Dynamic Effects of Animal Disease Outbreaks On Border Closure

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1 Abstract

International trade in live animals and animal products is hindered by animal disease outbreaks that quickly spread between countries. We rely on an empirical framework builds on the multi-sample selection model (MSSM) to investigate how animal-specific diseases affect aggregate trade flows at the extensive and intensive margins of trade in animal and animal products over time. We found that foot and mouth disease impacts negatively on the extensive and the intensive margins of trade in cattle and beef sector for seven years. Unlike the case of economic integration agreements (EIAs), our results show that the extensive margin effects of the disease outbreak are larger than its corresponding intensive margin effects. Regarding cross-species effects, the avian flu and swine fever reduce the probability and the level of trade in cattle and beef.

2 Introduction

Recent studies have highlighted the disastrous incidence that animal disease may cause to international trade in live animals and animal products (Yang et al., 2013). The cattle and beef sector is very often plagued by disease outbreaks such as the bovine spongiform encephalopathy (BSE) and foot and mouth disease (FMD) that quickly spread between countries (Yang et al., 2013). On the production side, the occurrence of disease can justify the destruction of many animals and the adoption of costly regulations. As an illustration, following the FMD outbreak in May of 2001, the UK Ministry of Agriculture, Fisheries, and Food reported that 465,000 cattle, 118,000 swine, and 2,418,000 sheep had been destroyed in an attempt to control the outbreak (Paarlberg et al., 2002). In the Netherlands, the classical swine fever (CSF) triggered the pre-emptive slaughter of 1.1 million pigs (Yadav et al., 2016). On the consumption side, disease outbreaks can alter consumers' perception about food safety. Paarlberg et al. (2002) showed that the largest losses on farm income of an FMD outbreak were from the loss of export markets and reductions in domestic demand arising from consumer fears, not from removal of infected animals. To avoid the risk of contamination between countries, the importing countries usually impose trade restrictions in response to disease outbreak alerts especially when public health is at risk. For example, the discovery of a bovine spongiform encephalopathy (BSE)-infected dairy cow in December of 2003 in Washington state led to an immediate closure of major US beef export markets, Japan, Korea, Mexico and Canada (Pendell et al., 2007). Similarly, when the Canadian Food Inspection Agency (CFIA) announced in May of 2003 the discovery of a single BSE case in Alberta, borders were immediately closed to all exports of live Canadian cattle and other ruminants, beef and other meat derived from ruminants. In July of 2003, Agriculture and Agri-Food Canada (AAFC) announced new regulatory measures requiring the removal of the infected tissues, specified risk materials from carcasse of cattle older than 30 months. With these measures in place, the US government allowed partial resumption of beef imports, as the US border opened for imports of Canadian beef from cattle under the age of 30 months. These examples illustrate the reasons why there is a continued interest about the incidence of animal diseases on trade and welfare.

The issue has attracted much literature as beef trade is of high importance for countries in particular and for the world in general. Canada's beef exports represents about 30-40% of its domestic production. In 2017, world beef exports amounted to US$ 18 billion and beef trade accounted for US$ 75 billion in 2017 (WITS, 2018). Koo et al. (1994) used a commodity-specific gravity model to evaluate the effects of import restriction policies on the world meat trade. The results showed that the hoof-and-mouth disease is a major trade-resistant factor and that the absence of the disease is an important determinant to trade. 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). Yang et al. (2013) also used a gravity model to show that pork exports are hindered during FMD outbreak in the origin country. Exporting countries that enforce slaughtering policy experienced smaller negative impacts than exporting countries with vaccination policy. More recently, Webb et al. (2018) found that country that has experienced BSE, will usually switch from markets that have not experienced BSE to markets that have. While numerous studies were devoted to examine the incidence of disease outbreak little attention has been given to the dynamic effect of these diseases. In fact, the return to trade does not follow immediately the reinstatement. The time it takes for importing countries to lift the embargo even after the eradication of the disease varies across countries and partners. Hong Kong reopened its border to boneless beef from Canada in December of 2004 and South Korea continued prohibiting the importation of Canadian bovine meat and meat products until 2012. Similarly, has failed to regain access to access to the United States market 6 years after it has experienced a FMD outbreaks. In May of 2002, Chilean sanitary authorities were notified of a possible outbreak of avian influenza. The European Commission adopted a sanitary measure forcing its member states to ban imports from Chile. Three months later, the Chilean authorities succeeded in proving Chile's sanitary status to the EU which accepted to grant it the regionalization. Later on, the EU has lifted the safeguard measure within six months. In addition, there is a waiting period before an exporting country can be recognized as being risk-free. The World Organization for Animal Health (OIE) sets out the conditions for recovery of freedom status country for countries that dealt with a disease outbreak. It specifies periods of time required for both certain veterinary measures and absence of disease outbreaks before a country may be considered free of disease. Developed countries usually have higher standards than OIE standards. This period can last (three, six or even 12 months depending on the situation) (Junker et al., 2009). In the case of BSE, a country must be free of the disease for at least 8 years before it can switch status from "controlled BSE risk" to "negligible BSE risk" by the OIE. Negligible Risk status is awarded to those countries or regions which satisfy the World Organization for Animal Health requirements in relation to BSE controls and instances. Negligible risk status allows a reduction in the risk materials which must be disposed of. Whereas, cattle which are "controlled risk" status have an increased list of materials which must be disposed of . The OIE has implemented a point system to assess the quality of BSE surveillance conducted by member countries. Animal ranging in age between 30 and 107 months are the most likely to develop BSE (Ortegon, 2015). The official recognition of a country as FMD-free is a trade promoting factor (Webb et al., 2018). Table 2.1 shows the waiting period before a previously free country that experienced an outbreak was able to recover its disease-free status by the OIE. The length of the waiting period differs across diseases types.

