A Counterfactual Experiment About The Eradication of Cattle Disease On Beef Trade

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Abstract

In response to disease outbreak alerts in exporting countries, importing countries usually impose trade bans that vary in terms of product coverage and in terms of duration. We rely on a unique balanced panel dataset that covers 4-digit disaggregated beef product over the 1996-2013 period, to estimate the effect of a hypothetical removal of animal diseases outbreaks on trade flows. More specifically, we investigate how bovine spongiform encephalopathy (BSE) and the foot and mouth diseases (FMD) affect beef trade flows. We use a sectoral structural gravity approach to measure direct, conditional and full effects, allowing inward and outward multilateral resistance indices and factory-gate prices to adjust to the eradication of animal disease. The indirect channels through which BSE and FMD impact trade are important. Our counterfactual experiment suggests that Canada would be one of the countries gaining the most from BSE and FMD eradication.

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1 Introduction

In 2017, world beef exports amounted to US$ 52 billion (WITS, 2018). Canada's beef exports contributed $2.4 billion or US$ 18 billion to this tally with India, Brazil and Australia being the top exporting countries. [1]. Canada's beef exports represents about 30-40% of its domestic production. The Canadian cattle and beef industry is concentrated in Alberta and Saskatchewan. Unfortunately, international trade in live animals and meat products, including beef, has been hindered by animal disease outbreaks that quickly spread between countries (Yang et al., 2013). Some of these diseases are highly contagious and disease outbreaks have a tendancy to be spatially concentrated and clustered regionally (Marsh et al., 2005). The beef sector is particularly vulnerable to bovine spongiform encephalopathy (BSE) and foot and mouth disease (FMD). BSE, also known as mad cow disease, is a fatal neurodegenerative disease with a long incubation period that can be transmitted to humans.[2] FMD may cause permanent damage to heart muscle and feet in susceptible cattle. It may also induce a high level of morbidity, but it is usually not fatal (McCauley, 1979). BSE cases have been reported in several European countries,Japan, Brazil, the United States and Canada. FMD cases have been mainly observed in South America and Asia.

Following an outbreak alert, importing countries usually impose trade bans and adopt sanitary and phytosanitary measures to minimize the risk of contamination.[3] Countries battling disease outbreaks typically enforce eradication programs. Following FMD outbreak in May of 2001, the UK Ministry of

[1]See http://www.agr.gc.ca/eng/industry-markets-and-trade/canadian-agri-food-sector-intelligence/red-meat-and-livestock/red-meat-and-livestock-market-information/exports/red-meat-exports-by-month/?id=1419963017182

[2]Eating BSE-contaminated beef can cause the Creutzfeldt-Jakob disease which is responsible for the death of 177 UK residents.

[3]During the UK BSE crisis, France and Germany were quick to call on an import ban on British beef, but they ignored warnings from the European Commission about how to avoid the spread of BSE within their borders. For more details see "Europe's Mad Cows" in The Economist, November 28, 2000

Agriculture, Fisheries, and Food reported the destruction of 465,000 cattle, 118,000 swine, and 2,418,000 sheep (Paarlberg et al., 2002). In the Netherlands, the classical swine fever (CSF) caused the destruction of a million hogs (Yadav et al., 2016). Countries may impose stricter regulations that add to production and processing costs, like the removal of specified risk material in the slaughter of ruminant animals. The magnitude of the outbreaks can vary substantially across countries and over time. In 1988, 421 cattle were diagnosed with BSE in the UK, but the number of BSE-infected cattle increased to 120000 in 1993. This led to an EU import ban and the implementation of an eradication program that destroyed 4.4 million cattle in 1996.[4]. The discovery of a single BSE case in Alberta in 2003 triggered import bans by 40 countries. The US beef industry suffered immediate import bans from 53 countries when a BSE infected cow was identified in December of 2003 (Pendell et al., 2007), and even though some markets like Canada and Mexico reopened in 2004, 2004 exports had dropped by 82% relative to their 2003 levels according to Coffey et al. (2005). Such variations in exports for a large exporting country like the United States has important welfare implications. Clearly, a single BSE case can create much friction for a country's exports. The length and product coverage of import bans vary a lot across countries. Following the discovery of the first Canadian mad cow in 2003, the US reopened its border to Canadian beef and live cattle less than 30-month old in 2005, but South Korea reopened its border only in 2012.

The cattle and beef industry is one known for its long production and price cycles.The production process is split between cow-calf operators and feedlots. A cow's gestation period is 9.5 months long and it takes 6 to 8 months for weaning calves. Calves are then fattened and are slaughtered when they are between 16 and 30-month old. Because calving and slaughter-

[4]for more details see https://www.centerforfoodsafety.org/issues/1040/mad-cow-disease/timeline-mad-cow-disease-outbreaks

ing decisions are separated by years, production cannot change very quickly to changing market conditions. This creates peculiar market dynamics that give rise to zero or negative supply response that attracted much attention as far back as the 1960s (Reutlinger, 1966). Beef production is conditioned by cattle supply and this has important implications for trade in beef and hence for the specification of a beef gravity model.

In the event of a disease alert, the cattle and meat slotted to be sold in countries imposing import bans must be re-directed and sold elsewhere or discarded. An obvious buffer market, when public health is not at risk, is the domestic market. The increase in domestic supply depresses domestic prices and this effect is compounded when domestic consumers change their behaviour because of lasting food safety concerns. Coffey et al. (2005) argues that US consumers have been minimally impacted by BSE, but BSE had a lasting adverse impact on beef consumption in Japan according to Ishida et al. (2010). It follows that to properly model the trade implications of disease alerts on trade, it is necessary to have data on international AND intra-national flows, even if one is interested in measuring only the partial equilibrium or direct effects of livestock diseases on trade. This is so because the estimated coefficients pertaining to livestock diseases cannot be precisely estimated if some trade flows are missing.

