Three Essays In International Trade In The Agricultural Sector

Thèse

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Résumé

Dans cette thèse nous avons exploré trois questions de recherche sur le commerce international dans le sector agricole. Dans le premier chapitre, nous avons regardé l'implication des coûts marginaux croissants sur la durée des flux d'exportation. Les récentes études empiriques suggèrent que les firmes ont des coûts marginaux croissants. Par conséquent, les ventes d'une firme sur un marché influent sur ses coûts et sa compétitivité sur tous les marchés, et donc sur sa survie sur divers marchés d'exportation. L'objectif de mon premier essai est la mise au point d'un cadre théorique permettant d'étudier l'incidence des coûts marginaux croissants et des contraintes de capacité sur les marges extensives et intensives des échanges commerciaux et sur la durée des exportations. Contrairement au cas avec coûts marginaux constants, avec une structure convexes des coûts, une augmentation de la productivité des firmes n'induit pas obligatoirement une augmentation des destinations. Nos résultats empiriques attestent que que les exportations perdues suite aux flux terminés accroissent les exportations vers les "marchés de repli" et réduisent la probabilité d'un échec d'exportation. À l'instar des autres études sur la survie des exportations, les tarifs réduisent la probabilité de l'échec d'exportation, mais nous montrons qu'ils ont l'effet opposés lorsque l'endogénéité est résolue.

Le deuxième essai s'intéresse à l'effet des maladies animales sur les flux commerciaux bilatéraux et la fermeture des frontières. Le commerce international des animaux vivants et des produits d'origine animal est très souvent entravé par les épidémies animales qui se propagent très vite entre pays. Nous nous appuyons sur un cadre empirique fondé sur le modèle de sélection multivariés pour examiner l'impact des maladies spécifiques aux animaux sur les marges extensives et intensives des flux commerciaux dans le temps. Les résultats montrent que la fièvre aphteuse et la 'encéphalopathie spongiforme bovine (ESB) ont un impact négatif sur les marges extensives et intensives du commerce des bovins et du bœuf et ce, pendant approximativement sept années. Nos résultats suggèrent que les effets des maladies animales sur la marge extensive sont plus grands que leur effets correspondants sur la marge intensive. En ce qui concerne les effets inter-espèces, la grippe aviaire et la peste porcine réduisent la probabilité et le niveau des échanges de bovins et de bœufs.

Dans le troisième chapitre, nous estimons l'effet d'une élimination hypothétique des maladies animales sur les flux commerciaux. Plus spécifiquement, nous examinons comment ESB et la fièvre aphteuse impactent les flux commerciaux de viande bovine. Le modèle de gravité structurelle sectorielle est utilisé pour mésurer les effets directs, conditionnels et globaux, en permettant ainsi aux indices de résistance multilatéraux entrants et sortants et aux prix à la production de s'ajuster à l'éradication des maladies animales. Les canaux indirects par lesquels l'ESB et la fièvre aphteuse influent sur le commerce sont importants. Notre expérience contrefactuelle suggère que le Canada serait l'un des pays tirant le meilleur parti de l'éradication de l'ESB et de la fièvre aphteuse.

Abstract

In standard trade models with constant average cost, the firm's sales in any given market is related to other markets only through price indices which are treated as exogenous in the firm's optimization. With cost convexity, the firm's decision in any given market is directly tied to sales in other markets through an index aggregating the trade cost-adjusted market size of the destinations supplied by the firm. The difference made by increasing costs is that the firm is cognizant that by changing its sales in a given destination it changes its unit cost for all destinations. This in turn triggers extensive and intensive margins adjustments. In the first essay, we develop a theoretical framework to address the incidence of increasing marginal costs and capacity constraints on trade at the extensive and the intensive margins and on export duration. Under convex costs, an increase in productivity may not increase the number of destinations supplied by a firm, making "ins and outs", not just new entries. We generated empirical evidence in support of the aforementioned trade adjustments by assessing the incidence of lagged foregone exports on exports to "fallback markets" and on export survival. Exports to the fallback markets systematically increase in response to foregone sales from terminated trade flows. Similarly, the sum of foregone sales from terminated trade flows make existing trade flows more resilient, less prone to an export failure. A distinguishing feature of our survival models is that they test and correct for the endogeneity of tariffs. Previous studies reported peculiar results about the incidence of tariff on export survival. We too find wrong signs when tariff is treated as an exogenous variable, but we find that higher tariffs increase the likelihood of export failures when tariff endogeneity is addressed.

The second essay investigates the dynamic impacts of animal disease outbreak on cattle and beef trade accounting for vertical linkage between cattle and beef. The empirical framework features a multi-sample selection model (MSSM) to investigate how animal-specific diseases affect aggregate trade flows at the extensive and intensive margins of trade in livestock and meat products over time, accounting for constraints imposed by the technological linkages between livestock and meat productions. The spontaneous emergence of foot and mouth disease adversely impacts the extensive and intensive margins of trade in cattle and beef for seven years. 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.

The third essay studies a counterfactual experiment about the elimination of bovine spongiform encephalopathy (BSE) and the foot and mouth diseases (FMD) on beef trade flows. Disease outbreak alerts typically prompt importing countries to impose trade bans. The bans vary a lot across importing countries in terms of product coverage and duration. We rely on a unique balanced panel dataset that covers 4-digit disaggregated beef product over the 1996-2013 period. Previous gravity studies reported only partial trade flow effects. However, a large shock like the complete elimination of BSE and FMD diseases must affect the inward and outward multilateral resistance indices (i.e., the importing countries' barriers on beef imports from all sources and the trade barriers faced by exporting countries in all destinations), factory-gate prices, consumer expenditures and the value of beef production in exporting countries. Our results confirm that the indirect channels through which BSE and FMD impact trade are important when it comes to measuring welfare gains. Interestingly, our counterfactual experiment suggests that Canada would be one of the countries gaining the most from BSE and FMD eradication.