Moreover while being an important aspect of beef trade, the literature on disease impacts has paid very little attention to cattle trade and how it is affected by disease outbreak. In 2017, world live cattle exports totalled to over US$ 8 billion (WITS, 2018). Canada, the world largest exporter of cattle, exported US$ 1 billion in 2016. With the occurence of BSE outbreak in Canada in 2003, Canadian beef exports decreased by 24% while cattle exports significantly dropped by 64% (see table 2.1). The same trend is observed in the U.S. The beef exports decreased by 77% and the cattle export by 90%. These shed light on the importance of the impacts that disease outbreak could have on cattle trade. In addition to that, allowing cattle diseases to affect differently cattle trade and beef trade is very important as the severity of trade restrictions differ between cattle and beef imports. For example, the US government partial resumption concerns only beef imports but not cattle. The increases in fixed and variable trade costs from post-outbreak measures also impact livestock and beef exporters differently. This paper is the first to account for vertical linkage between cattle and beef when estimating the impact of cattle disease outbreaks on trade.

Our study is related to the general strand of the literature on market access and non-tariff barriers (Winchester et al., 2012; Xiong and Beghin, 2017). Our objective is to investigate how animal disease outbreaks affect the selection of trade partners, the composition of trade and the size of trade flows over time in both the live cattle and cattle meat products. Our study differs from previous studies (Pendell et al., 2007; Yang et al., 2013; Webb et al., 2018) by accounting for vertical linkage between cattle and beef and by allowing infectious animal diseases to have different impacts on trade flows over time so that the dynamic effects of animal disease outbreaks can be measured. Our study also departs from previous ones by investigating the cross-effects of specific infectious animals diseases both on aggregate trade flows, intensive margins, and extensive margins. As alluded to earlier, an animal disease outbreak may induce substitution across sources on the part of wary importers. Still consumers may prefer substituting one meat for another or avoid all meats. Thus, there are likely cross-effects. To make matters worse, consumers can be confused about the species afflicted by diseases and the scope of the problem. During the FMD outbreak in the

United Kingdom, US consumers indicated confusion about the differences between FMD and BSE (Paarlberg et al., 2002).

The rest of this paper is organized as follows. The next section is about disease outbreak management, with an emphasis on Canada's protocols. This is followed by a methodology section in which the model is presented along with data sources. The last section summarizes our results and dwells on their policy implications.

3 Empirical strategy and the model

Bilateral trade flows at a disaggregated level contain a significant number of "zeros" because trade is often concentrated within a limited number of geographical areas. We assume that trade flows result from: (i) the firms' decision to engage or not in exporting and (ii) the firms' chosen level of trade. Accordingly, the estimation strategy naturally follows in two separate stages. The first estimation procedure accounts for market penetration while the second estimation procedure for the volume of trade rules out negative predicted trade flows (i.e. whether firms in the aggregate find it profitable to enter a foreign market). We use a binary variable to determine whether exports to a particular destination are positive and this indicator depends on a latent variable with a censored distribution and potential correlation between the error terms of the primary and processed goods. It can be construed as a generalization of Cragg (1971)' double-hurdle (DH) model. As a result, the impact of animal disease outbreak on trade flows can be decomposed into the intensive and the extensive margins, where the former relates to trade volume per exporter and the latter refers to the number of exporting firms in a given country.

Our estimation procedure draws on the multivariate sample selection (MSSM) of Yen (2005) and consider a two-good system for livestock ($i = 1$) and meat ($i = 2$). Bilgic and Yen (2015) used the MSSM to quantify alcohol and tobacco participation and spending level decisions for households. The main advantage of this framework is that it allows for vertical linkage in the cattle supply chain. The joint estimation of the equation system improves biases and statistical efficiency of the estimates. As indicated in Ghazalian et al. (2012), the cross-hauling in cattle and beef is common making the application of the MSSM on theses markets a very interesting case-study. Accordingly, our sectoral gravity framework is quite different from the gravity frameworks used in previous studies about BSE and FMD outbreaks (Koo et al., 1994; Winchester et al., 2012; Webb et al., 2018) which do not account for vertical linkage. In addition, we use current and lagged BSE and FMD variables on annual panel data to capture the dynamics of BSE and FMD outbreaks.. The BSE and FMD variables are dummy variables which take the value 1 when there is at least one infected animal and the buyer is an importing country and 0 if not. 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 importer-specific BSE and FMD dummy variables that equal one when importing country i has at least one infected animal and the seller is an exporting country. The latter condition is motivated by the fact that domestic authorities typically do not impose bans on beef originating from domestic sources. The economic motivation for including lagged of animal disease stems from the fact that return to trade does not follow immediately the reinstatement of country free status by the OIE. For example, the variable $BSE_{i,t-5}$ denotes an animal disease outbreak occurred 5 years prior to the trade-flow change. It is reasonable to expect a disease outbreak to have lagged effects on trade flows.

