	12.9	12.2	14.8	0.0	1.7	0.8	0.0
XCB	40.3	28.1	42.0	60.6	51.8	0.0	2.7	7.2	-16.8
XME	156.4	226.6	330.8	412.5	533.3	0.0	11.8	24.9	16.9
XAF	101.1	73.0	230.3	467.7	647.5	0.0	49.5	150.9	61.8
XEU	50	51.6	144.5	120.4	141.0	0.0	1.0	5.0	-10.9
Total	5,548.8	5,998.7	7,207.0	7,969.2	8,629.0	0.0	749.5	834.1	752.2

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.6. Total Beef Exports by Region in Counter-factual Simulation

Region[a]	Base	Counter-factual Simulation[b] P1	P2	P3	P4	Difference with Historical Simulation P1	P2	P3	P4
					1,000 MT				
United States	1,057.4	1,109.9	1,139.9	1,372.4	1,471.4	0.0	796.1	749.3	520.6
Brazil	148	397.8	889.1	1,001.3	1,077.5	0.0	-9.6	4.1	20.4
China	27.1	30.4	20.0	22.4	22.0	0.0	0.0	0.2	0.4
Argentina	170.7	137.6	360.6	385.1	230.2	0.0	-8.3	-9.1	-4.0
Australia	885.5	997.2	1,073.3	1,099.1	1,201.6	0.0	15.6	8.9	103.4
Russia	0.6	0.7	0.7	0.7	0.8	0.0	0.0	0.0	0.0
Mexico	3.4	3.9	4.8	11.1	34.5	0.0	-2.1	-8.0	-39.4
EU-27	1,933.9	1,805.7	1,983.2	2,211.1	2,529.3	0.0	-15.5	-15.4	-22.5
Canada	420.2	442.4	508.8	472.4	488.6	0.0	50.7	143.6	158.5
India	101.8	192.7	307.8	395.0	459.5	0.0	-4.3	-1.5	4.1
New Zealand	335.2	384.2	429.8	411.1	454.7	0.0	-6.6	18.8	50.8
Japan	0.6	0.7	0.5	0.3	0.4	0.0	0.0	-0.1	0.0
Korea	0.2	0.1	0.1	0.1	0.2	0.0	-0.1	-0.1	0.0
XAS	15.6	16.6	9.1	16.9	29.5	0.0	-0.3	-0.1	-0.2
XSM	198.4	210.3	307.5	426.0	406.1	0.0	-65.9	-43.3	-34.3
XOC	0.8	0.9	1.0	1.0	1.0	0.0	-0.1	-0.2	-0.3
XCB	37.8	43.1	46.9	49.1	82.3	0.0	0.8	-16.8	-5.1
XME	28.5	30.1	17.9	18.0	29.9	0.0	-0.5	-0.4	-2.2
XAF	40.5	49.2	37.3	30.0	44.2	0.0	-0.6	0.0	0.1
XEU	142.5	145.2	68.5	46.0	65.0	0.0	0.1	4.0	1.9
Total	5,548.7	5,998.7	7,206.8	7,969.1	8,628.7	0.0	749.4	833.9	752.2

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.7. Bilateral Beef Exports by Select Region in Counter-factual Simulation

Region[a]	Base	Counter-factual Simulation[b] P1	P2	P3	P4	Difference with Historical Simulation P1	P2	P3	P4
United States					1,000 MT				
United States	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brazil	3.5	4.3	6.8	7.4	4.9	0.0	6.7	7.4	4.9
China	11.1	16.1	13.8	12.5	53.2	0.0	13.7	12.5	53.1
Argentina	2.6	2.5	5.1	9.5	4.0	0.0	5.1	9.5	4.0
Australia	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	-0.1	0.0
Russia	60.5	64.3	0.1	7.1	34.4	0.0	-0.8	-13.7	-11.7
Mexico	296.4	317.2	322.1	301.7	274.3	0.0	81.9	12.4	66.4
EU-27	10.0	12.8	0.1	1.3	11.9	0.0	-0.9	-2.7	-4.7
Canada	85.1	79.1	98.9	105.1	101.9	0.0	60.0	7.7	-31.5
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	421.3	343.6	340.7	294.4	232.2	0.0	337.4	234.3	80.1
Korea	99.8	178.1	202.2	206.7	225.6	0.0	193.7	170.5	118.0
XAS	34.3	54.7	34.2	63.6	100.7	0.0	14.1	19.9	-5.9
XSM	9.9	8.8	25.3	71.0	141.0	0.0	23.8	65.3	127.0
XOC	0.1	0.2	0.2	0.1	0.2	0.0	-1.9	-0.3	0.0
XCB	17.4	15.6	27.1	36.1	30.0	0.0	10.1	15.0	-7.7
XME	1.1	1.7	2.6	0.8	2.6	0.0	1.1	-3.8	-8.4
XAF	2.9	9.7	53.6	246.4	238.7	0.0	46.7	211.3	125.7
XEU	1.6	1.3	7.1	8.8	15.8	0.0	5.8	4.2	11.3
Total	1,057.6	1,110.0	1,139.9	1,372.5	1,471.4	0.0	796.1	749.4	520.6