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À mes parents Edouard et Christine.
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Avant-propos

The chapters of this dissertation are papers that are either submitted to peer- reviewed academic journals, or are being prepared to be submitted to journals.

The paper in Chapter 2 was co-authored with my supervisor, Bruno Larue and my co-supervisor Carl Gaigné. I am the principal author of this paper and it will be submitted to a peer-reviewed journal as soon as it goes through some final editing.

The paper in Chapter 3 was co-authored with Bruno Larue and Lota D. Tamini. It will be submitted to a peer-reviewed journal as soon as it goes through some final editing. I am the principal author of this paper.

The paper in Chapter 4 was co-authored with my supervisor, Bruno Larue. I am the principal author of this paper and it has been submitted and accepted with minor revision to peer-reviewed journal : Canadian Journal of Agricultural Economics

Introduction

This thesis is related to the general trend in the literature on the incidence of tariffs and non-tariffs barriers on international trade of agricultural and agri-food products. More specifically, I measure the incidence of tariff and non-tariffs barriers on export survival as well as on the extensive and the intensive margins of trade.

The new international trade theories posit that firms have heterogeneous levels of productivity and face variable and fixed export costs. It follows that for a trade flow from exporting country i to importing country j to be observed, the most productive firm in country i must be able to compete in country j. These assumptions help explain why only a fraction of firms export at any point in time and the "ins" and "outs" by firms on export markets. Not only a fraction of firms in each country exports but -perhaps less know- also they have very low survival time in the export markets. Early empirical studies on export duration found that trade flows are short-lived and that "ins" and "outs" are frequent. Sabuhoro et al. (2006) report a median survival time of 20 months for exports made by Canadian plants while Besedeš and Prusa (2006) find that a median of 2 years for referenced price and homogenous products.These studies also report frequent "ins" and "outs". One might expect that the frequency of entries and exits also likely to be high in sectors for which trade flows originate from a few countries and the number of trading firms is limited. In such cases, firms export to many destinations and marginal destinations are likely to be highly substitutable. OECD/FAO (2017) argue that five countries or less typically account for at least 70% of world exports for many agricultural commodities. In addition many primary agricultural products take a long time to produce and are perishables.

The first chapter of this thesis focuses on the trade survival in the agricultural and agri-food products. We introduce into the standard trade framework the possibility that firms have increasing marginal cost. Under this hypothesis, a firm's sales in one market impact on its cost and competitiveness on all markets and hence on its survival on various export markets. More specifically, with cost convexity, the firm's decision in any given market is directly tied to sales in other markets through an index aggregating the market size of the destinations supplied by the firm. The hypothesis of convex costs is particularly relevant for agriculture as supply is typically very inelastic making supply rather insensitive to shocks in the export markets. As a result, the introduction of convex costs modifies the standard sales equation of a firm selling to a specific destination through an index that aggregates the size and trade costs of all markets supplied by the firm. Thus, other markets have a direct influence on the firm's behaviour that goes beyond the indirect effect through multilateral inward and outward resistance indices. Unlike the case of constant marginal costs, a more productive firm or country may export to fewer destinations than a less productive rival marginal costs are increasing. We rely on a unique data set that covers 235 agricultural products, 176 importing countries and 4 exporting countries including U.S. Canada, Australia and Brazil over 2005-2010 period to empirically ascertain whether theoretical patterns stemming from cost convexity are supported by empirical evidence. This is accomplished by introducing lagged foregone exports through exits in the model. Our findings confirm theoretical predictions about the ties between exits and entries. Exits, proxied by the aggregate value of export flows terminated at T-1, have a strong negative impact on the probability of export failure. One would expect entries and exits to be more frequent under cost convexity, all else equal as the link between markets forces firms to make adjustments at the intensive margins. The empirical results show that foregone exports from terminated flows increase exports to "fallback markets" and reduce the probability of export failure. Another special feature of our empirical framework is that it addresses tariff endogeneity, an issue that might be responsible for some the peculiar tariff coefficients reported in previous export survival studies. Non tariff barriers appear to be very important factors affecting trade survival.

The WTO advocates for openness of trade as a way to promote economic growth, to increase welfare among member countries. WTO member's countries have committed to favour the use of tariffs at their lowest level as the main trade policy. When countries agree to open their markets for goods or services, they "bind" their commitments. For goods, these bindings amount to ceilings on customs tariff rates. Despite these commitments, tariffs are still high specifically in the agriculture and agri-food. When countries agree to lower the level of their tariffs, they usually rely on non-tariffs barriers to protect their market by brandishing the food safety argument. 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 issue has been raised by many countries. This issue is even more important when it comes to animal disease outbreak. The immediate embargo that countries impose following an occurrence of animal disease outbreak in their trade partner countries, cause a significant and disastrous effect on bilateral trade flow. While the embargo measures are usually immediate, the conditions and timing of regaining market access differ across importing countries and can be a lengthly and uncertain process. On top of that, 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 slaughtering 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. Beef production is conditioned by cattle supply and this is a source of vertical linkage between cattle and beef production and trade and hence has an important implication in terms of econometrical specification. In our second chapter, we address the question of animal diseases 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. The estimation methodology relies on the Multivariate Sample Selection Model (MSSM) to investigate the impacts of cattle diseases on both the intensive and the extensive margins of export flows. The joint estimation of the equation system improves biases and statistical efficiency of the estimates as it accounts for contemporaneous correlations. 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.