We provide a short discussion about the MSSM approach developed by Yen (2005). Let $y^k_{ij,t}$ be the outcome variable, x the vector of explanatory variables of the level equations and z the explanatory variables of the selection equations. The binary sample-selection rule can be written as follow:

$$\begin{aligned} \log y^k_{ij,t} &= x'\beta_k + v_{k,t} \quad \text{if} \quad z'\alpha_k + u_{k,t} > 0 \\ y^k_{ij,t} &= 0 \quad \text{if} \quad z'\alpha_k + u_{k,t} < 0 \\ & \qquad\qquad\qquad\qquad k = 1, 2 \end{aligned} \tag{1}$$

where α_k and β_k are conformable parameters vectors. As in Yen (2005), Tamini et al. (2010) and Bilgic and Yen (2015), we use a more efficient maximum-likelihood procedure instead of the two-step estimation. To construct the sample likelihood function, we distinguish four different sample regimes. We assume that the error structure $[\mathbf{u}, \mathbf{v}] \equiv [u_1, u_2, v_1, v_2]$ is distributed as a 2x2-variate normal with zero mean and covariance matrix:

$$\Sigma = \begin{bmatrix} \Sigma_{uu} & \Sigma_{uv} \\ \Sigma_{vu} & \Sigma_{vv} \end{bmatrix} \tag{2}$$

Where $\Sigma_{uu} = E(\mathbf{uu'})$, $\Sigma_{vu} = \Sigma_{uv} = E(\mathbf{vu'})$ and $\Sigma_{vv} = E(\mathbf{vv'})$. We denote by ϕ_k the k-dimensional probability density function (PDF) and by Φ_k the cumulative distribution function for $k = 1, 2$. Consider first a sample regime in which the export flows for both livestock (y^1) and meat (y^2) are zeros. The sample likelihood contribution is the bivariate standard normal probability

Yen (2005):

$$
\begin{aligned}
L_1 &= \int_{-\infty}^{-z'\alpha_1} \int_{-\infty}^{-z'\alpha_2} f(u_1, u_2) du_2 du_1 \\
&= \Phi_2(-z'\alpha_1, z'\alpha_2; \rho_{21}^{uu})
\end{aligned} \tag{3}
$$

For sample regime with $y^1 > 0$ and $y^2 = 0$, the likelihood contribution is given by:

$$
\begin{aligned}
L_2 &= \int_{-z'\alpha_1}^{-\infty} \int_{-\infty}^{-z'\alpha_2} h(u_1, u_2|v_1) du_2 du_1 \\
&= (y^1)^{-1} \sigma_1^{-1} \phi_1(h_1) \Phi_2(r_1, -r_2; -\tau_{12})
\end{aligned} \tag{4}
$$

The sample regime L_3 with $y^1 = 0$ and $y^2 > 0$, is symmetric to L_2.

where $h(u_1, u_2|v_1)$ is the conditional pdf of $\mathbf{u}|\mathbf{v}$, $h_i = log(y^k - x'\beta_1)/\sigma_i$ is the normalized error terms. $\phi_1(h_1)$ is the marginal probability density function (pdf) of $h_1 \sim N(0, 1)$, $r_1 = (z'\alpha_1 + \rho_{11}^{vu} h_1)/[1 - (\rho_{11}^{vu})^2]^{\frac{1}{2}}$, $r_2 = (z'\alpha_2 + \rho_{12}^{vu} h_1)/[1 - (\rho_{12}^{vu})^2]^{\frac{1}{2}}$. The likelihood contribution for a regime with $y^1 = 0$ and $y^2 > 0$ is obtained by reciprocity. For a sample regime in which the outcome of all dependent variables are positive, $y^1 > 0$ and $y^2 > 0$, we define $h(\mathbf{u}, \mathbf{v})$ as the marginal conditional pdf of $\mathbf{u}|\mathbf{v}$. Yen (2005) shows that $\mathbf{u}|\mathbf{v}$=$(u_1, u_2|v_1, v_2)$ is distributed as bivariate normal with mean vector $\mu_{u|v} = \Sigma_{uv}\Sigma_{vv}^{-1}v = [\mu_1, \mu_2]'$ and covariance matrix $\Sigma_{u|v} = \Sigma_{uu} - \Sigma_{uv}\Sigma_{vv}^{-1}\Sigma_{vu}$. We define the diagonal elements $\Sigma_{u|v}$ can be $[\omega_1^2, \omega_2^2]'$ (Yen, 2005). The likelihood contribution is:

$$
\begin{aligned}
L_4 &= g(v_1, v_2) \int_{-z'\alpha_1}^{-\infty} \int_{-z'\alpha_2}^{-\infty} h(u_1, u_2|v_1, v_2) du_2 du_1 \\
&= (y^1)^{-1} (y^2)^{-1} \sigma_1^{-1} \sigma_2^{-1} \phi_2(h_1, h_2; \rho_{21}^{vv}) \Phi_2(q_1, q_2; \tau_{12}')
\end{aligned} \tag{5}
$$

where the conditional variance $[\omega_1^2, \omega_2^2]'$ are the diagonal elements of Σ_{uv} and the covariance ω_{12} are the off-diagonal element of the Σ_{uv}, $q_1 = (z'\alpha_1 + \mu_1)/\omega_1$ and $q_2 = (z'\alpha_2 + \mu_2)/\omega_2$ and $\tau_{12}' = \omega_{12}/(\omega_1, \omega_2)$

3.1 Estimation method

Equations (2.3), (2.4) and (2.5) constitute the basis of our estimation. The exogenous variables z and x include control pair-specific variables like distance, common border, FTA, and tariffs, exporter-specific variables such as BSE origin, FMD origin and and sectoral output. 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.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 importer-specific BSE and FMD dummy variables that equal one when importing country j has at least one infected animal. $y^k_{ij,t}$ is the bilateral trade flow from country i to country j, at time t. For $k = 1$ the bilateral trade flow is trade in the primary sector while $k = 2$ stands for trade in the meat processed sector. Our estimation method consists in estimating jointly the four likelihood function. We estimate the multivariate sample selection model (MSSM) by programming the four likelihood functions in R. We then use the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm to make the numerical optimization. The main package for the optimization procedure that we use is MaxLik.