The inclusion of intra-national flows is also required to take advantage of recent advances in gravity modelling that allow to assess the impact of trade costs on trade through the trade costs' incidence on inward and outward multilateral indices and on factory-gate prices. The multilateral resistance indices can be recovered by summing fixed effects terms over sources, for the inward index, and over destinations, for the outward one, provided all trade flows add up to sectoral production. Put differently, intra-national trade flows are required if one wants to measure the full effects of livestock diseases through multilateral indices and factory-gate prices. Thus, previous gravity models estimated on truncated data, without intra-national flows, were deficient. Intuitively, the magnitude of the defect is related to the relative size of intra-national trade flows. In this regard, there is much variation across exporting countries with a country like Australia that exports on average over the 1996-2013 period 70% of its production while countries like Canada and the United States have ratios of 30% and 10% respectively.

Another implication of the inelastic short run supply on the specification and estimation of the gravity model is the dynamics of disease alerts. Import bans vary in terms of product coverage and in duration. As for the effects of regional trade agreements in gravity equations estimated over aggregated manufactured exports, it is essential to allow for lagged responses and/or to perform the estimation on panels with time observations separated by two, three or four years, as advocated by Yotov et al. (2016).

The objective being pursued in this paper is to shed new light on the incidence of BSE and FMD outbreaks on beef trade flows. First, we compute short run and long run "direct" impact elasticities for BSE and FMD from three competing gravity models. The first model handles dynamics through several lagged BSE and FMD variables and is estimated on annual data. The second and the third models adopt a different strategy by estimating different specification model on a datasets with consecutive observations separated by 1 and 3 years respectively. After selecting a preferred specification, we use recent breakthroughs in structural gravity modeling to explore the implications of a counterfactual scenario showcasing the elimination of BSE and FMD outbreaks. The introduction of intra-national trade flows insures that trade flows add up to sectoral output and expenditures and this allows us to recover the multi-resistance inward and outward indices and measure how the elimination of BSE and FMD outbreaks change these indices. The modified indices can then be used to measure "conditional" trade flows that account for the direct effects of BSE and FMD elimination and the effect through the multi-resistance indices. The last step allows the elimination of BSE and FMD diseases to impact on multilateral resistance indices and factory-gate prices. The full effects of a hypothetical removal of animal diseases results from the iterations between multilateral resistance indices, factory-gate prices and trade. To the best of our knowledge, our paper is the first to examine the effects of animal disease outbreaks using a sectoral structural gravity framework. Our results show much heterogeneity in welfare changes across countries, but large gains for Canada.

Our work is related to that of Yang and Saghaian (2010) which investigates the effects of FMD in foreign markets on exports of U.S. swine meat. They argue that the presence of FMD in foreign countries tends to increase the demand for swine meat from the U.S. Felt et al. (2011) examine the incidence of the Japanese ban on Taiwanese pork following the foot and mouth disease outbreak in Taiwan on the shares and market power of other exporters. The ban made the U.S. residual demand more inelastic and reinforced U.S market power, but the adjustment took a few years. A recent study by Zongo et al. (2017) accounting for vertical linkages between the cattle and beef sectors, measures the incidence of animal disease outbreaks on the extensive and the intensive margins of trade for both cattle and beef. BSE and FMD are found to have negative and significant impacts at both margins for trade in cattle and in beef, but the effects at the intensive margin are stronger. Webb et al. (2018) show that disease outbreaks, induce exporters to substitute away from markets that have not experienced BSE or FMD toward lower value markets. These animal disease outbreaks can have drastic effects on trade flows. Ekboir (1999) performs the simulation of a scenario in which Japan and Korea respond to a US FMD outbreak by banning all imports of American beef for two years after the eradication of the last reported case.

Our study is related to the general strand of the literature on market access and non-tariff barriers (e.g., Winchester et al. (2012) and Xiong and Beghin (2017)). The General Agreement on Tariffs and Trade, under its Article XX, provides guidelines about health standards for international trade to protect animal and human health through Sanitary and Phytosanitary (SPS) Agreement. While WTO members are committed to develop standards in line with scientific evidence and not use standards as disguised trade barriers, there is much heterogeneity in the way countries set standards (see Winchester et al. (2012)) and in the way they react to disease outbreaks. This is true for countries hosting diseases and countries dealing with countries hosting diseases. For example, vaccination of poultry against H5N1 was implemented by Vietnam and China, but it was not by Thailand (Walker et al., 2012). As for previous studies, we find that exporting countries with BSE and/or FMD cases export less all else equal, but we also we test whether importing countries plagued with domestic BSE and/or FMD cases import more, all else equal, than importing countries which do not have to contend with domestic BSE and/or FMD cases.

Trade costs can take different forms. The level of export and import bureaucracy in dyads of exporting and importing countries could be thought as a measure of fixed cost reducing trade through the extensive margin. In the case of agricultural products, squabbles over SPS measures can possibly have a similar bureaucratic effect. An importing country's SPS measures can be targeted by exporting countries as unnecessarily strict and hence acting as non-tariff trade barriers. Exporting countries targeting a specific SPS measure are "issue raisers" and several exporting countries can raise the same SPS issue. For importing countries with legitimate SPS measures, issue raisers are potential troublemakers. Countries whose SPS measures are contested are "targets". Being frequently targeted suggests that the importing country tends to be protectionist, even though most standards constrain domestic and foreign firms. We find that trade flows involving exporting countries that are frequent SPS issue raisers and/or importing countries whose SPS measures are frequently targeted are expected to be smaller, all else equal, as SPS squabbles increase trade costs. Trade cost variables like common official language, colonial linkages and contiguity were not significant.

In terms of methodology, our study follows in the footsteps of the pioneering sectoral structural gravity study of Anderson et al. (2015) which perform counterfactual analyses about the elimination of regional trade agreements for more several sectors. We adapt the model by introducing lagged BSE and FMD variables, tariffs and an SPS involvement indicator to reflect the trade costs that are specific to beef sector.