Recent developments have made it possible to use structural gravity models to conduct counterfactual experiments, like the elimination of a trade agreement, that allow for multilateral resistance terms, factory-gate prices and expenditures to adjust. A general equilibrium analysis accounts for all the direct and indirect linkages between the various elements in the economic system considered (Larch and Yotov, 2016). In addition, 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 in a general equilibrium framework. A general equilibrium analysis accounts for all the direct and indirect linkages between the various elements in the economic system considered Larch and Yotov (2016). My counterfactual experiment is about the elimination of bovine spongiform encephalopathy (BSE) and the foot and mouth diseases (FMD) on beef trade flows. Disease outbreak alerts typically prompt importing countries to impose trade bans. The bans vary a lot across importing countries in terms of product coverage and duration. I rely on a unique balanced panel dataset that covers 4-digit disaggregated beef product over the 1996-2013 period. Previous gravity studies reported only partial trade flow effects. However, a large shock like the complete elimination of BSE and FMD diseases must affect the inward and outward multilateral resistance indices (i.e., the importing countries' barriers on beef imports from all sources and the trade barriers faced by exporting countries in all destinations), factory-gate prices, consumer expenditures and the value of beef production in exporting countries. My results confirm that the indirect channels through which BSE and FMD impact trade are important when it comes to measuring welfare gains. Interestingly, my counterfactual experiment suggests that Canada would be one of the countries gaining the most from BSE and FMD eradication.

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Chapitre 1

Trade Margins and Export Duration with Convex technologies

1.1 Abstract

We develop a theoretical framework to explore the implications of decreasing returns on trade at the extensive and intensive margins. The export equation features an index that aggregates trade costs adjusted for the size of markets supplied by firms. This index can be absorbed by exporter-time fixed effects in the estimation of gravity models, but it induces linkages between trade flow terminations, the survival of existing trade flows and the creation of new trade flows. Under convex costs, an increase in productivity may not increase the number of destinations supplied by a firm, making "ins and outs", not just new entries. Using agri-food export from Australia, Brazil, Canada and the United State, it is shown that foregone exports from terminated flows increase exports to "fallback markets" and reduce the probability of export failure. As in several other studies on export survival, tariffs reduce the probability of an export failure when tariffs are treated as exogeneous, but they have the opposite effect when their endogeneity is addressed.

1.2 Introduction

The gravity model has had much success in explaining agricultural trade flows (e.g., Sun and Reed (2010),Winchester et al. (2012) and Gaigné et al. (2017)), but its microfoundations do not explain the frequent ins and outs and short export duration observed on export markets as documented in empirical studies. [1]. In this paper, we relax a key hypothesis, that of constant marginal cost, to rationalize frequent ins and outs. Recent empirical evidence suggests that firms have increasing marginal costs (Vannoorenberghe, 2012; Blum et al., 2013; Soderbery, 2014; Karasik, 2014; Antras et al., 2017). As a

1. Sabuhoro et al. (2006) report a median survival time of 20 months for exports made by Canadian plants while Besedeš and Prusa (2006a) find that a median of 2 years for referenced price and homogenous products.These studies also report frequent ins and outs.

result, a firm's sales in one market impact on its cost and competitiveness on all markets and hence on its survival on various export markets. Cost convexity induces adjustments at the intensive and at the extensive margins of trade between export markets and between export and domestic markets. Cost convexity is particularly pertinent in agricultural trade because many primary agricultural products take a long time to produce and are perishable. As such, there is an extreme form of convexity as capacity is fixed in the short run. Processing plants may also face capacity constraints due to investment lags. The frequency of entries and exits is also likely to be high due to the ease with which a marginal destination can be replaced by another. For products for which exports account for a small share of domestic production, export exits are often offset by increases in domestic sales(Vannoorenberghe, 2012). However for many agri-food products, exports make up a large share of domestic production and in such cases exits from marginal export markets are likely to trigger intensive margins adjustments in large export markets.

The first contribution of this study is the development of a theoretical framework to address the incidence of increasing marginal costs and capacity constraints on trade at the extensive and the intensive margins and on export duration. In the standard trade model (i.e., Melitz (2003)), the firm's sales in any given market is related to other markets only through price indices which are treated as exogenous in the firm's optimization. With cost convexity, the firm's decision in any given market is directly tied to sales in other markets through an index aggregating the market size of the destinations supplied by the firm. Unlike with constant marginal costs, more productive firms will not necessary sell to more destinations. The difference made by increasing costs is that a significant change in sales in a given destination, like the termination of a trade flow or the creation of a new trade flow, triggers changes at the intensive and possibly the extensive margins in other markets. Our model differs from that of Soderbery (2014) which focuses on the welfare implications of capacity constraints. We assume CES-preferences to facilitate the comparison with the standard Anderson-van Wincoop gravity model, at the cost of not allowing firms to adjust their markup. Vannoorenberghe (2012) used cost-induced linkages between markets to highlight the role of the share of exports in a firm's total sales on the volatility of the firm's domestic sales. Like us, Blum et al. (2013) is interested in the implications of convex costs on export survival. We make different technological assumptions and we emphasize extensive margin choices in a multi-market environment. Antras et al. (2017) analyze the global sourcing decisions of firms in a multi-country world where production of a final good in country i combines multiple inputs from different sources. While the authors emphasized input markets linkage through the cost function, we use a different technological assumption and our empirical analysis focusses on the implications of cost linkages on export duration. As such, our model and that of Antras et al. (2017) can be seen as distinct extensions of Melitz (2003)'s model to accommodate cost linkages.

Our second contribution is an empirical application about export survival that allows us to ascertain whether theoretical patterns stemming from cost convexity are supported by empirical evidence. This is accomplished by introducing lagged foregone exports through exits in the model. One special feature of our empirical framework is that it addresses tariff endogeneity, an issue that might be responsible for some the peculiar tariff coefficients reported in previous export survival studies. Tariff endogeneity has been addressed in the trade literature by (Goldberg and Pavcnik, 2005; Buono and Lalanne, 2012), but not in export survival models. Our dataset covers 176 destinations and 235 agri-food products and it allows us to compare the export performance of the United States, Canada, Brazil and Australia and to test various hypotheses regarding the factors that condition export performance beside cost-convexity.