The "Protection for Sale" hypothesis posits that importing countries make tariff adjustments in response to lobbying by organized import-competing industries suffering from greater import penetration. As pointed out by Trefler (1993), the theory of endogenous protection predicts that higher levels of import penetration will lead to greater protection. This is less obvious when the study focuses on a specific agricultural sector. To test for possible presence of endogenous tariffs, we perform the Durbin-Wu-Hausman test. The bound tariffs are used as instruments. We use the bound tariff $T^k_{ij,t}$ of country i on product k at year t ,as an instrument on the grounds that it imposes an upper limit on tariffs set by WTO members and that countries very rarely change their bound tariffs. The latter can be treated as exogenous given that our sample is short enough not to overlap with the conclusion of a GATT or WTO trade negotiation round. While some countries have high bound tariffs and relatively low applied ones, it is hypothesized that countries with high bound tariffs tend to have higher applied tariffs. Countries that have high bound tariffs have more flexibility to make tariff adjustments in response to industry pressure

3.2 The estimation of elasticities

Upon the Maximum-likelihood estimation of the MSSM, we calculate the elasticities of the key variables to make the interpretation easier to understand. The estimation of elasticities differs on whether the variables are continuous or binary. For continuous variables, we compute the elasticities of probability and conditional mean with respect to a common element of $\mathbf{x}$ and $\mathbf{z}$ using the following formula:

$$e^p_i = \lambda(\mathbf{z}\alpha_i)\alpha_{ij} \tag{6}$$

$$e_i^c = [\beta_{ij} + [\lambda(\mathbf{z}\alpha_i + \rho_{ii}^{vu}\sigma_i) - \lambda(\mathbf{z}\alpha_i)]\alpha_{ij}]x_j \tag{7}$$

We obtain the elasticity of the unconditional mean with respect to x_j by using the property: $E(y_i) = Pr(y_i > 0)E(y_i|y_i > 0)$. The formula for the unconditional mean is given by:

$$e_{ij}^u = [\beta_{ij} + \lambda(\mathbf{z}\alpha_i + \rho_{ii}^{vu}\sigma_i)\alpha_{ij}]x_j \tag{8}$$

With $\lambda(.) = \frac{\phi(.)}{\Phi(.)}$ is the "inverse Mills ratio". For binary variables, we compute the probability by: $e_i^p = \frac{p(D=1)-p(D=0)}{p(D=0)}$.
where p(D=1) is the probability that the binary variable takes the value 1 while the other variables are kept at their mean or median. The conditional mean is obtained by: $e_i^c = \frac{E(D=1)-E(D=0)}{E(D=0)}$. The asymptotic standard errors of the elasticities are calculated using the delta method.

4 Data and descriptive statistics

4.1 Data

Our data covers 40 countries export flows over the 1996-2015 period of time. The dependent variables are the volume of livestock and meat exports. HS four-digit products include HS 0102 (Live bovine), HS 0103 (Live swine), HS 0105 (Live poultry), HS 0201 (meat of bovine animals, fresh or chilled), HS 0202 (meat of bovine animals, frozen), HS 0203 (meat of bovine, fresh, chilled, or frozen), HS 0209 (meat of pig fat, free of lean meat), HS 0206 (edible offal of bovine animals), HS 0207 (meat and edible offal of poultry). Furthermore, HS 0201, HS 0202 and HS 0206 are merged to create a single beef meat. Drawing from our theoretical framework, explanatory variables include applied tariffs for both livestock and meat products, a binary variable of animal disease, GDP, distance, common border, common language. Bilateral trade volumes of livestock and meat are obtained from the UN COMTRADE database and data on tariffs are collected from the WITS database. Data on distance are from CEPII, and data on GDP are obtained from World bank database. Unlike existing literature that focuses on the effect of a single disease at a time, our study will consider the diseases identified by Perrings (2016) as the four most damaging livestock diseases: foot and mouth disease, H9N2 avian influenza, bovine spongiform encephalopathy and swine fewer. The incidence of animal diseases on trade flows must be measured in dynamic framework. The number of cattle, chicken and pork infected by animal diseases is kindly provided by the World Animal Health Information and Analysis. The OIE imposes that animal health situation in the exporting country, in transit countries and in the importing country be considered before implementing requirement for trade. This creates much heterogeneity in the way countries react to disease outbreaks. For this reason we include both the number of infected animals in exporting country and in importing country as regressors.

4.2 Descriptive statistics

This section provides important insights on the structure of the beef sector and reports of exports variation following the occurrence of animal disease outbreaks. In table 2.2 we presents descriptive statistics of the variables used in the model. The means of cattle and beef applied tariffs are respectively 5% and 33%, which are approximately similar to those (6.2% and 31.1%) in Tamini et al. (2010). Beef exports face much higher tariffs (around 6 times) than cattle exports. The database covers 39 countries which have heterogeneous occurrence of disease outbreaks. Only five countries have not experienced neither BSE nor FMD while seven have experienced both BSE and FMD during the 1996-2013 period. BSE is more frequent than FMD in our sample (see table 2.3). At the intensive margin side, the BSE countries and FMD countries see a significant drop of their export level respectively by 50% and 65%. This 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 (80%) for beef and (90%) for cattle while slightly increasing for Canada for beef (39%). Table 2.5 and 2.6 indicate 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.