Appendix Table A.7. Continued

Region[a]	Base	Counter-factual Simulation[b] P1	P2	P3	P4	Difference with Historical Simulation P1	P2	P3	P4
Canada					1,000 MT				
United States	343.5	347.1	404.3	343.8	342.5	0.0	56.6	98.9	105.0
Brazil	0.5	0.6	0.8	1.4	0.2	0.0	-0.5	-4.0	-0.3
China	1.3	1.6	1.3	1.8	8.6	0.0	1.3	1.8	4.7
Argentina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.1
Australia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia	2.3	2.9	0.1	1.0	0.9	0.0	0.0	-3.1	-1.9
Mexico	27.4	48.7	46.2	67.2	70.4	0.0	-28.5	25.0	42.5
EU-27	0.7	0.7	1.6	0.2	1.4	0.0	-0.6	-0.6	-2.3
Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	22.1	20.0	18.6	24.9	22.6	0.0	17.8	18.2	8.7
Korea	11.9	11.5	12.2	19.3	21.2	0.0	12.1	19.0	21.1
XAS	2.8	2.3	6.2	4.6	9.6	0.0	-3.0	-12.3	-15.5
XSM	4.0	3.1	8.3	0.2	0.4	0.0	0.9	-0.2	-0.3
XOC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XCB	2.8	2.2	3.2	6.4	6.2	0.0	-2.9	6.1	5.9
XME	0.5	0.7	1.0	0.5	1.9	0.0	-0.5	-1.1	-3.1
XAF	0.3	0.9	4.8	0.8	2.1	0.0	-1.9	-3.0	-4.4
XEU	0.0	0.0	0.2	0.3	0.6	0.0	0.0	-0.8	-1.5
Total	420.1	442.3	508.8	472.4	488.6	0.0	50.8	143.6	158.5

Appendix Table A.7. Continued

Region[a]	Base	Counter-factual Simulation[b] P1	P2	P3	P4	Difference with Historical Simulation P1	P2	P3	P4
Australia					1,000 MT				
United States	312.7	390.4	468.9	321.2	338.6	0.0	139.7	43.9	139.7
Brazil	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.1
China	7.1	7.7	5.9	6.4	36.9	0.0	-2.0	-1.8	-17.1
Argentina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Australia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia	13.4	15.0	27.9	58.3	54.9	0.0	6.2	11.9	-2.3
Mexico	8.3	12.9	11.6	13.1	14.5	0.0	1.7	11.3	11.1
EU-27	11.9	11.4	7.0	13.2	13.7	0.0	1.8	3.1	-0.3
Canada	41.0	66.9	74.5	95.0	112.5	0.0	64.9	82.9	99.5
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	2.7	1.4	0.8	1.1	0.5	0.0	0.2	0.2	0.0
Japan	331.2	290.1	256.3	265.8	255.8	0.0	-168.0	-125.9	-86.1
Korea	64.7	79.2	80.1	98.3	116.7	0.0	-59.7	-60.4	-42.5
XAS	62.6	98.8	109.0	180.3	184.1	0.0	23.3	36.9	6.3
XSM	0.9	0.6	1.5	5.0	12.0	0.0	0.3	0.7	-3.1
XOC	1.3	2.7	3.0	2.6	3.4	0.0	1.0	0.6	0.2
XCB	1.8	1.2	1.7	2.7	2.7	0.0	0.0	0.7	2.1
XME	6.3	7.2	10.0	15.0	28.1	0.0	2.4	3.7	0.1
XAF	14.3	8.7	11.4	15.7	22.1	0.0	3.0	0.2	-3.1
XEU	5.3	3.0	3.7	5.5	5.0	0.0	0.8	1.2	-1.0
Total	885.5	997.2	1,073.3	1,099.3	1,201.5	0.0	15.6	9.2	103.4

Appendix Table A.7. Continued

Region[a]	Base	Counter-factual Simulation[b]				Difference with Historical Simulation			
		P1	P2	P3	P4	P1	P2	P3	P4
New Zeland					1,000 MT				
United States	203.9	208.5	210.5	172.3	168.9	0.0	10.0	-3.0	9.2
Brazil	0.1	0.1	0.2	0.3	0.2	0.0	0.1	0.0	0.0
China	4.6	4.5	3.1	4.2	26.6	0.0	0.3	-0.1	13.7
Argentina	0.1	0.0	0.1	0.2	0.1	0.0	0.0	-0.2	-0.1
Australia	1.3	0.8	3.3	4.1	3.2	0.0	0.5	0.0	-0.5
Russia	3.6	3.7	3.3	4.2	3.8	0.0	0.6	0.0	-0.5
Mexico	3.2	4.5	3.7	5.1	5.3	0.0	0.4	4.2	3.9
EU-27	8.1	7.0	13.4	2.1	12.5	0.0	3.0	0.1	-1.5
Canada	33.9	52.7	53.4	84.7	93.2	0.0	23.1	59.1	70.1
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	18.8	17.1	13.8	17.7	15.9	0.0	-27.4	-17.9	-18.4
Korea	8.7	13.6	12.5	19.0	18.4	0.0	-37.1	-22.3	-16.9
XAS	35.2	52.1	88.4	80.5	78.6	0.0	14.7	-0.3	-4.3
XSM	1.6	1.0	3.1	0.7	1.6	0.0	0.4	-0.1	-0.6
XOC	4.2	7.8	7.7	8.4	10.3	0.0	2.4	0.4	-0.2
XCB	0.6	0.3	0.5	0.9	0.8	0.0	0.0	-0.3	-0.3
XME	2.7	2.8	3.5	1.5	6.1	0.0	0.7	0.0	-0.5
XAF	3.0	6.7	8.7	3.6	7.9	0.0	2.0	-0.8	-2.0
XEU	1.8	0.9	0.8	1.5	1.2	0.0	0.1	0.0	-0.4
Total	335.4	384.1	430.0	411.0	454.6	0.0	-6.2	18.8	50.7

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.8. Beef Production by Region in Counter-factual Simulation