Our findings confirm theoretical predictions about the ties between exits and entries. Exits, proxied by the aggregate value of export flows terminated at T-1, have a strong negative impact on the probability of export failure. Unlike the case of constant marginal costs, a more productive firm may export to fewer destinations than a less productive rival. One would expect entries and exits to be more frequent under cost convexity, all else equal as the link between markets forces firms to make adjustments at the intensive margins. The empirical results show that foregone exports from terminated flows increase exports to "fallback markets" and reduce the probability of export failure. Another special feature of our empirical framework is that it addresses tariff endogeneity, an issue that might be responsible for some the peculiar tariff coefficients reported in previous export survival studies.

1.2.1 Related literature

Several papers investigated why some firms may exit at a certain point in time and later return to the same market. Vernon (1966) developed a product cycle model featuring three phases : introduction, maturity and standardization. In his model, access to knowledge and the embodiment of this knowledge into a marketable product is costly. The ease of communication and geographical proximity facilitate decision-making and new products tend to be introduced and sold in countries with cheap access to knowledge, high per capita income and high labor cost. The introduction phase is done in industrialized countries with strong domestic demand. Once the product is mature, it is exported and once the product has become standardized, production moves to countries with low labor costs. Innovations create new cycles of export entries and exits. This suggests spells of exports from rich countries lasting a few years before being followed by longer spells without export during which the product is standardized and new products are being developed. This does not explain short ins and short outs by firms manufacturing the same product throughout.

Search costs theory provides insights about ins and outs by exporting firms. In Rauch and Watson (2003)'s model, a domestic importer searches for a foreign supplier and then must choose between starting the relationship with a small or a large order. Subsequently, the importer must decide between continuing the relationship with the exporter or to search for a new supplier, possibly from a different country. If exporters and importers are properly matched, importers will place larger orders that are more likely to allow exporters to cover their fixed export costs. Importers are more likely to start with large orders when they have had a past successful relationship with the exporter, but lower search costs increase the probability that the importer will switch to a new exporter. The search cost model generated many of the priors of Besedeš and Prusa (2006b). Reasoning that differentiated goods involve larger search and investment costs, the authors found that new trade flows tend to be smaller and to last longer when they involve differentiated goods as opposed to homogenous goods. Our theoretical model show that the elasticity of substitution and cost convexity reduce the length of export spells. While it is generally believed that agricultural processed products tend to be more differentiated than primary agricultural products, little is known about the extent of the cost convexity of one group of products versus the other. Our empirical analysis sheds some light on this issue.

Trade models allowing for heterogeneous firms within a sector provide valuable insights about how changes in fixed and variable trade costs can bring about the creation of new trade flows and the disappearance of old ones. In Melitz (2003), only a fraction of firms are productive enough to export and a country's exports cease when increases in fixed and/or variable export costs are such as to prompt the country's most productive firm to exit. Typically, a firm's average cost of production is conditioned by an exogenous productivity level (drawn from a Pareto distribution) which does not vary with the level of production. Markets are linked through the multilateral resistance indices which are treated as exogenous in the optimization of monopolistic firms. Accordingly, a trade cost reduction in one market does not impact directly on the firm's sales in other markets. The impact is indirect through the multilateral resistance indices (the conditional effect) and through changes in national income and expenditures (the general equilibrium effect). Blum et al. (2013) allows markets to be connected through cost and shows that ins and outs are to be expected when markets are subjected to large demand shocks.

On the empirical side, Brenton et al. (2009) highlight the importance of previous export experience. Hess and Persson (2012) used the Besedeš and Prusa (2006b) data to illustrate the advantage of discrete-time models relative to the Cox proportional model. At the plant level, Bernard et al. (2006) showed that low-wage country imports reduce plant survival and employment growth. Namini et al. (2013) investigate the incidence of sector-wide export growth on firm survival. Their results suggest that larger, older, more productive plants, and plants that imported intermediate inputs and use foreign technology, are more likely to survive. Skill intensity and sector-wide export have negative impacts on firm survival. A few studies have focussed on agri-food exports. Bojnec and Fertő (2012) use the Cox estimator on a dataset covering 557 products and find that improved access to the EU market has extended the duration of agri-food exports of new EU members like Poland, Hungary and Romania. Peterson et al. (2017) focus on exports of fresh fruits and vegetables and the role of price changes and sanitary and phytosanitary regulations on export duration.

1.3 Theoretical Framework

The assumption of constant marginal costs is most practical because it allows firms to make decisions about trade at the extensive and intensive margins for a given destination independently from decisions about other export destinations, including the domestic market. Convexity in production costs makes the marginal cost vary with the level of production and it ties markets together as changes in sales in a given market impact on the marginal cost and on the competitiveness of the firm in all markets. Thus, the firm's optimization is much more complicated as all of the markets must be simultaneously considered. In this context, policies or shocks impacting on the domestic market may have important implications for the competitiveness of firms on export markets. This argument is not new. Krugman (1991) showed that strategic import protection policies could be used as export promotion policies when oligopolistic firms enjoy economies of size in production. With deseconomies of size in a two-country world, a positive demand shock on the domestic market may induce a reduction or even the termination of export sales (Vannoorenberghe, 2012). The model developed below builds on the received literature on monopolistic competition in a N-country world.

1.3.1 Consumption, technology and the optimization of exporting firms

In a world with N countries, a firm from country i sells a variety within product class k to n_i^k destinations, where $n_i^k \in [1,N]$. Consumers all over the world have identical CES sub-utility function such that $U_j^k = [\int_{\omega\in\Omega_j^k}[\zeta_j^k q(\omega)]^{\frac{\varepsilon^k-1}{\varepsilon^k}}\mathrm{d}\omega]^{\frac{\varepsilon^k}{\varepsilon^k-1}}$ where Ω_j^k represents the set of available varieties within product class k in country j, $q(\omega)$ is the consumption of variety ω in country j, and $\zeta_j^k(\omega)$ represents demand shocks which are product and country specific. The elasticity of substitution across products is defined by ε^k and is the same in every country. Expenditure on product k in country j is defined as $E_j^k = \int_{\Omega_j^k} p(\omega)q(\omega)\mathrm{d}\omega$ where $p_(\omega)$ is the price of variety ω.