5 Results and interpretations

In table 2.8, we display results from the Durbin-Wu-Hausman test. The result suggests that the tariffs are exogenous in our data. This may be explained by the fact that our sample covers only beef sector. Table 9 reports the results from the MSSM for cattle and bovine. The results attest that animal diseases have significant negative effects on trade flows and border closer. Our findings are similar with those found in the trade literature (Webb et al., 2018; Knight-Jones and Rushton, 2013; Yang et al., 2013; Paarlberg et al.,

2002) and consistent with our expectations. Our findings are also in line with the results from studies on food safety and market access (Crivelli and Gröschl, 2016; Disdier et al., 2008) which provided evidence that Non-Tariff Measures (NTMs) hamper trade. Our findings attest that sample selectivity appears to be important. Despite some insignificant error correlations, the significant correlation between the two level equations (0.15) and the significance of correlation between selection of cattle and the level equation of beef (-0.055) and the level of cattle and the selection of beef (-0.025) justify the joint estimation rather than pairwise sample selection model. To make the result interpretation easier to understand, we divide this section into two subsections. From tables 2.10-2.13, we report elasticities of key variables.

5.1 The extensive margin of trade

Applied tariffs, distance and dBSE-origin and dFMD-origin have negative and significant "partial" impacts on export probability while sectoral output and expenditures have positive and significant on export probability both for cattle and beef. A larger distance between countries means higher transportation costs, so the negative sign consistent with our expectations. By accounting for vertical linkage between bovine livestock and bovine meat, we found that diseases have very strong incidence on the market selection. The probability of entering a new market decreases in both primary cattle and meat sectors with the presence of dBSE origin or dFMD origin in the exporting country and last over 7 years. A result that is consistent with findings by the Commission et al. (2002) which suggests a full recovery from a large outbreak can take eight years. In table 2.10, the coefficient on distance is an elasticity that says that increasing distance by 10% decreases the probability of cattle exports by 6.4% and beef by 20.04%. our result is approximately similar to Webb et al. (2018) which found a decrease of 6.8%. Similarly, Crivelli and Gröschl (2016)'s results suggest that Sanitary and Phytosanitary (SPS) measures deter market entry uniformly across all trading partners. The tariff variable is defined as "the log of one plus ta", where ta is an ad valorem tariff. Tariffs levied on cattle decreases the exports of cattle but increase the export of beef. Intuitively, a shock that induces high trade costs for cattle exports, would result in a substitution of cattle for beef. The sectoral output and the expenditure significantly increase the probability of exports in cattle and beef sector. A 10% increase of the sectoral output increase the probability of cattle exports by 3.13% and beef exports by 7.8%. The results in table 2.11 reveal that the emergence of BSE and/or FMD prompts border closure in most importing countries. In the first year, the occurrence of BSE in the exporting, reduce the number of destination by 10% for cattle and by 26% for beef. The impact of FMD is more important than BSE as it reduces the probability of export by 28.0% for cattle and 74% for beef. This may be explained by the fact that the international trade in meats is largely segregated into two markets resulting fro the fact that countries free from FMD refuse to allow imports from regions with FMD. As pointed out by Krystynak and Charlebois (1987), a consequence of that is that an outbreak of FMD in Canada will result on immediate embargo on exports of animal products to countries free of the disease, which include the U.S and Japan. In addition, as compared to BSE, FMD is highly contagious and the actions of one farmer affect the risk of FMD occurring on other holdingsKnight-Jones and Rushton (2013). These effects last over seven years. 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 BSE or/and FMD in a destination country increases the probability to export in that country. The reduction of domestic sales due to the presence of disease, induces the infected-country to substitute domestic suppliers for foreign suppliers in short term. In term of cross-effects, the occurrence swine fever or avian flu in the origin country reduces the probability of beef exports with the effect of swine fever much stronger than the effect of avian flu.

5.2 The intensive margin of trade

Similarly, applied tariffs, distance and dBSE-origin and dFMD-origin have negative and significant "partial" impacts on bilateral trade while sectoral output and expenditures, positively affect trade. Conditionally on entering the export market, a 10% increase in distance will induce a decrease of the trade flows in cattle by 2% and beef by 6%. On overall, a 10% increase in distance reduces cattle export by 8.34% and beef export by 26.4%. Similarly, an increase in ad valorem tariff levied on beef imports, decreases significantly the beef exports while encouraging the exports of cattle. The conditionally on entering new market, the BSE infected-country will increase slightly its exports while FMD infected-country decreases their exports by 18%. This finding suggests that an exit following the emergence of BSE, prompt the infected countries to sell more in the remaining and/or new markets. However, the incidence that BSE and FMD have on the level is smaller compared to the impact on the probability. Therefore the effect on border closure outweigh the level effect. This result seems intuitive and consistent with our expectations as most importing countries usually immediately close their borders following the outbreak announcement in their partner country. Our result implies that in general, the imported beef is an imperfect substitute of the domestic beef. Results in Table 2.10 and 2.11 reveal that BSE and FMD have statistically significantly seven year lagged effects on trade flows. FMD impacts are stronger than BSE both on the level and on the probability. Overall, the presence of BSE and FMD in the destination country have positive impact on the cattle exports. However, after the first two years, the impact become negative. Similarly, the long run effects of FMD-destination is negative. Swine fever outbreak that occurs in the exporting country has a positive and significant impact on the selection and a negative and significant effect on the level of cattle and beef. Avian influenza affect negatively the exports of cattle and beef. The negative sign of swine fever may be explained by the fact that consumer may substitute beef for pork. The same can be said about chicken meat and beef. The BSE in the destination country appears to have a positive effect on the cattle and beef export. Unlike the case of economic integration agreements (EIAs) in Baier et al. (2014), our results show that the extensive margin effects of the disease outbreak are larger than its corresponding intensive margin effects. The point is that BSE and/or FMD have more prohibitive impact on market access.