Region[a]	Base	Counter-factual Simulation[b] P1	P2	P3	P4	Difference with Historical Simulation P1	P2	P3	P4
					1,000 MT				
United States	12,066.7	12,119.8	12,326.4	12,886.9	12,482.6	0.0	925.1	853.4	630.8
Brazil	6,262.1	7,045.4	8,434.7	9,064.9	9,269.4	0.0	-17.4	-1.9	15.0
China	4,286.7	4,921.9	5,343.6	5,875.5	6,266.5	0.0	-7.1	-7.9	7.4
Argentina	2,635.7	2,537.8	3,042.9	3,243.0	2,645.7	0.0	-11.2	-13.5	-6.4
Australia	1,984.6	2,085.8	2,083.3	2,140.2	2,265.4	0.0	-8.0	-11.9	104.8
Russia	2,003.2	1,940.0	1,794.0	1,733.9	1,651.1	0.0	-23.0	0.6	-4.4
Mexico	1,396.0	1,471.9	1,519.4	1,608.9	1,588.8	0.0	-39.1	-44.7	-168.9
EU-27	8,559.6	8,248.3	8,064.0	8,046.9	7,813.7	0.0	-42.8	-37.1	-32.1
Canada	1,236.4	1,242.1	1,456.2	1,398.7	1,325.6	0.0	-3.6	116.9	151.4
India	993.2	959.3	979.5	1,006.5	983.8	0.0	-5.1	-3.3	3.6
New Zealand	589.1	620.9	658.9	657.8	671.9	0.0	-12.1	17.7	52.6
Japan	533.4	497.4	517.6	526.5	549.0	0.0	13.9	13.9	38.7
Korea	341.3	210.4	230.6	248.9	271.8	0.0	36.9	-0.3	-21.6
XAS	1713	1,719.5	1,849.4	2,177.1	2,574.8	0.0	-58.0	-65.3	-30.5
XSM	2,516.8	2,447.5	2,699.5	2,947.7	3,069.3	0.0	-86.1	-44.8	-38.8
XOC	21.6	21.3	21.3	20.3	20.6	0.0	0.1	-0.5	-0.3
XCB	518.6	507.4	513.0	570.6	629.5	0.0	-1.3	-26.1	6.4
XME	1,768.1	1,856.1	2,096.6	2,258.8	2,491.6	0.0	-11.9	-14.0	-3.7
XAF	3,783.9	4,066.9	4,527.2	5,009.5	5,560.9	0.0	-34.6	-23.5	66.6
XEU	1,953.1	1,750.6	1,638.1	1,582.9	1,820.7	0.0	-22.4	-16.0	-42.1
Total	55,163.1	56,270.3	59,796.2	63,005.5	63,952.7	0.0	592.3	691.7	728.5

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table A.9. Differences in the Value of Beef Production between the Historical and Counter-factual Simulations for Selected Regions by Destination and Time Period

	Domestic				Exports			
Region	P2	P3	P4	Total	P2	P3	P4	Total
				$millions				
United States	-204.6	-34.4	322.6	83.6	2,997.9	2,100.9	1,014.6	6,113.4
Australia	7.7	8.4	3.0	19.1	-775.1	-704.6	24.6	-1,455.1
Canada	-424.8	-368.5	-217.6	-1,010.9	232.7	725.4	735.5	1,693.6
New Zealand	-129.3	-88.5	-18.0	-235.8	-135.1	-153.3	-169.0	-457.4
EU-27	3.6	0.5	-1.2	2.9	-281.7	-50.2	96.5	-235.4
Brazil	-21.9	-6.7	14.9	-13.7	-113.3	-125.3	-189.1	-427.7
XAS	-223.5	-295.9	-161.0	-680.4	-1.0	-3.0	-0.9	-4.9
XSM	-12.7	48.2	19.6	55.1	-266.2	-220.9	-159.5	-646.6
All other regions	-187.2	-207.5	91.8	-302.9	-179.6	-558.4	-1,390.6	-2,128.6
Total	-1,192.7	-944.4	54.1	-2,083.0	1,478.6	1,010.6	-37.9	2,451.3

Appendix B: Model Equations

The following is a list of all model equations. The model is solved using the GEMPACK solver (Harrison and Pearson, 1996) with all equations being specified as first-order differentials. Thus, all lower case variables are expressed as percentage changes. All upper case coefficients are budget or revenue shares, which are updated as GEMPACK solves the system of equations. All parameters are also denoted by upper case names.

Demand Equations

Demand for composite commodity i in region d

(B.1)
$$qp(i,d) - pop(d) = \sum_{k \in DEMD} EP(i,k,d)\,pp(k,d) + EY(i,d) * y(d) - pop(d) + ap(i,d) - ap\_avg(d)$$

Average value of ap by region

(B.2)
$$ap\_avg(d) = \sum_{k \in DEMD} CONSHR(k,d)\,ap(k,d)$$

Price index for composite consumption goods

(B.3)
$$pp(i,d) = PMSHR(i,d)\,ppm(i,d) + (1 - PMSHR(i,d))\,ppd(i,d)$$

Demand for domestically produced meat product

(B.4)
$$qpd(i,d) = qp(i,d) + ESUBD(i)\,(pp(i,d) - ppd(i,d)) + (1 - ESUBD(i))\,apd(i,d)$$

Demand for composite imported meat product

(B.5)
$$qpm(i,d) = qp(i,d) + ESUBD(i)\,(pp(i,d) - ppm(i,d)) - (1 - ESUBD(i))\left((1 - PMSHR(i,d))/PMSHR(i,d)\right) apd(i,d)$$