The constrained maximization of utility by consumers yields the following demand for variety ω supplied by a firm exporting from country i to country j :

$$q_{ij}^k(\omega) = (\zeta_j^k(\omega))^{\varepsilon^k-1}A_j^k[p_{ij}^k(\omega)]^{-\varepsilon^k} \tag{1.1}$$

where $p_{ij}(\omega)$ is the price of variety ω produced in country i and delivered in destination j and $A_j^k \equiv E_j^k P_j^{1-\varepsilon^k}$ with $P_j^k = [\int_{\omega\in\Omega_j^k} p(\omega)^{1-\varepsilon^k}]^{\frac{1}{1-\varepsilon^k}}$ being a price index which aggregates the prices of all available varieties in country j.

Each firm produces a different variety $\omega \in \Omega^k$ using one factor of production, labour. The variable cost function is :

$$VC(y_i^k) = \frac{1}{\varphi}(y_i^k)^{\gamma^k} \tag{1.2}$$

Firms draw heterogeneous productivities φ from a given distribution. The average variable cost of a firm located in country i supplying market j as $AVC(y_i^k) = \frac{1}{\varphi}(y_i^k)^{\gamma^k-1}$. Firms face the same average variable production cost across destinations. Naturally, per unit variable costs vary across destinations when iceberg trade costs τ_{ij} and tariffs T_{ij}^k are factored in. The firm's profit can be depicted as :

$$\pi_{ij}^k(\omega) = \frac{p_{ij}^k q_{ij}^k(\omega)}{T_{ij}^k} - AVC^k(y_i^k)\tau_{ij}q_{ij}^k - f_{ij} \tag{1.3}$$

With CES preferences, the marginal revenue of a firm in a given market is a linear function of price and given that the marginal production cost is $\frac{\gamma^k}{\varphi}(y_i^k)^{\gamma^k-1}$, profit-maximizing prices are :

$$p_{ij}^k = p_i^k \tau_{ij} T_{ij}^k \quad \text{with} \quad p_i^k = \frac{\varepsilon^k}{(\varepsilon^k - 1)\varphi}\gamma^k (y_i^k)^{\gamma^k - 1} \tag{1.4}$$

where p_i^k is factory-gate price. The price must exceed average variable cost and this requires that $\gamma^k > \frac{\varepsilon^k-1}{\varepsilon^k}$. Increasing returns, $\gamma^k < 1$, is possible, but its extent falls with the elasticity of substitution. Accordingly, weakly decreasing returns is a more plausible assumption for monopolistic competition models and we will assume decreasing returns henceforth. Prices paid by consumers are increasing with the convexity parameter, trade costs and tariffs and decreasing with productivity. The effect of productivity, φ, on prices is negative as the positive effect of productivity through the output is more than offset by the direct productivity effect. Using (1.2) and (1.4), the firm's profit π_i^k over all of the n_i^k destinations that it can supply given its productivity φ can be rewritten as :

$$\pi_i^k = \frac{(y_i^k)^{\gamma^k}}{\varphi}\left(\frac{\varepsilon^k \gamma^k}{\varepsilon^k - 1} - 1\right) - \sum_j^{n_i^k(\varphi)} f_{ij}^k \tag{1.5}$$

The above expression tell us that firms with identical φ and producing the same level of output y_i^k would elect to sell in the smallest possible number of destinations to avoid fixed export costs. Thus, there is a weakly monotonic relationship between a firm's output and the number of destinations and between a firm's output and productivity. Profit must be weakly positive and from the above expression it follows that ε^k>1 under increasing cost, γ^k>1. Similarly, the decreasing costs assumption imposes the following inequality restriction : ε^k<1. Given that $y_i^k = \sum_j^{n_i^k(\varphi)} q_{ij}^k \tau_{ij}^k$,it can be shown that :

$$(y_i^k(\varphi))^{\gamma^k} = \left(\frac{\varepsilon^k}{\varepsilon^k - 1}\frac{\gamma^k}{\varphi}\right)^{\frac{1-\varepsilon^k}{1+(\gamma^k-1)\varepsilon^k}} \left(\Lambda_i^k(\varphi)\right)^{\frac{\gamma^k}{1+(\gamma^k-1)\varepsilon^k}} \tag{1.6}$$

with

$$\Lambda_i^k(\varphi) \equiv \sum_j^{n_i^k(\varphi)} A_j^k (\tau_{ij}^k)^{1-\varepsilon^k} (T_{ij}^k)^{-\varepsilon^k}$$

which is a firm-specific outward multilateral index capturing the size of all of the markets where the firm is present. More productive firms tend to be present on more markets and this makes their $\Lambda_i^k(\varphi)$ larger. With linearly increasing production costs, the ratio of output $y_i^k(\varphi)$ of two firms producing the same product k depends only on the ratio of their productivities. This is not true when costs are convex (or concave) as characteristics of foreign markets targeted by the firms come into play. Under convexity (concavity) in costs, the $\Lambda_i^k(\varphi)$ tend to deflate (inflate) the incidence of the productivity ratio on the output ratio of two firms. Finally, while an increase in productivity lowers prices and increase production in existing markets and weakly increase the number of destinations under constant returns, this is not necessarily so under decreasing returns. To shed more light on this, we discuss in more details the intensive and extensive margins of trade under decreasing returns below.