Error correlation appears to be very important. The livestock selection equation is negatively and significantly correlated with the beef level equation. The two level equation are positively correlated. A statistic descriptive of exports originating from Canada, U.S and China shows that the export growth of cattle and beef follow similar trends. The positive sign of the error correlation between the selection of cattle and the level of beef (0.0282) suggests that when a shock increases the probability of entry in the cattle market, it will induce an increase in the volume of beef exports. Our findings also show that an exit in the cattle market, prompt the country to sell more in the beef market ceteris paribus.

6 Conclusion

This study is the first, to the best of our knowledge, to uncover the animal disease outbreak impacts on primary and processed products at the intensive and extensive margins in a dynamic framework. We extended the bivariate sample selection model of Heckman to multi-equation framework to fully measure the BSE and FMD effects on the cattle supply chain. Disease outbreaks constitute one of the most important shock on international trade of meat and meat products and the importing countries policy response following an outbreak is usually that the resumption of trade will take time even after the outbreak. The empirical framework consists in estimating simultaneous the selection and the level equations of both meat and livestock sector based on panel data of 40 countries over the period 1996-2013,. The multivariate sample selection model is used for it allows us to take in consideration the contemporaneous correlations of the error terms. this study is the first, to the best of our knowledge, to uncover the animal disease outbreak impacts on primary and processed products at the intensive and extensive margins in a dynamic framework.

We found strong evidence of the negative effects that animal diseases outbreak have on international trade. More specifically, BSE and foot and mouth disease have negative and significants impacts on the both the extensive and the intensive margins of trade in the cattle and beef sector. The effects that BSE has on the selection and the level of trade last over seven years, suggesting that trade can be discontinued quickly after an outbreak, but regaining market access can be lengthy. Evidence shows that foot and mouth disease also affects negatively the extensive and the intensive margin of trade up to three years. The effects that BSE and FMD have on the conditional level are smaller than on the selection of trade partners. Results from this study also shed light on the cross effects of the animal disease outbreak Avian flu and swine fever reduce the probability and the level of trade in their respective supply chain as well as in the cattle and the beef sector. This may be explained by the fact that consumer can make confusion about the differences between the different diseases. Therefore, the consumers would express caution about consuming beef meat when a swine fever happens in the pork sector.

The BSE effects influence negatively the probability and level of trade in beef over four years. The return to trade does not follow immediately the reinstatement of the country by the OIE. In addition to the OIE guidelines, every country has its own standards which are usually higher than those impose by the OIE. This may contribute to exacerbate the perverse effects of the disease outbreaks. In terms of policy implication, the harmonization of safety standards and "best practices" across countries can possibly help reduce the recovery period for exporting countries dealing with diseases. The recognition and acceptation of a containment zone can be used to insure that countries dealing with limited outbreak involving a few animals in a narrowly defined location are not unduly penalized. The identification of a contamination effect raises the need for adjustment assistance in sectors not directly affected. Such assistance can take the form of export promotion activities.

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Figure 1: Illustration of BSE effect in data on the U.S beef exports

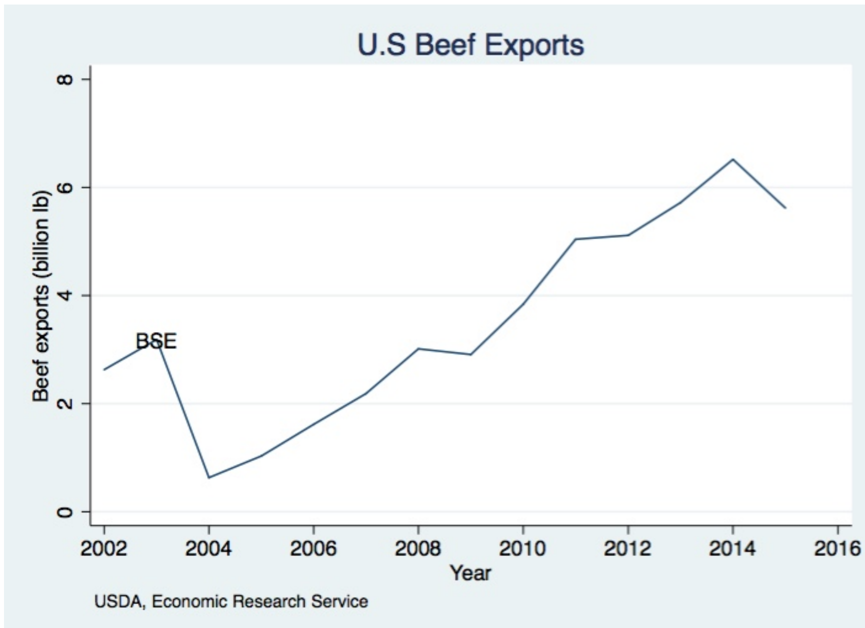

Table 1: Waiting period

	Vaccination is not practised	Vaccination is practised	Conditions by OIE
FMD	3 months		stamping out policy No emergency vaccination policy Surveillance policy
	6 months	6 months	Stamping out policy With emergency vaccination policy Not slaughtering of all vaccinated animals Surveillance policy
		12 months	No Stamping out policy With emergency vaccination policy Surveillance policy
Swine fever	3 months		Stamping-out policy With/without emergency vaccination policy Slaughtering all vaccinated animals
Avian Flu	3 months		stamping out policy Des-infection Surveillance policy

Table 2: Summary statistics

Variable	**Mean**	**Std. Dev.**	**N**
Applied tariffs cattle (%)	4.5	15.08	28080
Applied tariffs beef (%)	33.32	73.5	28080
Cattle bilateral trade (1000 USD)	2685.607	41743.02	28080
Beef bilateral trade (1000 USD)	12129.79	77905.35	28080

Table 3: 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, India, Korea, Morocco Paraguay, Peru, Turkey, Uruguay.
BSE and FMD	Brazil, China, Greece, Japan, Malaysia, Thailand, United Kingdom.