Price linkage between domestic producer and domestic consumer price

(B.6)
$$ppd(i,d) = tpd(i,d) + pmd(i,d)$$

Price linkage between tariff-inclusive import prices and consumer price

(B.7)
$$ppm(i,d) = tpm(i,d) + pim(i,d)$$

Price index for imported meat products

(B.8) $$pim(i,d) = \sum_{o \in REG} MSHRS(i,o,d)\, pms(i,o,d)$$

Price linkage between exporter price and tariff-inclusive import price

(B.9) $$pms(i,o,d) = tms(i,o,d) + pme(i,o,d)$$

Demand for imports by source

(B.10) $$qme(i,o,d) = qpm(i,d) + ESUBM(i)\, ppm(i,d) - pms(i,o,d) + 1 - ESUBM(i)\, apm(i,o,d) - apm\_avg(i,d)$$

Average value of apm by region

(B.11) $$apm\_avg(i,d) = \sum_{o \in REG} MSHRS(i,o,d)\, apm(i,o,d)$$

Supply Equations

Supply of meat product i to domestic market

(B.12) $$qod(i,o) = vo(i,o) + ESUBT1(i)\, pm(i,o) - pmd(i,o) - ad(i,o) + ad(i,o)$$

Supply of composite export of meat product i

(B.13) $$qom(i,o) = vo(i,o) + ESUBT1(i)\, pm(i,o) - pmei(i,o) - ade(i,o) + ade(i,o)$$

Supply of exports of meat product i to destination d from origin o

(B.14) $$qxs(i,o,d) = qom(i,o) + ESUBT2(i)\, pmei(i,o) - pme(i,o,d) - adx(i,o,d) + adx(i,o,d)$$

Supply of aggregate factor used to produce meat product i

(B.15) $$vo(i,o) = ELASTV(i,o)\, pm(i,o)$$

Producer export price index

(B.16) $$pmei(i,o) = \sum_{d \in REG} SHRXD(i,o,d)\, pme(i,o,d) + adx(i,o,d)$$

Composite producer price index for meat product i in region o

$$pm(i,o) = SHRDM\,(i,o)\; pmd\,(i,o) + ad\,(i,o) + \tag{B.17}$$
$$1 - SHRDM\,(i,o)\; pmei\,(i,o) + ade(i,o)$$

Market Clearing Conditions

Market clearing condition for domestic meat products

$$qpd\,(i\,,\,o\,) = qod\,(i\,,o) \tag{B.18}$$

Market clearing for traded meat products

$$qme\,(i\,,\,o,\,d\,) = qxs\,(i\,,\,o,\,d\,) \tag{B.19}$$

Variable Definitions

ad(*i*,*o*)	technology shifter for domestic good *i* in region *o*, technology
ade(*i*,*o*)	shifter for composite export good *i* in region *o*, technology shifter
ade(*i*,*o*,*d*)	for exports of good *i* from region *o* to region *d*, preference shifter
ap(*i*,*d*)	for composite good *i* in region *d*, consumption share weighted
ap_avg(*d*)	average of *ap* in region *d*, preference shifter for domestic good *i*
apd(*i*,*d*)	in region *d*,
apm(*i*,*o*,*d*)	preference shifter for imported good *i* from region o in region *d*, consumption
apm_avg(*i*,*d*)	share weighted average of *apm* for good *i* in region *d*, percentage change in
pim(*i*,*d*)	the consumer price index of imported good *i* in region *d*, percentage change in
pm(*i*,*o*)	the producer price index of good *i* in region o, percentage change in the
pmd(*i*,*o*)	producer price for domestic of good *i* in region o, percentage change in the
pme(*i*,*o*,*d*)	producer price of exported good *i* from region *o* in region *d*,
pmei(*i*,*o*)	percentage change in the producer price index of exported good *i* from region *o*,
pms(*i*,*o*,*d*)	percentage change in the tariff-inclusive price of imported good *i* from region *o* in region *d*,
pop(*d*)	percentage change in population in region *d*,
pp(*i*,*d*)	percentage change in the consumer price of composite good *i* in region *d*,
ppd(*i*,*d*)	percentage change in the consumer price of domestic good *i* in region *d*,
ppm(*i*,*d*)	percentage change in the consumer price index of imported good *i* in region *d*,
qme(*i*,*o*,*d*)	percentage change in the demand of imported good *i* from region *o* in region *d*,
qod(*i*,*o*)	percentage change in the supply of domestic good *i* in region *o*,
qom(*i*,*o*)	percentage change in the supply of composite export good *i* in region *o*,
qp(*i*,*d*)	percentage change in the demand for composite good *i* in region *d*,
qpd(*i*,*d*)	percentage change in the demand for domestic good *i* in region *d*,
qpm(*i*,*d*)	percentage change in the demand for composite imported good *i* in region *d*,

qxs(*i*,*o*,*d*)	percentage change in the supply of export good *i* from region *o* in region *d*,
tpd(*i*,*d*)	percentage change in consumption tax on domestic good *i* in region *d*,
tpm(*i*,*d*)	percentage change in consumption tax on composite imported good *i* in region *d*,
vo(*i*,*o*)	percentage change in supply of aggregate factor for good *i* in region *o*,
y(*d*)	percentage change in income for the representative consumer in region *d*,