1.3.2 Intensive margin

Export sales to destination j by a country i firm is given by :

$$\frac{p_{ij}^k q_{ij}^k}{T_{ij}^k} = \frac{A_j^k(\tau_{ij}^k)^{1-\varepsilon^k}(T_{ij}^k)^{-\varepsilon^k}}{\left(\Lambda_i^k(\varphi)\right)^{\frac{(1-\varepsilon^k)(1-\gamma^k)}{1+(\gamma^k-1)\varepsilon^k}}}\left(\frac{\varepsilon^k}{\varepsilon^k-1}\frac{\gamma^k}{\varphi}\right)^{\frac{2(1-(\varepsilon^k)+\gamma^k\varepsilon^k}{1+(\gamma^k-1)\varepsilon^k}} \tag{1.7}$$

Log-linearizing the above expression and setting $X_{ij}^k \equiv p_{ij}^k q_{ij}^k$ gives :

$$\begin{aligned}\log(X_{ij}^k) = -(\varepsilon^k-1)\log(\tau_{ij}^k) - \varepsilon^k\log(T_{ij}^k) \\ - \frac{(1-\varepsilon^k)(1-\gamma^k)}{1+(\gamma^k-1)\varepsilon^k}\log(\Lambda_i^k(\varphi)) + FE_{product} + FE_{dest} + \mu_{ij}\end{aligned} \tag{1.8}$$

The distinguishing feature of equation (1.8) is the inclusion of the $\Lambda_i^k(\varphi)$ component which aggregates the size of individual markets chosen by the firm. This term disappears under constant returns, when $\gamma = 1$. If we compare equation 1.7 for two firms from country i selling in j, their sales in j will differ because of the direct effect of φ and of its indirect effect through the total number of destinations entering Λ_i^k. Cost convexity (concavity) tends to reduce (increase) the number of export flows at the firm level and at the exporting country level when integrating over firms.

To get some more insights into the implications of convex costs at the intensive margin, we restrict productivity, φ, to be the same across firms. We retain cost convexity and our model is more like a generalization of Anderson and van Wincoop's (2003) model which provides the micro-foundation for many structural gravity models (e.g., Anderson and Yotov (2016)). We show that the specification of the gravity equation under cost convexity does not change and neither does the manner with which one can endogenize multilateral resistance indices and expenditures while implementing the structural gravity framework. This is so because cost convexity impacts on the level of the factory-gate price, but the latter still relate to total sales Y_i^k in the usual manner :

$$(p_i^k)^{1-\varepsilon^k} = \frac{Y_i^k}{(\Pi_{ij}^k)^{1-\varepsilon^k}} \tag{1.9}$$

where $(\Pi_{ij}^k)^{1-\varepsilon^k} = \sum_j E_j^k P_j^{\varepsilon^k-1}(\tau_{ij}^k)^{1-\varepsilon^k}(T_{ij}^k)^{-\varepsilon^k}$ is the outward multilateral resistance index, $Y_i^k \equiv \sum_j X_{ij}^k$ and $P_j^{1-\varepsilon^k} = \sum_i \frac{Y_i^k}{\Pi_i^{1-\varepsilon^k}}(\tau_{ij}^k)^{1-\varepsilon^k}(T_{ij}^k)^{-\varepsilon^k}$ is the inward multilateral resistance index. As a result, export sales from i to j can still be expressed as :

$$X_{ij}^k = \frac{Y_i^k E_j^k}{(\Pi_{ij}^k)^{1-\varepsilon^k} P_j^{1-\varepsilon^k}}(\tau_{ij}^k)^{1-\varepsilon^k}(T_{ij}^k)^{-\varepsilon^k} \tag{1.10}$$

The trade equation does not allow us to identify the existence of increasing unit cost. A key step in the implementation of the structural gravity framework is the recovery of the multilateral resistance indices. This can be done even when the factory-gate price is non-linear in output. Rearranging 1.9 in terms of the outward multilateral resistance index and exploiting that with CES preferences bilateral sales $X_{ij}^k = E_j^k P_j^{1-\varepsilon^k} p_{ij}^{1-\varepsilon^k}$, then one can estimate the following equations in the process of conducting counterfactual experiments :

$$\frac{(\Pi_{ij}^k)^{1-\varepsilon^k}}{Y_i^k} = [\frac{\varepsilon^k}{(\varepsilon^k-1)}\gamma^k \tau_{ij} T_{ij}^k]^{(\varepsilon^k-1)}(y_i^k)^{(\gamma^k-1)(\varepsilon^k-1)} \tag{1.11}$$

$$X_{ij}^k \frac{P_j^{1-\varepsilon^k}}{E_j^k} = [\frac{\varepsilon^k}{(\varepsilon^k-1)}\gamma^k \tau_{ij} T_{ij}^k]^{(1-\varepsilon^k)}(y_i^k)^{(1-\gamma^k)(1-\varepsilon^k)} \tag{1.12}$$

From the above equations, one can make an inference about the magnitude of γ^k. The incidence of convex costs on the intensive margin is relatively straightforward to the extent that the effect is channelled through the factory-gate price. The incidence on the extensive margin is less straightforward. We now return to our model with firm-specific productivity to explore the incidence of cost convexity at the extensive margin.