Table 4: Exports growth of countries with BSE and FMD cases over 6 consecutive years for beef trade

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

Table 5: The number of destinations of countries with BSE and FMD cases over years for beef trade

Group of countries	1997-2003	2004-2010	Growth rate
BSE countries	957	838	-15%
FMD countries	693	637	-9%

Table 6: The number of destinations of countries with BSE and FMD cases over years for cattle trade

Group of countries	1997-2003	2004-2010	Growth rate
BSE countries	437	325	-34%
FMD countries	72	59	-22%

Table 7: Illustration of US beef exports after the BSE outbreak in 2003

Year	**Japan**	**Mexico**	**South Korea**	**Canada**	**All destination**
2003[1]	919	623	754	309	3186
2004	13	393	2	105	631
2005	18	584	3	194	1031
2006	53	786	4	415	1617
2007	160	737	124	576	2187
2008	232	895	291	683	3014
2009	275	770	215	622	2909
2010	352	669	504	731	3839
2011	457	791	661	1,039	5041
2012	450	647	548	1,189	5114
2013	672	739	567	1,197	5721
2014	663	943	824	1,052	6519
2015	539	852	778	925	5621

Table 8: Results of Durbin-Wu-Hausman test for cattle and beef tariffs

	(1) Applied tariffs cattle	(2) Applied tariffs beef	(2) Trade
Bound tariff cattle	0.026***(7.00)		
Bound tariff meat		0.0083***(148.36)	
Residue 1ere regression (cattle)			-0.0928(-0.94)
Residue 1eme regression (Beef)			0.0233 (0.87)

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Maximum-Likelihood Estimation of Sample-Selection System of Cattle and Beef

	Selection		Level	
	Cattle	Beef	Cattle	Beef
Applied tariffs beef	0.0146	-0.0033***	0.2781***	-0.2315***
Applied tariffs cattle	-0.0872***	-0.0221***	-0.1927**	0.2989***
Distance	-0.8148***	-0.6006***	-0.6886***	-1.0741***
dBSE origin	-0.1747**	-0.0998***	0.2495	-0.05942***
dBSE_{t-1} origin	-0.0009*	-0.0520***	-0.0733	-0.4417
dBSE_{t-2} origin	-0.1497	-0.0067***	0.5299	0.1978***
dBSE_{t-3} origin	0.1464	0.0398***	0.2887	0.0341***
dBSE_{t-4} origin	0.1508	0.0817 ***	0.2195	0.0320
dBSE_{t-5} origin	-0.0634	-0.1561***	0.0521	-0.2720***
dBSE_{t-6} origin	0.1819*	0.1311***	-0.0368	-0.1346*
dBSE_{t-7} origin	0.0818	-0.15987***	-0.2518	-0.5452***
dBSE destination	0.0180	0.0350***	0.0756	0.1616***
dBSE_{t-1} dest	0.0307	0.0766***	-0.0479	0.1206***
dBSE_{t-2} dest	0.0201	0.0753***	-0.1537	-0.0227
dBSE_{t-3} dest	-0.0293	0.0065***	0.0278	0.0675**
dBSE_{t-4} dest	0.0249***	0.0056***	-0.17200	-0.0529*
dBSE_{t-5} dest	-0.0383	0.0118***	0.1280	-0.0559*
dBSE_{t-6} dest	-0.0122	-0.0269***	-0.1108	-0.0634**
dBSE_{t-7} dest	-0.0394	-0.0491 ***	0.0909	-0.0940***
dFMD origin	-0.4683***	-0.4325***	-1.8499***	0.4229***
dFMD_{t-1} origin	-0.3001 **	-0.3081***	-0.6262	0.0622***
dFMD_{t-2} origin	-0.3695***	-0.3123***	-0.0031	-0.2347***
dFMD_{t-3} origin	-0.1907*	-0.0193***	-0.0090	-0.5329 ***
dFMD_{t-4} origin	0.0101	-0.1510***	-0.8959 **	-0.5045***
dFMD_{t-5} origin	-0.2034 **	0.0844***	-0.2742	-0.4220***
dFMD_{t-6} origin	0.0066	0.1247***	-0.7925***	-0.0904
dFMD_{t-7} origin	-0.0545	-0.0542***	-1.6116 ***	-0.6507 ***
dFMD destination	0.1578	0.2473***	-0.1187	0.2248***
dFMD_{t-1} dest	-0.0160	0.0945***	0.4718	-0.0851
dFMD_{t-2} dest	-0.0022	0.0713***	0.3991	-0.1324**
dFMD_{t-3} dest	-0.0091	-0.0060***	1.0382***	-0.1373*
dFMD_{t-4} dest	0.0806	-0.1511***	0.5828**	-0.0787
dFMD_{t-5} dest	-0.0543	-0.2048***	-0.0241	-0.3701***
dFMD_{t-6} dest	-0.0619 ***	-0.0247 ***	0.28043	-0.0649
dFMD_{t-7} dest	-0.1023	-0.2658***	-0.0036	-0.4557***
Output	0.3947***	0.2308***	0.6743***	0.6639***
Expenditure	0.2419***	0.0927***	0.6729***	0.2302 ***
FTA	-0.2272***	-0.51704***	0.0706	-1.1181***
Avian flu	0.1547**	-0.1193***	0.5530**	-0.5736***
Swine fever	0.2293**	-0.3415***	-1.3105***	-1.2871***
Contiguity	0.4660***	0.0398***	2.1284***	1.0648***
Common off. language	0.1477 **	0.0804***	-1.24607*	-0.1755
Constant	-1.8135***	-2.1583 ***	-3.7358**	-9.9263***