Coefficient Definitions

EP(*i*,*o*,*d*)	uncompensated price elasticity of good *i* from region *o* in
EY(*i*,*d*)	region *d*, income elasticity of good *i* in region *d*,
CONSHR(*i*,*d*)	consumption share of good *i* in region *d*,
PMRSHR(*i*,*d*)	consumption share of imported good *i* in region *d*,
MSHRS(*i*,*o*,*d*)	share of imported good *i* from from region *o* in region *d* in total imports,
SHRDM(*i*,*o*)	share of output of good *i* in region *o* sold in domestic market,
SHRXD(*i*,*o*,*d*)	revenue share of exported good *i* from region *o* to region *d* in total exports,

Parameter Definitions

ELASTV(*i*,*o*)	supply elasticity of aggregate factor for good *i* in region *o*,
ESUBD(*i*)	elasticity of substitution between domestic and composite imported good *i*,
ESUBM(*i*)	elasticity of substitution between origin regions for imported good *i*,
*ESUBT*1(*i*)	elasticity of transformation between domestic and composite exported good *i*,
*ESUBT*2(*i*)	elasticity of transformation between export destinations for good *i*,

Set Definitions

DEMD	set of demand good (all meat products plus outside good),
COMM	set of meat products,
REG	set of regions

Appendix C: Exogenous Shocks

This appendix provides the set of exogenous shocks implemented for the historical simulation.

Appendix Table C.1. Exogenous Shocks to Population and GDP

Region[a]	Population				Nominal GDP			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
	Percentage change							
United States	3.09	2.81	2.86	2.90	14.01	18.45	11.18	9.10
Brazil	4.29	3.80	3.29	3.30	39.52	44.34	38.14	46.03
China	1.72	1.58	1.62	1.71	34.41	53.43	64.16	60.47
Argentina	2.94	3.08	3.32	3.70	10.44	71.80	86.86	105.75
Australia	3.70	3.62	3.79	4.21	20.84	23.10	26.66	21.58
Russia	-1.42	-1.50	-0.64	0.06	123.41	98.82	72.88	53.02
Mexico	4.08	4.00	4.03	5.05	30.35	32.58	24.70	25.04
EU-27	0.96	1.17	1.25	1.04	14.33	13.44	11.88	5.45
Canada	2.63	2.39	2.53	2.87	17.22	18.62	13.17	12.26
India	5.16	4.87	4.55	4.95	28.81	45.21	52.22	69.07
New Zealand	3.05	3.85	3.07	3.26	20.33	20.10	15.77	11.97
Japan	0.66	0.29	0.04	-0.27	-1.55	0.72	-1.91	-3.61
Korea	2.00	1.20	0.80	0.87	29.87	22.15	19.46	22.81
XAS	5.28	4.77	4.30	4.71	19.51	31.58	37.33	39.25
XSM	4.09	4.25	3.98	4.40	34.59	54.20	50.22	70.83
XOC	6.95	6.66	6.55	6.55	22.49	29.24	33.66	39.63
XCB	4.25	3.86	3.53	3.48	25.94	33.24	30.73	20.36
XME	5.16	5.02	5.06	5.68	46.92	66.63	51.03	48.79
XAF	7.53	7.61	7.57	8.80	36.74	50.91	48.66	64.09
XEU	-1.68	-1.41	-1.03	-0.57	17.29	21.71	26.71	22.24

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table C.2. Exogenous Shocks to GDP Price Deflator and Composite Beef Consumption

Region[a]	PGDP				Composite beef - QP			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
	Percentage change							
United States	6.06	8.01	7.40	5.42	0.84	0.90	1.20	-2.60
Brazil	30.47	29.66	21.73	27.94	8.68	13.18	6.70	1.70
China	4.81	13.47	17.16	17.05	14.90	8.58	9.90	8.80
Argentina	23.23	41.90	56.41	73.05	-2.75	11.77	6.56	-15.59
Australia	9.80	10.90	14.95	11.67	-1.01	-4.59	2.99	-0.07
Russia	85.25	62.86	47.23	44.37	2.59	3.50	7.75	-1.50
Mexico	24.97	21.34	16.69	15.93	7.26	1.36	5.13	-3.75
EU-27	6.62	6.42	6.61	5.15	-2.33	2.34	2.27	-1.90
Canada	7.08	9.25	8.09	6.21	1.48	5.25	2.00	-3.25
India	10.82	15.45	20.54	30.98	-13.99	-12.27	-8.81	-14.43
New Zealand	7.06	7.10	10.50	7.49	-7.20	-1.25	5.81	-13.25
Japan	-4.00	-4.17	-3.05	-4.86	-12.25	-29.95	6.89	11.50
Korea	7.39	6.91	5.95	8.60	11.00	-34.13	21.48	37.50
XAS	7.19	10.95	18.17	17.80	10.32	11.00	23.57	20.00
XSM	31.54	32.20	27.27	51.56	-3.28	12.50	11.31	6.70
XOC	19.14	16.25	16.99	15.57	33.48	-4.31	-5.21	12.10
XCB	13.52	19.67	18.60	14.14	-5.88	3.64	16.12	4.00
XME	35.05	36.51	30.40	29.96	7.62	16.00	9.65	14.00
XAF	22.11	24.64	26.20	44.14	6.73	19.00	16.42	18.00
XEU	9.01	10.11	16.31	18.34	-9.54	28.10	-12.51	10.83

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table C.3. Exogenous Shocks to Composite Chicken and Pork Consumption