Our paper is organized as follows. The next section presents the sectoral structural gravity framework and how it is developed to fit the economics of the beef industry. The third section focusses on the data, by listing data sources and presenting descriptive statistics. The fourth section discusses the results from the estimation of three competing structural gravity models and presents the results of a counterfactual analysis contrasting partial and full effects stemming from the complete elimination of BSE and FMD diseases. The last section highligths the main results and their policy implications

2 Sectoral Structural Gravity and Animal Disease Alerts

As indicated above, our framework draws heavily from that of Anderson et al. (2015) who rely on a sectoral structural gravity framework to estimate the effects of regional trade agreements on trade for 2-digit manufacturing sectors. The main advantage of this framework is that it allows for regional trade agreements to have different impacts across sectors. Unlike the supply-side or Ricardian gravity framework of Eaton and Kortum (2002) which imposes an infinite elasticity of transformation between tradable goods, the demand-side framework has a zero elasticity of transformation and as such it can be likened to an endowment or fixed output-mix general equilibrium model. In the demand-side approach to gravity, the general equilibrium effects results from consumers substituting goods within and between sectors that ultimately influence factory-gate prices and the value of output. The endowment feature nicely fits with the long production lags in cattle production that restricts adjustments in beef production over time and make prices more volatile. [5] As indicated by Yotov et al. (2016), the separability property implies that the gravity system of equations holds for each sector. As a result, we can specify a fully consistent sectoral structural gravity model for beef trade to measure partial effects of BSE and FMD diseases on trade flows, treating multilateral resistance indices and factory-gate prices as exogenous, as well as full effects that allow multilateral resistance indices and factory-gate prices to adjust to the presence or absence of BSE and FMD diseases.

We also draw from Yotov et al. (2016) in the manner with which we address various empirical challenges. Accordingly, our sectoral structural gravity framework is quite different from the gravity frameworks used in previous studies about BSE and FMD outbreaks (e.g., Webb et al. (2018), (2013)). For example, we use lagged BSE and FMD variables on annual panel data and current BSE and FMD variables on panel data with intervals (i.e., skip 1 or 3 years between observations) to precisely measure long run trade flow

[5] The coefficients of variation for the beef quantity produced for the United States and Canada are 3% and 14% while the corresponding statistics for prices are 22% and 25% respectively. Canadian production is trending upward and this explains in part the larger Canadian statistic for quantity produced.

adjustments in counterfactual experiments. We rely on a balanced panel dataset about trade in beef defined at the 4-digit level between 40 countries over the 1996-2015 period to estimate the effect of a hypothetical removal of animal diseases outbreak on trade flows. To insure that expenditures and production add up to world output, a "rest of the world" economic entity was added to the list of countries. As for most agricultural products, beef exports is highly concentrated with the top five exporters accounting for over 70% of world exports. We also include intra-national flows to be able to identify the incidence of importer-specific trade costs like tariffs which would otherwise be absorbed by importer fixed effects. However, the most important difference between our framework and that used in previous studies on animal diseases is that we are allowing diseases to impact directly on trade flows and indirectly through multilateral resistance indices and factory-gate prices. This makes it possible to estimate the partial and full impacts of BSE and FMD disease outbreaks.

2.1 Endogenizing multilateral indices and factory-gate prices

We provide a short discussion about the structural sectoral gravity approach developed by Anderson and Yotov (2016) to describe the theoretical foundation behind the empirical procedure described in the next subsection. The emphasis is on the linkages between trade costs stemming from BSE and FMD outbreaks, the IMR and OMR indices, factory-gate prices and trade flows. The model rests on specific assumptions that are common in the literature. As in Yotov et al. (2016), the world is made up of N countries and consumers all over the world have identical CES preferences such that $U_j^k = [\int_{\omega \in \Omega_j^k} [q(\omega)]^{\frac{\varepsilon^k - 1}{\varepsilon^k}} \mathrm{d}]^{\frac{\varepsilon^k}{\varepsilon^k - 1}}$ where Ω_j^k represents the set of available varieties of product k in country j, $q(\omega)$ is the consumption of variety ω in country j, and the elasticity of substitution between varieties is denoted by ε^k.

Consumers in country j purchase varieties from different sources, including domestic ones when $i = j$, at delivered prices $p_{ij}^k(\omega) = p_i^k(\omega)\tau_{ij}T_{ij}^k$, where $p_{ij}^k(\omega)$ is the price observed in country j of variety ω of product k originating from country i, $\tau_{ij} \geq 1$ is the bilateral iceberg trade costs which describes how much is lost during transit, and T_{ij}^k is the tariff applied by destination country j to imports from country i.[6] To simplify we define $t_{ij} = \tau_{ij}T_{ij}$. The constrained maximization of utility by consumers yields the following demand for variety ω supplied by a firm based in country i selling to country j:

$$X_{ij}^k(\omega) = E_j^k P_j^{1-\varepsilon^k}[p_{ij}^k(\omega)]^{1-\varepsilon^k} \tag{1}$$

where $P_j^k = [\int_{\omega \in \Omega_j^k} p_{ij}^k(\omega)^{1-\varepsilon^k}]^{\frac{1}{1-\varepsilon^k}}$ is the aggregate consumer price index. E_j^k denotes expenditures on product k in country j. It is hypothesized that the CES preferences over varieties of product k define a subutility function which is nested in a Cobb-Douglas utility function. As a result, E_j^k is a constant share η^k of country j's total expenditures E_j.

$$E_j^k = \eta^k E_j \tag{2}$$

On the supply side, we have an endowment economy with an exogenous quantity Q_i^k. The value of sectoral output at the factory gate price is given by $p_i^k Q_i^k = Y_i^k$. The fixed-endowment model is consistent with the production rigidities observed for agricultural products with long production cycles. In an endowment model, supply is zero-elastic and variations in the value of production stem from the changes in factory-gate prices.

[6] This formulation is consistent with our sectoral endowment model. In a model with several sectors and firms with endogenous markups, tariff revenue would have to be factored in and tariffs would be levied on the markup-inclusive price and would be more potent than iceberg trade costs of the same value.