1.3.3 Extensive margin

Using equilibrium prices, the operating profit associated with a destination can be written as follows :

$$\Pi_{ij}^k = \left(\frac{\varepsilon^k}{\varepsilon^k-1}\gamma^k - 1\right)\frac{1}{\varphi_i} y_i^{\gamma^k-1} \tau_{ij}^k q_{ij}^k \tag{1.13}$$

Because $q_{ij}^k = A_j^k (p_{ij}^k)^{-\varepsilon^k}$, the expression below must exceed the fixed cost for entry to take place :

$$\Pi_{ij}^k = \varphi_i^{\varepsilon^k-1}\left(\tau_{ij}^k q_{ij}^k + Q_{ij'}^k\right)^{(\gamma^k-1)(1-\varepsilon^k)} A_j^k \left(\tau_{ij}^k\right)^{1-\varepsilon^k}\left(T_{ij}^k\right)^{\varepsilon^k} c^k \tag{1.14}$$

with $c^k \equiv \left(\frac{\varepsilon^k}{\varepsilon^k-1}\gamma^k - 1\right)\left(\frac{\varepsilon^k}{\varepsilon^k-1}\gamma^k\right)^{-\varepsilon^k}$ and $Q_{ij'}^k = \sum_{j \neq j'} a_{ij'}^k$

The problem at the extensive margin can be approached as an algorithm that begins by ranking markets in terms of their profitability conditional on $n_i^k(\varphi)$=1,...,N where N is the number of potential destinations. For $n_i^k(\varphi)$=1, the firm must choose the best destination given that it sells to only one destination. Thus, $\pi_i(1) = max(\pi_{i1}, \pi_{i2}, ..., \pi_{iN})$ is the most profitable 1-market configuration. The second step entails ranking 2-market configurations : $\pi_i(2) = max(\pi_{i1,2}, ..., \pi_{i1,N}, ..., \pi_{iN-1,N})$. Similarly, the best 3-market configuration is $\pi_i(3) = max(\pi_{i1,2,3}, ..., \pi_{i1,2,N}, ..., \pi_{iN-2,N-1,N})$. The firm can then pick the number of markets it will serve by comparing $\pi_i(1)$, $\pi_i(2)$... This iterative process classifies firms into 1-market,...,n-market configurations, where $n_i \leq N$ is the highest number of destinations targeted by exporting firms from country i. Cost convexity exacerbates the incidence of fixed export costs on the number of destinations that firms will supply.

Figure 1.1 illustrates the equilibrium conditions to profitably operate in a market. The firm's first order condition for profit maximization in this market entails choosing a quantity for which marginal revenue must equal marginal cost : $MR - MC$=0. At the proposed quantity, q_a, the firm must make a positive profit. The variable profit, the difference between revenue and variable cost is the area under the $MR - MC$ line between zero and q_a, while the profit is the rectangle connecting q_a and the average profit line. The difference between the two areas is the fixed cost. If a second market exists, say market b, the firm can operate on market a or on market b or on both markets. If it was to operate in both markets, the firm would equate its marginal revenue to its marginal cost in both markets. The level of production to supply two markets would be higher and so would the marginal cost. In market a, this makes the $MR - MC$ and the average profit lines shift down as shown by the dashed lines. The new potential equilibrium quantity in market a is reduced to $q_{a'}$, but because the firm would lose money at this quantity, the firm would not operate in two markets simultaneously and the firm would then choose the most profitable 1-market equilibrium.

The role of fixed cost

Firms maximize their variable profit in each destination and the variable profit in a given destination must be sufficient to cover the destination's fixed export costs. A firm will supply a high fixed cost market only if it is a large market, all else being equal. However, since the average variable cost increases with the output produced, the inclusion of a large market amongst a firm's destinations makes the firm less competitive in other markets and more likely to add low-fixed cost markets with smaller minimum sales levels to break even rather than high-fixed costs markets requiring larger minimal sales to cover the fixed cost. Firms with high productivities have more scope to increase output, but this does not necessarily translate into exporting to more destinations. This implies that, unlike in Helpman et al. (2008), the number of destinations for which there is a trade flow emanating from a given exporting country is no longer identified by the number of destinations supplied by the most productive firm in the exporting country. Threshold profits may not be increasing in the number of markets supplied by threshold firms. To show that the monotone relationship between a firm's profit, its productivity and the number of destinations supplied by the firm breaks down under convex costs, consider the example in Figure 1.2. Initially, the most productive firm operates with marginal cost mc_a and faces fixed costs of $f_1 = 27 < 51 = f_2$ in markets 1 and 2 with the latter being twice the size of the former. The marginal revenue curves are represented by the dashed lines and their horizontal sum is the Smr curve. Consumers in both markets have the same CES preferences. The firm selling in both markets will equate marginal revenues across markets at the level at which the mc_a and Smr curves intersect. Because the demand elasticity is the same in both markets, the firm's prices in both markets will be the same if trade costs are the same or absent. To simplify, trade costs are ignored and the potential 2-market equilibrium with variable profits of 23.23 and 46.46 is discarded because the fixed costs are not covered. Amongst the one-market equilibria, selling in market 1 is profitable, as the variable profit of 29.13, given by the rectangle a,b,c,d in Figure 1.2, exceeds the fixed cost by 2.13. Let us now assume that the firm experiences an increase in productivity that shifts down the marginal cost curve down to mc_b. Selling to both markets become profitable with variable profits of 31.37 and 61.89. However, by incurring only one fixed cost in market 2, the firm can earn a higher profit of $68.2 - 51 = 17.2$. The increase in productivity lowers the optimal price, which is proportional to marginal cost. However, because the latter is increasing in output, the decrease in price is less than under constant returns. Productivity increases output and variable profit, especially in larger markets with a large A_j^k. This favors the larger market 2. The variable profit, given by the e,f,g,h surface in Figure 1.2 exceeds the fixed cost. The firm exits market 1 to sell only in market 2. The higher total output that would result from catering to both markets, identified by point i in Figure 1.2, inflates marginal costs enough to make the 2-market alternative less profitable. Had fixed cost in market 1 been 20 instead of 27, the productivity shifts would have triggered a switch from a 1-market equilibrium to a 2-market equilibrium. Differences in fixed costs across markets matter a lot and it is easy to deduce that a firm serving say six markets experiencing a productivity shock may actually drop two or three markets to enter a large high-fixed cost market. Therefore, a more productive firm may export to fewer destinations than a less productive rival.