Region[a]	Composite chicken - QP				Composite pork - QP			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
	Percentage change							
United States	7.94	17.70	1.07	4.43	1.34	2.55	1.39	-2.46
Brazil	15.48	4.02	17.88	21.67	2.32	-2.27	4.88	10.60
China	11.95	8.68	19.07	10.78	9.18	9.76	10.81	13.19
Argentina	-17.12	16.55	23.47	24.46	-19.41	7.72	36.52	23.76
Australia	10.40	13.06	8.53	24.36	5.56	10.68	5.02	3.33
Russia	43.87	13.40	23.07	12.93	12.74	7.03	22.71	16.74
Mexico	20.57	18.08	9.31	10.52	13.88	12.97	7.17	12.90
EU-27	9.61	-1.78	4.96	10.66	-0.94	-0.88	0.47	3.73
Canada	12.42	7.87	2.66	6.36	3.31	2.58	-5.58	-1.68
India	37.85	31.16	35.58	18.22	0.81	-9.33	-10.25	-5.17
New Zealand	34.02	11.23	-5.86	10.09	5.34	16.64	6.50	-0.13
Japan	0.50	-3.03	4.98	5.86	6.69	7.02	2.68	-0.44
Korea	20.11	4.63	9.89	19.87	8.60	8.87	12.80	-2.05
XAS	12.71	7.62	23.67	21.36	12.82	18.21	17.28	7.18
XSM	20.52	12.48	28.63	23.66	12.32	9.71	17.59	16.07
XOC	22.72	14.66	12.48	30.97	12.80	3.60	5.35	9.35
XCB	15.87	21.60	10.49	5.14	7.15	18.68	33.67	2.03
XME	24.86	20.46	25.06	16.48	34.88	15.83	0.72	-10.88
XAF	43.72	-8.96	23.14	24.28	10.48	15.53	25.79	6.43
XEU	22.67	37.06	29.56	24.74	-9.02	-6.06	4.89	13.07

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

Appendix Table C.4. Exogenous Shocks to Domestic Beef, Chicken, and Pork Consumption

Region[a]	Domestic beef- QPD				Domestic chicken - QPD			
	P1[b]	P2	P3	P4	P1	P2	P3	P4
				Percentage change				
United States	0.01	0.43	3.19	-4.46	.	.	.	.
Brazil	.[c]	13.63	6.83	1.58	.	.	.	.
China	.	8.98	9.95	6.42	11.17	12.09	14.95	14.69
Argentina	.	11.87	6.60	.	.	.	.	.
Australia	.	-5.06	.	.	.	.	.	.
Russia	-3.16	-6.34	-4.61	-4.49	29.54	44.30	51.40	.
Mexico	5.41	5.69	5.34	3.02	19.00	17.68	7.99	6.56
EU-27	-2.76	-5.19	-4.10	-9.62	9.00	-6.83	4.06	0.75
Canada	-2.03	25.26	-4.87	-11.42	.	.	.	.
India	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	.	.	.	.
Japan	-6.76	1.31	1.78	-0.44	2.21	5.65	6.42	2.81
Korea	-38.36	-8.00	28.70	17.76	2.37	21.11	12.77	12.11
XAS	0.32	11.46	17.25	15.74	19.52	13.86	19.72	19.34
XSM	-3.50	7.83	4.60	5.73	.	.	.	.
XOC	-2.36	.	-2.28	-0.07	.	.	.	.
XCB	.	0.85	13.35	0.94	.	.	.	.
XME	4.97	14.46	7.86	9.26	26.16	17.70	20.58	10.71
XAF	7.33	12.60	10.59	8.94	42.11	-11.51	19.94	14.19
XEU	-11.34	-0.83	-2.21	15.60	23.07	31.51	37.21	29.56

Appendix Table C.4. Continued

Region[a]	Domestic pork- QPD			
	P1[b]	P2	P3	P4
	Percentage change			
United States	0.23	2.80	2.50	-2.84
Brazil	.	.	.	.
China	8.81	9.85	10.09	12.04
Argentina	.	.	.	.
Australia	-0.58	1.77	-8.05	-0.24
Russia	5.10	0.36	26.63	24.66
Mexico	7.37	3.15	6.23	5.16
EU-27	-2.99	-6.64	-4.66	-14.99
Canada	0.43	-0.53	-9.64	-2.89
India	.	.	.	.
New Zealand	.	.	.	.
Japan	-1.91	0.13	1.36	1.73
Korea	14.65	-6.29	10.66	-5.74
XAS	12.18	18.74	11.82	7.43
XSM	.	.	.	.
XOC	.	.	.	.
XCB	.	.	.	.
XME	.	.	.	.
XAF	.	.	.	.
XEU	.	.	.	.

[a] Region abbreviations: Rest of Africa (XAF), Rest of Asia (XAS), Rest of Central America, Caribbean (XCB), Rest of Europe (XEU), Rest of Middle East (XME), Rest of Oceania (XOC), and Rest of South America (XSM).

[b] The four time periods in the historical simulation are: P1 2001-2003; P2 2004-2006; P3 2007-2009; and P4 2010-2013.

[c] A missing value indicates no exogenous shock is applied.

Appendix Table C.5. Exogenous Shocks to Bilateral Beef Trade Quantities (QME)

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 1[a]					Percent Change					
United States	.[b]	.	.	.	.	6.26	7.00	.	-7.00	.
Brazil	.	.	.	.	.	4015497.75	.	84.32	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	-91.09	.	.	.	.	.	.	.	-88.94	.
Australia	24.87	.	.	.	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	23.65	.	-7.84	.	.
Canada	1.04	.	.	.	.	.	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	2.27	.	.	.	.	.	.	.	55.43	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	.	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.5. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 1					Percent Change					
United States	.	-18.42	.	59.15	.	.	.	.	.	.
Brazil	.	.	.	132.10	217.79	.	.	351.41	.	150.48
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	-68.01	.	.	-12.17	.	.
Australia	.	-12.40	22.48	57.88	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	-47.16	-90.96	4.30
Canada	.	-9.35	-3.35	.	.	.	.	.	.	.
India	.	.	.	76.57	.	.	.	165.34	.	.
New Zealand	.	-8.79	55.91	48.07	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	.	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.5. Continued