Market clearing implies:

$$Y_i^k = \sum_j X_{ij}^k \tag{3}$$

$$= \sum_j E_j^k P_j^{1-\varepsilon^k} [p_{ij}^k(\omega)]^{1-\varepsilon^k} \tag{4}$$

Define $Y^k \equiv \sum_i^N Y_i^k$ where N is the number of countries and divide equation (3) by Y^k it can be shown that:

$$(p_i^k \Pi_i^k)^{1-\epsilon^k} = \frac{Y_i^k}{Y^k} \tag{5}$$

Inserting equation 4 in equation 5 gives the outward multilateral resistance index (OMR):

$$(\Pi_i^k)^{1-\epsilon^k} = \sum_j (\frac{\tau_{ij} T_{ij}^k}{P_j^k})^{1-\epsilon^k} \frac{E_j^k}{Y^k} \tag{6}$$

The OMR aggregates all bilateral trade costs that exporters in country i face across destinations j. Increases in trade costs increase the OMR, the more so when the trade costs increases occur in large countries. Substituting the equilibrium scaled prices given by (5) into equation (4), we obtain the inward multilateral resistance (IMR):

$$(P_j^k)^{1-\epsilon} = \sum_i (\frac{\tau_{ij}^k T_{ij}^k}{\Pi_i^k})^{1-\epsilon^k} \frac{Y_i^k}{Y^k} \tag{7}$$

The IMR defines the weighted average of all bilateral trade costs that consumers in country j face when importing goods from different sources. Increases in trade costs increase the IMR. The IMR may not be interpreted as a consumer price index (CPI) if the purchases are made by intermediate goods users. The structural gravity export equation can be rewritten in terms of the OMR and IMR indices:

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} (\frac{t_{ij}^k}{\Pi_i^k P_j^k})^{1-\epsilon} \tag{8}$$

The factory-gate price is related to the OMR and is given by:

$$p_i^k = (\frac{Y_i^k}{Y^k})^{\frac{1}{1-\epsilon_k}} \frac{1}{\alpha_i \Pi_i^k} \tag{9}$$

The factory-gate price and the IMR and OMR indices are fixed in the short run and partial trade costs effects on trade flows can be obtained from the trade cost coefficients of the empirical version of the export equation. Fally (2015) has shown that the IMR and OMR indices can be recovered from the importer and exporter fixed effects in the empirical export equation estimated by Poisson Pseudo Maximum Likelihood (PPML).[7] Only with the PPML are the fitted output and expenditures, defined as the sum of fitted outward and inward trade flows for each country, equal to observed output and expenditures. More specifically, the baseline OMR and IMR indices are given by:

$$(\Pi_i^k)^{1-\epsilon^k} = \frac{Y_i^k}{exp(FE_i)} E_r^k \tag{10}$$

$$(P_j^k)^{1-\epsilon^k} = \frac{E_j^k}{exp(FE_j)} \frac{1}{E_r^k} \tag{11}$$

where FE_i designates the exporter-time fixed effects associated with exporter i and E_r^k is the level of expenditures in a reference country whose importer fixed effects are normalized to one. A counterfactual experiment with some trade costs set at zero can be implemented by estimating a constrained empirical export equation. The trade cost effect is constrained by

[7]The PPML estimator delivers consistent estimates in the presence of zeros and heteroskedasticity (Silva and Tenreyro, 2006).

the product of a vector of constrained trade costs and benchmark trade cost coefficients. A new set of fixed effects is estimated and used to compute new OMR and IMR indices reflecting the removal of certain trade costs, like the ones associated with BSE and FMD disease outbreaks. The constrained multilateral resistance indices can be used to compute changes in factory-gate prices as follows:

$$\Delta p_{i,t}^{CFL} = \frac{p_{i,t}^{CFL}}{p_{i,t}} = \frac{\exp(\hat{\pi}_i{}^{CFL})/E_{R,t}^{CFL}}{\exp(\hat{\pi}_i)/E_{R,t}} \tag{12}$$

where $\hat{\pi}_i$ is the PPML estimates exporter fixed effects, $E_{R,t}$ is the expenditure of the reference country. Changes in OMR and IMR indices and in factory-gate prices change output and expenditures which in turn change trade flows. New fixed effects can be estimated from the new trade flows and another set of OMR and IMR indices can be computed. The system can iterate until the changes recorded are very low. Full trade effects are computed by comparing counterfactual and benchmark statistics

3 Empirical strategy

The above structural gravity framework is typically applied to conduct counterfactual experiments about pair-specific time-varying variables like regional trade agreements. A counterfactual experiment about BSE and FMD disease outbreaks poses a challenge because outbreaks are taking place in specific exporting and importing countries in different years. If country i has BSE and/or FMD-infected cattle in year t, several importing countries will impose import bans in year t of various lenghts. If the import bans are levied near the end of the year, they will not have much of an impact on year t's trade flows. Accordingly, the import bans are likely to have a larger impact on subsequent years' trade flows. As time passes, import bans can be softened to allow some trade. The scope of products covered by import bans can be narrowed and exporters can implement various food safety and risk management procedures to appease importers, like the removal of "BSE specified risk material" during cattle slaughter. The emergence of BSE and/or FMD cases in importing countries may also impact on trade flows, and possibly over several years. To account for this, we define exporter-specific BSE and FMD dummy variables that equal one when exporting country i has at least one infected animal and the buyer is an importing country. The latter condition is motivated by the fact that domestic authorities typically do not impose bans on beef originating from domestic sources. Lagged BSE and FMD effects must also be introduced to capture the dynamics of BSE and FMD outbreaks. The addition of these BSE and FMD variables that are exporter and importer-specific and time-varying means that exporter-time and importer-time fixed effects must be replaced by exporter and importer fixed effects and exporter and importer time-varying variables that enter the theoretical structural export equation, like sectoral expenditures and output. We use the PPML estimator to obtain benchmark coefficient estimates for an empirical version of export equation (8):

$$X_{ij,t} = exp(\Gamma_{ij,t}\beta + \Lambda_{it}\theta + \Sigma_{jt}\gamma + \Delta_{ij}\alpha + \tau_i + \chi_j) + \epsilon_{ij,t} \tag{13}$$