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: The elasticities of cattle and beef exports with respect to continuous explanatory variables

	Cattle			**Beef**		
	Prob	Cond. Level	Uncond. Level	Prob	Cond. Level	Uncond. Level
Distance	-0.646***	-0.188	-0.834 ***	-2.040 ***	-0.600*	-2.640***
Applied tariffs cattle	-0.069***	-0.139***	-0.208***	-0.075*	0.316 ***	0.241***
Applied tariffs meat	0.012*	0.269***	0.281*	-0.011	-0.229***	-0.240***
Output	0.313 ***	0.432 *	0.745***	0.784***	0.482**	1.266***
Expenditure	0.192***	0.524***	0.716***	0.315 ***	0.157**	0.472***

Table 11: The elasticities of cattle and beef exports with respect to binary BSE explanatory variables

	Cattle			Beef		
	Prob	Cond. Level	Uncond. Level	Prob	Cond. Level	Uncond. Level
dBSE origin	-10.180**	2.422***	-8.005***	-26.016	0.932	-25.326***
dBSE$_{t-1}$ origin	-0.053	-0.712**	-0.764	-14.430	6.933***	-8.498***
dBSE$_{t-2}$ origin	-8.695*	5.142***	-4.000 ***	-1.993	-3.104*	-5.036***
dBSE$_{t-3}$ origin	8.025	2.802***	11.052***	12.496	-0.536*	11.892***
dBSE$_{t-4}$ origin	8.257	2.130***	10.563***	27.102	-0.502	26.464**
dBSE$_{t-5}$ origin	-3.631*	0.506 **	-3.144***	-37.825	4.268	-35.171***
dBSE$_{t-6}$ origin	9.884*	-0.358***	9.491**	46.491	2.112	49.585**
dBSE$_{t-7}$ origin	4.555	-2.443***	2.000***	-38.546*	8.557*	-33.288***
dBSE destination	1.018*	0.734***	1.759**	10.910 *	-2.537*	8.096***
dBSE$_{t-1}$ dest	1.730*	-0.466***	1.256***	25.246	-1.893	22.875***
dBSE$_{t-2}$ dest	1.136	-1.492***	-0.373**	24.785*	0.357*	25.231**
dBSE$_{t-3}$ dest	-1.672	0.270***	-1.407***	1.962*	-1.060	0.882***
dBSE$_{t-4}$ dest	1.402**	-1.669***	-0.290***	1.687	0.832***	2.533***
dBSE$_{t-5}$ dest	0.000	1.242***	1.242**	-9.674	0.878	-9.601***
dBSE$_{t-6}$ dest	-0.696	-1.076***	-1.765	-7.728	0.996	-6.810***
dBSE$_{t-7}$ dest	-2.248	0.882***	-1.385***	-13.685	1.476	-12.411***

Table 12: The elasticities of cattle and beef exports with respect to binary FMD explanatory variables

	Cattle			**Beef**		
	Prob	Cond. Level	Uncond. Level	Prob	Cond. Level	Uncond. Level
dFMD origin	-28.021***	-17.950***	-40.941***	-74.636*	-6.637**	-76.319***
dFMD$_{t-1}$ origin	-17.753**	-6.076***	-22.750***	-61.696*	-0.976	-62.070***
dFMD$_{t-2}$ origin	-21.982 ***	-0.031***	-22.006***	-62.218	3.684	-60.826***
dFMD$_{t-3}$ origin	-11.742*	-0.088***	-11.820***	-5.686*	8.311***	2.153***
dFMD$_{t-4}$ origin	0.607	-8.693***	-8.139*	-37.297*	7.868**	-32.364***
dFMD$_{t-5}$ origin	-12.538*	-2.661***	-14.865***	28.640	6.582***	37.108***
dFMD$_{t-6}$ origin	0.398	-7.690***	-7.323*	44.713	1.411	46.755***
dFMD$_{t-7}$ origin	-3.303	-15.638***	-18.425***	-14.999**	10.149***	-6.372***
dFMD destination	9.194	-1.153***	7.935***	10.525*	-3.507	9.805***
dFMD$_{t-1}$ dest	-0.964	4.579***	3.571*	-32.519*	-1.328*	-34.279***
dFMD$_{t-2}$ dest	-0.134	3.873***	3.734	23.745	2.066	26.302***
dFMD$_{t-3}$ dest	-0.552	10.075***	9.467*	-1.822	2.141*	0.281***
dFMD$_{t-4}$ dest	4.771	5.655***	10.696***	-37.321	1.228	-36.551**
dFMD$_{t-5}$ dest	-3.290***	-0.235***	-3.517***	-47.172***	5.773***	-44.122***
dFMD$_{t-6}$ dest	-3.756***	2.721***	-1.137***	-7.225***	1.012***	-6.285***
dFMD$_{t-7}$ dest	-6.237	-0.035***	-6.270***	-56.637	7.107	-53.555***

Table 13: The elasticities of cattle and beef exports with respect to binary explanatory variables

	Cattle			Beef		
	Prob	Cond. Level	Uncond. Level	Prob	Cond. Level	Uncond. Level
Avian flu	9.015**	5.366***	14.865***	-30.317	8.947***	-24.083***
Swine fever	13.141**	-12.717***	-1.247***	-65.656*	20.074***	-38.761***

	Selection		Level	
	Cattle	Beef	Cattle	Beef
Error correlations				
Selection: Beef	-0.097			
Level: Cattle	-0.102**	-0.025*		
Level: Beef	-0.055***	0.91*	0.150***	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$