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 2					Percent Change					
United States	.	-98.32	-99.49	-99.86	.	-98.61	-24.28	-92.00	-50.88	.
Brazil	.	.	.	.	.	507.46	.	.	.	.
China	.	.	.	.	.	-96.50	.	.	.	.
Argentina	-98.94	.	.	.	.	3682.00	.	.	.	.
Australia	-15.68	.	.	.	.	44.50	.	.	-85.61	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	-53.92	.	.	.	.
Canada	0.17	.	-99.82	.	.	-95.00	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	-3.82	.	-38.00	.	.	-27.00	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	-71.70	.	.	.	.
XSM	201.00	-34.84	1265.00	.	.	.	.	.	-13.70	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	-13.10	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	-93.93	.	.	.	.
XAF	.	.	.	.	.	.	.	-48.11	.	.
XEU	.	.	.	.	.	-62.67	.	.	.	.

Appendix Table C.5. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 1					Percent Change					
United States	.	-99.04	-95.20	-63.24	-83.00	.	9.13	-8.26	-28.17	-0.89
Brazil	.	.	.	66.82	18.77	.	.	29.16	11760.00	481.07
China	.	.	.	15.10	.	.	.	.	.	.
Argentina	.	.	.	88.80	264.79	.	.	39.73	194.97	.
Australia	.	46.25	76.50	-13.23	.	.	.	.	-3.08	-4.14
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	-83.70	.	.	.	23.13	297.44	25.20
Canada	.	-95.91	-99.27	295.00	.	.	.	.	.	.
India	.	.	.	32.52	.	.	.	112.75	168.87	.
New Zealand	.	140.72	265.73	41.52	.	.	.	.	0.87	-25.96
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	169.00	.	.	-31.67	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	-79.14	.
XAF	.	.	.	.	.	.	.	.	-36.39	2.77
XEU	.	.	.	.	.	.	.	.	.	370.35

Appendix Table C.5. Continued

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 3					Percent Change					
United States	.	.	.	.	.	2223.91	20.47	288.35	150.78	.
Brazil	.	.	.	.	.	65.26	.	-54.70	.	.
China	0.00	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	.	-7.56	.	-4.10	.	.
Australia	-15.78	.	.	.	.	114.41	.	94.20	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	-95.00	.	.	.	.	-58.02	.	17.10	.	.
Canada	-29.55	.	.	.	.	2700.00	.	-63.60	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	-12.59	.	.	.	.	56.97	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	0.00	.	.	.	.	.	.	.	.	.
XSM	-59.04	.	.	.	.	.	.	147.10	.	.
XOC	31.07	.	.	.	.	.	.	.	.	.
XCB	24.40	.	.	.	.	.	.	.	.	.
XME	0.00	.	.	.	.	.	.	.	.	.
XAF	0.00	.	.	.	.	.	.	.	.	.
XEU	0.00	.	.	.	.	-51.13	.	.	.	.

Appendix Table C.5. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 3					Percent Change					
United States	.	1718.11	323.50	117.29	283.25	.	24.10	200.00	405.29	270.24
Brazil	.	.	.	47.21	-41.86	.	.	19.64	84.22	-62.06
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	26.08	.	.	79.22	-33.81	-44.20
Australia	.	-7.67	13.51	67.38	.	.	16.43	49.06	85.37	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	-48.28	4.69	61.29
Canada	.	713.30	.	83.05	-95.00	.	-95.00	.	-43.30	.
India	.	.	.	-11.16	.	.	.	44.10	213.30	.
New Zealand	.	-13.67	-16.74	9.72	-70.00	.	.	.	-34.00	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	621.00	.	.
XSM	.	.	.	966.51	243.68	.	.	4.20	40.88	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	-46.12	.
XEU	.	.	.	.	.	.	.	.	.	-63.43

Appendix Table C.5. Continued

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 4					Percent Change					
United States	.	.	.	.	.	121.93	-28.15	318.86	36.86	.
Brazil	.	.	.	.	.	-33.57	.	-47.67	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	.	-63.52	.	-34.55	.	.
Australia	-28.26	.	557.30	.	.	23.12	.	39.36	7.06	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	287.59	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	48.01	.	9.12	.	.
Canada	-3.03	.	40571.90	.	.	.	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	-8.91	.	197.70	.	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	-63.24	.	3575.00	.	.	.	.	-15.30	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	84.72	.	.	.	.

Appendix Table C.5. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 4					Percent Change					
United States	.	153.28	197.19	144.13	145.09	.	78.71	140.65	222.13	.
Brazil	.	.	.	34.66	174.36	.	.	12.47	98.60	-68.04
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	-44.52	.	.	-5.19	-62.00	-76.68
Australia	.	-12.71	.	23.98	.	.	-71.43	147.14	62.26	40.22
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	125.04	132.50	112.80
Canada	.	108.39	.	48.26	.	.	.	.	71.22	.
India	.	.	.	7.70	.	.	.	6.48	48.07	.
New Zealand	.	-3.45	-14.36	2.49	.	.	-13.36	.	122.12	4.11
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	153.71	.	.
XSM	.	.	.	.	-53.31	.	.	69.76	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	2713.08	.	.	.	.	.
XME	.	.	.	.	.	.	.	408.70	.	.
XAF	.	.	.	.	.	.	.	.	365.98	.
XEU	.	.	.	.	.	.	.	.	.	-28.93