where $X_{ij,t}$ is the bilateral trade flow (in levels) between countries i and j at time t. τ_i is the exporter fixed effects which will be used to recover the (log of) outward multilateral resistance index. Similarly, χ_j is the importer fixed effect for country j, which will be used to recover the (log of) IMR. $\Gamma_{ij,t}$ are control pair-specific variables that vary over time, like applied tariffs. The effect of regional trade agreements on tariffs is embodied in the coefficient for the tariff variable, but this does not mean that regional trade agreements do not impact on trade flows through other channels. Copeland (1990) contends that negotiated tariff reductions can induce protectionist responses through non-negotiated policy instruments. Since regional trade agreements can be seen as incomplete contracts, they can have a non-tariff negative effect once tariff reductions are accounted for. However, regional trade agreements usually have non-tariff negotiated provisions that could be trade-enhancing. Accordingly, the sign and significance of the regional trade agreement coefficient is an issue that can only be resolved empirically. We have an indicator of SPS involvement specified as: $SPSijt = 0.6 * SPSIR_t + 0.3 * SPSIR_{t-1} + 0.1 * SPSIR_{t-2} + 0.6 * SPS_I T_t + 0.3 * SPS_I T_{t-1} + 0.1 * SPS_I T_{t-2}$, where SPSIR is the number of SPS issues raised by the exporting country in the pair times an international trade flow indicator and $\text{SPS}_I T$ is the number of SPS issues for which the importer in the pair is being targeted. Our SPS indicator takes into account the exporting country's tendancy to complaint and the controversial nature of the importing country's SPS measures.

Λ_{it} are time-variant variables specific to the exporting country, like the dBSE origin and dFMD origin variables and sectoral output. Σ_{jt} stands for time-varying variables that are specific to the destination country (dBSE dest, dFMD dest and sectoral expenditures). Δ_{ij} are time-invariant bilateral variables, like distance, contiguity and common official language. The latter is defined by a dummy variable that takes the value 1 if the two countries have the same official language and 0 otherwise. Meat production is subject to long biological lags and supply can be treated as somewhat fixed in the short run Moro and Sckokai (2002). The dynamics can be handled by adding lagged variables, a common procedure to properly evaluate the incidence of regional trade agreement and by dropping years between any two observations. Anderson and Yotov (2016) relies on a panel with three-year intervals. In the process of recovering the IMR and OMR indices, one must evaluate or set the elasticity of substitution. We do the latter and fix it at 14. Previous studies show that the elasticity of substitution for beef can be very high given the structure of the market (Brester, 1996; Broda and Weinstein, 2006). As mentioned before, not all importer and exporter fixed effects can be identified and an importer fixed effect must be dropped. As a result, the IMR_j and OMR_i resistance terms have to be interpreted as relative to the indices of the normalizing country (Anderson and Yotov, 2010; Yotov et al., 2016). We set the IMR for our country of reference, China, to one. Thus, all other inward and outward multilateral resistances will be measured relative to the IMR for China. We chose China as a reference group because China is a large country which has not been impacted nearly as much by BSE and FMD as other large countries. Thus, the relative impact for all affected countries can be expected to approximate closely the absolute effect in China.

In a first step, the PPML estimation delivers estimates of the partial effects of distance, applied tariffs, BSE, and FMD disease variables. These estimates are are use to construct all baseline indexes of interest, such as the IMRs and OMRs, and predicted exports. In the second step, we estimate redefined trade costs without BSE and FMD diseases, and estimate new fixed effects to compute new IMRs and OMRs and conditional trade effects, while output and, expenditure and factory-gate prices are maintained constant.

$$WS_i = \frac{W_i^{CFL}}{W_i^{BLN}} = (\frac{\lambda_{ii}^{CFL}}{\lambda_{ii}^{BLN}})^{\frac{1}{1-\epsilon}} \tag{14}$$

where $W_i = E_i/P_i$ denotes welfare/real consumption in country i, $\lambda_{ii} = \frac{X_{ii}}{E_i}$ the share of expenditure on home goods.

Finally, in the third step, we compute full counterfactual effects from iterated IMR and OMR indices and factory-gate prices that in turn change output, expenditures and hence welfare. Arkolakis et al. (2012) has shown that the gains from trade for many models can be measured by a simple formula which can be applied to estimate the gains from the elimination of

BSE and FMD diseases. The formula is simply the ratio of the share of intranational flows in total expenditures without and with BSE and FMD diseases elevated to the power one minus the elasticity of substitution:

4 Data and descriptive statistics

4.1 Data

Our data come from several sources. The product definition is the 4-digit HS classification for beef. Data on import values and tariffs comes from the World Integrated Trade Solutions (WITS) website. The World Trade Organization (WTO)'s Tariff Analysis Online was used to obtain tariffs that were not in WITS. Data series on language, distances, colony and border were downloaded from CEPII's database. Data on the number of cattle infected by BSE and FMD are collected from the OIE database and the missing one have been kindly provided by the OIE, Head of World Animal Health Information and Analysis Department. We collected beef production data from the Food and Agriculture Organization (FAO) database. For each country, we obtained a quantity produced in tonnes and an annual price. Distance for the aggregate region ROW is weighted by both the population of the rest of the world and the importing country. The weighted distance is calculated by the following formula: $dist\_pond = (pop\_exp/poprow) * (pop\_imp/poprow) * dist$, where pop_imp and pop_exp stand for the size of the population in the importing and exporting countries respectively. $dist$ is short for the distance. One country ,*Venezuela*, has many years with zero bilateral trade flows. To avoid multicollinearity and the drop of fixed effects, we excluded *Venezuela* from our sample. Data pertaining to SPS issues was downloaded from the WTO website.

4.2 Descriptive statistics

This section sheds lights on the structure of the beef sector and reports on export variations following the occurrence of disease outbreaks. In table (2) we display changes in exports for countries that have experimented BSE or FMD cases over 6 consecutive years. Countries such as France, Belgium Germany, Ireland, Netherlands, Portugal, Thailand, United Kingdom and Switzerland have been affected by BSE cases between 1997 to 2003. Their total exports decreased by approximately 50%. During the same period, FMD affected countries located in South America and Asia, such Bolivia, Brazil, Colombia, Ecuador, India, Malaysia and Thailand. Their total beef exports decrease by 65%.

These large changes in exports contrasts with the relatively stable production levels previously discussed. Production cycles in the cattle/beef industry are particularly long as it takes approximately 18 to 22 months to feed a calf and produce beef. This slow production cycle induces rigidities in beef production and explains the possibility of a negative supply response in the beef market. (Jarvis, 1974; Ospina and Shumway, 1979; Rosen, 1987; Aadland and Bailey, 2001). If production is highly inelastic, at least in the short and medium terms, it means that domestic markets absorb much of the export losses due to BSE and FMD cases. For most of the countries in our sample, intra-national sales account for much of the production. The share of intra-national sales in production is at least 90% in 24 of the 40 countries over the 1996-2013 period. This applies to some very large exporting countries like India, and the United States. Brazil's average ratio of domestic sales to production is 87%. Other large exporting countries like Australia and New Zealand have much lower average ratios (31% and 50% respectively). Therefore, large percentage export variations often correspond to rather small volume for many of the countries in our sample.

Table 3 indicates that BSE and FMD outbreaks have permanent effects at the extensive margin of trade with the number of export destinations being substantially lower after an alert than before. Many importing countries had not resumed purchasing beef from former suppliers who had BSE and/or FMD-infected cattle. The incidence of BSE and FMD diseases at the intensive margin of trade for Canada and the US varies, with exports sales dropping significantly in the US and slightly increasing for Canada. Table 4 shows that there is much cross-country heterogeneity in export growth among Asian countries. Some countries had very small exports in 1996 and this explains the staggering growth rates between 1996 and 2013.

5 Results

5.1 Partial effects of BSE and FMD disease outbreaks

Table (4) reports the results from the PPML estimation of three gravity models. The first model is estimated on a panel of consecutive years with many lagged BSE and FMD variables while the second and third models are estimated on panels of 2-year (e.g., 2013, 2011...) and 4-year intervals (e.g., 2013, 2009). The R2s are very high which is not surprising given the large number of fixed effects entering the specifications. Our findings are similar with those found in the trade literature and consistent with our expectations. Applied tariffs, distance and dBSE-origin and dFMD-origin have negative and significant "partial" impacts on bilateral trade while sectoral output and expenditures, the sectoral counterparts of GDPs in standard gravity models estimated on total manufacturing trade flows, positively affect trade. All three models are estimated with importer, exporter, and time fixed effects. The time fixed effects are included to account for macro shocks. The estimated coefficients can be used to assess the magnitude of partial trade effects that treat IMR, OMR and factory-gate prices as constant. The coefficient on distance is an elasticity that says that increasing distance by 10% decreases beef trade flows by 2.74%. The tariff variable is defined as "the log of one plus ta", where ta is an ad valorem tariff. A tariff elasticity is not very enlightening unless one knows the base tariff and it is preferable to report the semi-elasticity, the percentage change in export following a 0.01 change in ta. This is calculated by dividing the tariff coefficient by $100(1 + ta)$. With an average tariff of 5%, the semi-elasticity tells us that trade flows fall by 1.2% when the tariff increases from 5% to 6%. The output and expenditures coefficients can be interpreted as elasticities. In the first model, a 10% increase in the value of domestic production increases beef trade flows by 2.7%. Note that this is an average over export and intra-national sales.

The dBSE-origin and dFMD-origin variables are dummy variables that equal 1 when the exporting country in the trading pair has BSE and FMD-infected cattle. These variables switch to zero when sales are intra-national ones. The null that all dBSE-origin coefficients are zero in the first model is rejected with a p-value of 0.000. The same applies for the dFMD-origin coefficients and it is apparent that exporting countries with cattle diseases export significantly less. Coefficients of dummy variables can be transformed to generate elasticities. Since there are many lagged effects, we can report on short run and long run BSE and FMD "partial" elasticities. The short run partial BSE-origin elasticity is computed as $\exp(dBSE - origin) - 1$.[8] The immediate trade reduction caused by a BSE outbreak is 43%, a highly significant reduction considering that our data is annual and BSE outbreaks can happen early or late in any given year. The long run FMD elasticity is computed by adding up all of the BSE-origin coefficients in the exponential. As expected, the long run elasticity is much larger at -97%. For dFMD-origin, the short run elasticity is larger than for BSE at -0.82%. This might have more to do with the timing of the outbreaks than the importing countries'

[8]Standard errors around elasticity estimates can easily be computed with Stata's NL-COM command.

policy response. The long elasticity, like its BSE counterpart, is such that exports are almost eliminated. Model 3's (long run) dBSE-origin and dFMD-origin elasticities are essentially the same as those of models 1 and 2.

The variables dBSE-destination and dFMD-destination are equal to one when the destination country has at least one disease-infected cattle. The emergence of a disease in the destination country might increase imports, as domestic beef is substituted in favor of foreign beef, or it might make all beef regardless of origin suspect. In model 1, the null that all dBSE-destination coefficients are zero and the null that all dFMD-destination coefficients are zero (against the alternative that at least one coefficient is not zero) are soundly rejected with p-values of 0.0039 and 0.0000. Interestingly, the short run BSE and FMD destination elasticities are respectively negative (-0.49) and positive (4.9). The dfta or free trade area coefficient has a negative sign which implies that non-tariff provisions in free trade areas decrease beef trade flows. Tariff reductions and non-tariff provisions differ markedly across commodities in free trade agreements. As suggested by Copeland (1990), tariff reductions may prompt fta partners to use blunt non-tariff instruments to offset the trade liberalizing effects of tariffs. This seems to be the case for beef trade. Finally, the coefficient for the SPS (animosity) index can be interpreted as an elasticity as a 1% increase in the index causes beef trade flows to fall by 0.08%. Other variables, like contiguity, colonial linkages and common official language were not statistically significant and they were dropped.