Appendix Table C.6. Exogenous Shocks to Bilateral Beef Unit-Values

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 1					Percent Change					
United States	.	.	.	.	.	.	.	.	.	.
Brazil	.	.	.	.	.	-3.67	.	-16.29	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	6.15	.	.	.	.	.	.	.	.	.
Australia	.	.	.	.	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	.	.	.
Canada	.	.	.	.	.	.	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	.	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.6. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 1					Percent Change					
United States	.	.	.	.	.	.	.	.	.	.
Brazil	.	.	.	-19.42	31.12	.	.	-19.81	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	.	.	.	.	.	.
Australia	.	.	.	.	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	.	100.17	.
Canada	.	.	.	.	.	.	.	.	.	.
India	.	.	.	-6.52	.	.	.	-18.00	.	.
New Zealand	.	.	.	-0.23	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	.	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.6. Continued

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 2					Percent Change					
United States	.	.	10.87	-42.25	.	-1.86	14.89	43.46	52.97	.
Brazil	.	.	.	.	.	25.64	.	33.05	.	.
China	.	.	.	.	.	37.52	.	.	.	.
Argentina	.	.	.	.	.	25.79	.	38.26	.	.
Australia	.	.	.	.	.	27.05	.	57.52	70.70	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	36.88	.	.	.	.
Canada	9.24	.	.	.	.	69.44	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	.	20.12	.	.	38.87	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	31.83	.	.	.	.
XSM	5.23	60.12	-18.57	.	.	22.08	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	3.39	.	.	.	.
XAF	.	.	.	.	.	.	.	31.72	.	.
XEU	.	.	.	.	.	47.61	.	56.04	.	.

Appendix Table C.6. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 2					Percent Change					
United States	.	53.30	16.98	6.33	36.52	.	19.96	1.61	2.83	5.56
Brazil	.	.	.	.	.	.	.	18.50	74.22	33.25
China	.	.	.	20.59	25.90	.	.	.	.	.
Argentina	.	.	.	.	.	.	.	.	19.44	46.73
Australia	.	47.52	.	.	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	30.28	.	.	.	.	.	27.66
Canada	.	97.85	-43.59	14.46	40.25	.	.	.	.	.
India	.	.	.	.	.	.	.	30.38	16.39	.
New Zealand	.	.	.	.	38.17	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	.	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	29.38	.	.
XAF	.	.	.	.	.	.	.	.	93.71	.
XEU	.	.	.	.	.	.	.	32.75	.	.

Appendix Table C.6. Continued

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 3					Percent Change					
United States	.	.	.	.	.	.	14.25	.	19.96	.
Brazil	.	.	.	.	.	.	.	.	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	.	.	.	.	.	.
Australia	.	.	.	.	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	-1.48	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	.	.	.
Canada	.	.	.	.	.	.	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	.	.	.	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.6. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 3					Percent Change					
United States	.	-5.96	42.42	41.12	10.30	.	9.11	53.27	115.98	.
Brazil	.	.	.	.	78.60	.	.	.	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	.	.	.	.	42.94	.
Australia	.	.	.	.	.	.	.	.	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	.	.	.
Canada	.	-14.48	.	.	13.94	.	60.33	.	39.61	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	12.56	.	.	.	23.20	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	26.45	.	.
XSM	.	.	.	57.48	31.29	.	.	.	15.03	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	7.61	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	91.68	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.6. Continued

	USA	Brazil	China	ARG	AUS	Russia	Mexico	EU-27	Canada	India
Time Period 4					Percent Change					
United States	.	.	.	.	.	.	26.21	-3.68	19.47	.
Brazil	.	.	.	.	.	.	.	41.54	.	.
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	.	.	.	27.90	.	.
Australia	.	.	22.86	.	.	.	.	.	22.18	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	4.64	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	.	.	.
Canada	.	.	125.06	.	.	.	29.37	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	.	.	.
XSM	.	.	78.08	.	.	.	.	20.35	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	.	.	.	.	.	.
XME	.	.	.	.	.	.	.	.	.	.
XAF	.	.	.	.	.	.	.	.	.	.
XEU	.	.	.	.	.	.	.	.	.	.

Appendix Table C.6. Continued

	NZL	Japan	Korea	XAS	XSM	XOC	XCB	XME	XAF	XEU
Time Period 4					Percent Change					
United States	.	2.75	-4.80	16.22	.	.	-26.43	24.33	4.23	.
Brazil	.	.	.	.	36.99	.	.	.	-8.29	48.41
China	.	.	.	.	.	.	.	.	.	.
Argentina	.	.	.	.	53.87	.	.	.	47.24	119.57
Australia	.	.	.	.	.	.	.	19.35	.	.
Russia	.	.	.	.	.	.	.	.	.	.
Mexico	.	.	.	.	.	.	.	.	.	.
EU-27	.	.	.	.	.	.	.	31.16	2.69	25.53
Canada	.	-10.09	.	.	.	.	.	.	.	.
India	.	.	.	.	.	.	.	.	.	.
New Zealand	.	.	.	.	.	.	.	.	.	.
Japan	.	.	.	.	.	.	.	.	.	.
Korea	.	.	.	.	.	.	.	.	.	.
XAS	.	.	.	.	.	.	.	10.10	.	.
XSM	.	.	.	.	21.87	.	.	.	.	.
XOC	.	.	.	.	.	.	.	.	.	.
XCB	.	.	.	.	-41.60	.	.	.	.	.
XME	.	.	.	.	.	.	.	67.76	.	.
XAF	.	.	.	.	.	.	.	.	20.27	.
XEU	.	.	.	.	.	.	.	.	.	.