5.2 Full effects of BSE and FMD disease outbreaks

In this subsection, we implement a counterfactual experiment involving the hypothetical removal of all BSE and FMD outbreaks. This is similar in spirit to the counterfactual experiments about the hypothetical removal of international borders. Our partial results above suggest that BSE and FMD diseases have tremendous effects on trade costs. Our counterfactual experiment is conducted with model 3. The full effects computed from the counterfactual experiment are presented in Table 6. The first column show that the elimination of BSE and FMD would substantially boost trade in most countries. Canadian beef exports would increase by roughly 20% which is similar to the increase for Australia, but much smaller than the 74% increase for US exports and the 78% increase for India. Some small exporters would see their exports being multiplied severalfold. This is especially true for Japan, Korea and China. In contrast, Portugal, Sweden and Finland, would experience export reductions.The last column reports export changes due to changes in the IMR and OMR indices, holding factory-gate prices constant. By construction, these conditional changes are smaller than the full export changes reported in the first column, but they are not minuscule. For Canada, the conditional export change is about one-third the size of the full export change. This suggests that this channel matters when trying to gauge the incidence of trade costs or regional trade agreements on trade flows. The multilateral resistance indices for Canada decrease a lot. In the trade flow equation, the IMR embodies the trade costs from all sources and is a metric to assess the relative height of the trade cost for imports sourced from exporting country i. Thus a decrease in the IMR makes imports from all sources generally cheaper, but makes import from a given source relatively more expensive, all else equal. Similarly, the OMR is a measure that aggregates the trade costs faced by an exporting country across all destinations. The elimination of cattle diseases would enormously reduced the barriers faced by Canadian exporters. Factory-gate prices would increase in most countries. For Canada, the increase would be almost 32%. While the removal of cattle disease lower trade costs and hence the IMRs, the increase in factory-gate prices tend to increase IMRs.This effect is particularly in some countries because their IMR increases. Finally, the welfare results in the column labelled real (sectoral) GDP indicates that Canada would gain tremendously, 60%, from the elimination of BSE and FMD.Other countries like Uruguay, Paraguay, Ecuador, Denmark and Austria would also be in the set of countries gaining most. Finland and Italy would gain very little and Portugal would experience a small loss.

6 Conclusion

Trade flows at the commodity level are very different from trade flows aggregating all manufactured products. There are more zeros and much more volatility at the commodity level. This is so because trade flows for highly aggregated products reflects the offsetting positive and negative shocks from the different sectors that are aggregated together. Agricultural trade flows are notoriously volatile, in part because of the inelastic supply and in part because of the devastating effects of adverse shocks like cattle disease outbreaks. Our paper estimates the partial and full effects of BSE and FMD on beef trade flows. As mentioned in a recent document (OECD/FAO, 2017), agricultural exports are highly concentrated, with a handful of countries typically accounting for over 70% of all exports and exports representing a small fraction of domestic production. Countries experiencing cattle disease outbreaks are typically confronted to import bans. Some trade flows partially resume after a few years, but others never recover. Because a large part of the adjustment to import bans is done through intra-national sales, it is particularly important to analyse trade flows that include intra-national sales. Another reason is to facilitate the estimation of tariff effects which typically play an important at the commodity level. We conduct a counterfactual experiment about the elimination of BSE and FMD using a structural sectoral gravity framework that allows BSE and FMD to impact directly on trade flows and indirectly through the multilateral resistance indices and factory-gate prices. We estimate three models that handle the dynamics of BSE and

FMD effects differently. One relies on a panel of consecutive annual observations and many lagged BSE and FMD variables while the others rely on panels with 2 and 4-year intervals.

The removal of BSE and FMD would significantly increase most bilateral trade flows. Conditional export increases are fairly large and this suggests that that indirect BSE-FMD removal effects through the multilateral resistance indices, holding factory-gate prices constant, are an important trade liberalization channel. Factory-gate prices would increase substantially in most countries to the benefit of beef producers. Finally, welfare effects in our so-called endowment trade model are simple to compute and we show that Canada is amongst the countries that would gain the most from the elimination of BSE and FMD. Because almost all countrie would gain from the elimination of BSE and FMD, one can only hope that countries will collaborate to eradicate these diseases. Our paper is the first to implement a counterfactual experiment about animal diseases that report more than just partial trade effects. However, future research should pool different agricultural commodities to allow substitution between sources for a given product and substitution between products and build up a dynamic production component.

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Table 1: Country's disease status over the 1996-2013 period

BSE-FMD free	Australia, Chile, Mexico, New-Zealand. Norway.
BSE-only	Austria, Belgium, Canada, Denmark, Finland, France, Germany, Indonesia Ireland, Italy, Netherland, Poland, Portugal, Spain, Sweden, USA, Switzerland.
FMD-only	Argentina, Bolivia, Colombia, Denmark, India, Korea, Morocco Paraguay, Peru, Turkey, Uruguay.
BSE and FMD	Brazil, China, Greece, Japan, Malaysia, Thailand, United Kingdom.

Table 2: Exports growth of countries with BSE and FMD cases over 6 consecutive years

Group of countries	Exports 1997	Exports 2003	Growth rate
BSE countries	$2.9E+10	$2 E+10	-50%
FMD countries	$2 E+10	$1.2 E+10	-65%

Table 3: Exports growth for Canada and USA before and after BSE

Country	**Canada**	**USA**
Number of zero-trade flow before BSE	92	28
Number of zero-trade flow after BSE	103	40
Average exports before BSE	$1.2 billion	$2.9 billion
Average exports after BSE	$1.3 billion	$1.8 billion

Table 4: Exports growth of selected countries

Year	China	Japan	Korea	Thailand	Colombia
1997	-42.99	37.08	-35.17	0.00	2.73
1998	-71.39	29.69	372.75	0.00	-100.00
1999	-19.58	145.47	36.33	0.00	0.00
2000	16.04	-70.65	-80.01	0.00	0.00
2001	19.77	7.08	-89.12	-70.51	0.00
2002	16.36	-99.58	34.80	498.38	-58.75
2003	-5.14	2447.25	233.78	129.82	13553.64
2004	-87.38	96.43	10.12	-90.03	-99.46
2005	289.34	9.44	55.03	19.72	958.66
2006	844.34	1656.61	55.30	1207.52	241.21
2007	23.85	133.94	-17.14	-16.80	-93.19
2008	-14.99	2.07	-1.82	-86.26	159.65
2009	-66.57	-30.16	508.39	19.51	583.86
2010	19.20	-60.75	-33.82	702.34	1086.67
2011	133.68	-89.39	28.46	160.04	30.69
2012	2.45	1208.51	-90.55	-27.86	-41.54
2013	-50.73	192.16	590.52	-73.52	-29.05

Table 5: Estimation results

	(1) PPML 1	(2) PPML 2	(3) PPML 3
Applied tariffs	-1.3009***	-1.7164***	-1.9369***
Distance	-0.2746***	-0.1801***	-0.1876*
dBSE origin	-0.5650***	-0.8630***	-2.7511***
dBSE_{t-1} origin	-0.6725***		
dBSE_{t-2} origin	-0.3727***	-1.1551***	
dBSE_{t-3} origin	-0.3860***		
dBSE_{t-4} origin	-0.4222***	-0.9240***	
dBSE_{t-5} origin	-0.1235		
dBSE_{t-6} origin	-0.3127***	-0.7960***	
dBSE_{t-7} origin	-0.8791***		
dBSE destination	-0.0904**		
dBSE_{t-1} dest	-0.1095**		
dBSE_{t-2} dest	-0.0373		
dBSE_{t-3} dest	-0.0691*		
dBSE_{t-4} dest	-0.0343		
dBSE_{t-5} dest	-0.1079***		
dBSE_{t-6} dest	-0.0793		
dBSE_{t-7} dest	-0.1493***		
dFMD origin	-1.7217***	-2.6574***	-7.2212***
dFMD_{t-1} origin	-1.4765***		
dFMD_{t-2} origin	-1.0369***	-1.1073***	
dFMD_{t-3} origin	-0.7243***		
dFMD_{t-4} origin	-1.3820***	-2.3100***	
dFMD_{t-5} origin	-2.6433***		
dFMD_{t-6} origin	-2.3021***	-2.3023***	
dFMD_{t-7} origin	-3.1464***		
dFMD destination	0.1116**		
dFMD_{t-1} dest	0.2669***		
dFMD_{t-2} dest	0.3766***		
dFMD_{t-3} dest	0.3004***		
dFMD_{t-4} dest	0.2799***		
dFMD_{t-5} dest	0.1686**		
dFMD_{t-6} dest	0.1715***		
dFMD_{t-7} dest	0.1014*		
Output	0.2669	0.7620***	0.9731***
Expenditure	0.6092***	0.4146**	0.4905*
dFTA	-1.8739***	-1.9416***	-2.1887***
SPS_{ijt}	-0.0859***	-0.1038***	-0.1577***
N	17600	9600	6400
r2	0.9734	0.9451	0.9304
ll	-6.428e+05	-4.073e+05	-3.275e+05

Standard errors in parentheses, exporter, importer, time fixed effects

* p<0.10, ** p<0.05, *** p<0.01

Table 6: Full effects from the eradication of BSE and FMD

Country	Exports FULL	Real GDP	Gate prices	Full IMRs	Full OMRs	Exports CDL
Argentina	19.92	8.76	30.56	85.61	-76.22	0.38
Australia	22.22	46.48	27.06	-91.24	-75.28	0.39
Austria	12.59	73.47	56.41	-93.37	-82.10	0.48
Belgium	14.32	68.40	52.63	-94.16	-81.34	0.43
Bolivia	30.32	33.84	38.42	-26.77	-78.19	0.32
Brazil	67.26	25.62	-13.51	-76.97	-61.38	3.09
Canada	19.01	60.44	31.73	-95.87	-76.52	6.16
Switzerland	25.49	39.18	46.70	-64.97	-80.08	2.01
Chile	12.55	15.60	45.60	75.63	-79.84	4.63
Colombia	134.58	19.79	17.09	-8.37	-72.42	23.20
Germany	20.36	33.75	48.90	-67.64	-80.56	4.07
Denmark	24.96	75.03	52.53	-95.12	-81.32	1.22
Ecuador	34.21	73.07	57.94	-91.31	-82.40	6.08
Spain	19.09	56.45	61.56	-85.87	-83.09	2.89
Finland	-17.84	4.42	92.17	460.11	-87.92	0.49
France	33.79	9.89	47.93	96.70	-80.35	11.21
United Kingdom	34.17	30.68	49.19	-56.91	-80.62	9.78
Greece	14.56	60.93	55.95	-78.69	-82.01	0.41
Indonesia	77.70	47.12	8.06	-88.71	-69.54	9.56
India	78.28	56.20	33.60	-96.69	-77.00	23.60
Ireland	10.91	52.76	71.75	-84.04	-84.88	2.01

Table 7: Table 4: Continued

Country	Exports FULL	Real GDP	Gate prices	Full IMRs	Full OMRs	Exports CDL
Italy	21.00	2.88	59.58	298.44	-82.72	8.33
Japan	347.24	54.85	-53.36	-97.53	-40.14	20.09
Korea	277.18	36.80	-30.21	-80.35	-53.59	29.63
Morocco	52.58	47.44	20.69	-82.31	-73.49	2.42
Mexico	38.34	16.10	26.59	4.54	-75.15	19.76
Malaysia	22.96	10.88	112.35	455.49	-90.33	37.14
Netherlands	21.43	44.92	40.35	-86.76	-78.64	1.31
Norway	19.31	58.49	60.54	-75.94	-82.90	2.36
New-Zealand	21.41	35.74	33.71	-72.57	-77.03	0.32
Peru	44.78	64.79	40.27	-85.88	-78.62	4.20
Poland	29.50	86.55	60.56	-96.78	-82.90	3.94
Portugal	-84.85	-6.54	91.86	901.40	-87.88	3.59
Paraguay	12.71	74.30	44.74	-90.40	-79.65	0.05
Sweden	-6.68	13.43	71.57	198.10	-84.85	0.75
Thailand	157.05	49.66	1.68	-75.71	-67.32	18.37
Turkey	86.84	55.05	46.82	-93.27	-80.11	36.01
Uruguay	9.64	75.26	43.07	-94.25	-79.27	0.47
USA	73.88	11.59	-25.66	-27.30	-55.86	5.05
China	237.10	8.21	-21.83	2.39	-57.68	77.70