We are not the first to point out that some of the key results of monopolistic competition trade models are not robust to changes assumptions about technologies. For example, Hallak and Sivadasan (2013) introduces two sources of firm heterogeneity by defining two types of productivity : a process productivity and a product productivity. The first concept is about a firm's use of resources to increase the output of a standardized product while the latter is about a firm's use of resources to raise product quality. They show that highly process-productive firms are not necessarily the ones that will enter multiples foreign markets. Gaigné and Larue (2013) show that increases in productivity have ambiguous effects on price and output depending on how quality impacts on a firm's fixed and variables costs. In these papers, an increase in productivity may prompt a firm to increase quality to penetrate high per capita income markets. However, the firms would not have incentives to drop markets where consumers have lower per capita income. With convex costs, productivity increases generally create entries and exits that may decrease, leave the same, or increase the number of destinations. Antras et al. (2017) emphasized that the extensive marginal of sourcing in not necessarily increasing in firm productivity as firm may not have incentive to add further locations after paying a large fixed cost to offshore to a country with highly sourcing potential.

The role of market size

Intuitively, large markets are more likely to be chosen when comparing potential configurations involving a small number of markets and are more likely to be retained by the firm when it entertains exporting to additional destinations. When costs are convex, large markets raise the marginal cost of the firm and, all else equal, this favors marginal markets with low fixed costs making small exports profitable. This is consistent with the Costa Rican import pattern described by Arkolakis et al. (2012) who argued that marginal varieties contributed little to the gains from trade because of the small volumes imported. A separate implication of convex costs is that when a firm exits one or more smaller marginal markets, it will have a tendency to make intensive margin adjustments. Thus, it will increase sales in its larger markets.

To illustrate this, consider the effect of the 2014 Russian embargo on Canadian frozen pork. Russia was the largest importer of Canadian frozen pork in 2014. Canadian firms reacted by increasing the number of tons of frozen pork exports to China and the US by 14.6% and 11.4% respectively, reducing the total number of tons of frozen pork exports by 10% and increasing the total number of tons of fresh pork exports by 11%. Almost all of the growth in Canadian fresh pork exports is accounted for by increases in export to Japan and Mexico. [2]. Furthermore, production has remained stable, with total hog slaughter slowly increasing since 2013 in spite of the Russian embargo. [3]. In this example, the "fallback" markets were large export markets, but the domestic market may serve this purpose. Vannoorenberghe (2012) shows that a firm's domestic sales tend to be more volatile when the share of exports in the firm's total sales increases.

The number of destinations changes with productivity, possibly in a non-monotonic manner. Still, there are productivity bounds defined by firms that make the same profit under two different number of destinations or with the same number of destinations, but with different sets of destinations. The cut-off profits depend on fixed costs and price indices from all destinations, a point also made by Blum et al. (2013); Antras et al. (2017). In Melitz (2003)'s original model, there is an explicit concern about dynamics with the inclusion of a probability that a firm might experience a "bad shock" and be forced to exit a market in the future. Let us assume that a firm sells on n markets and that a demand shock makes one of these markets unprofitable. If the lost market is small, average variable costs will not fall by much and it might be easy to find another market of similar size. On the other hand, if the lost market is large and the firm exports to many destinations, the reduction in average variable cost will make it easier to penetrate new markets, but since many untapped markets are small, sales from new export destinations are likely to be small, provided fixed exports costs are also small. The reduction in variable production costs also favour intensive margin adjustments on the n-1 other markets. Similarly, when a positive demand shock occurs on a large market, this is likely to encourage entry by firms that export to few destinations while triggering intensive margin adjustments by firms that export to a large number of destinations.

The role of trade cost

Cost convexity has also implications for the analysis of tariffs and trade costs. An ad valorem tariff generates a per unit monetary revenue that is increasing with the level of the border price. As a result, the $MR-MC$ line and the $average profit$ line shifts down for the destination which applies the tariff, but unlike the parallel shifts shown in Figure 1, the spreads between the tariff-distorted and non-distorted lines get smaller as the quantity sold increases and the border price decreases. A tariff minimally triggers a reduction in the quantity sold in the destination imposing the tariff, but it can also trigger the exit of the firm from that market. However, the reduction in sales in the destination imposing the

2. Trade statistics are from StatCan's Canadian International Merchandise Trade Database, http://www5.statcan.gc.ca/cimt-cicm/home-accueil?lang=eng

3. Slauther statistics are from Agriculture and Agrifood Canada, http://www.agr.gc.ca/eng/industry-markets-and-trade/market-information-by-sector/red-meat-and-livestock

tariff decreases output and hence average production cost which has intensive and extensive margins effects in other markets. Thus, the $MR - MC$ and average profit lines in other markets would shift up, the exact opposite of what is shown in Figure 1, and it follows that a tariff-induced exit may induce entries elsewhere. This effect reinforces the inward multilateral resistance. The incidence of a tariff is conditioned by the elasticity of substitution, as foreign consumers will reduce their consumption of taxed varieties by a greater extent in response to a tariff hike when taxed and untaxed varieties are close substitutes. Accordingly, the lowest tariff that induces the exit of an exporting firm will be lower when the elasticity of substitution is high. By the same token, the probability of a tariff-induced entry is higher when varieties are quite homogeneous. The large number of products in our dataset allows us to categorize products in terms of their degree of differentiation and to test whether tariffs have a more potent effect on the probability of ending export spells when products are homogeneous. The purpose of the next section is to ascertain whether hypotheses stemming from convex costs about export survival are supported empirically.

1.3.4 Empirical illustration

The first row of Table 1.1 reports the mean number of destinations over all 2350 product-year pairs for the US, Canada, Australia and Brazil while the second row report the p-values for matched-pair differences between the number of destinations of country i and the number of destinations for US exports. On average, US agricultural exports reach 20 destinations while Canadian, Australian and Brazilian exports reach respectively 7, 10 and 9 destinations. Matched-pairs differences between the number of US destinations and the number of Canadian, Australian and Brazilian destinations are all highly significant as indicated by the reported p-values in the second row of Table 1.1. The same statistics are produced for different groups of products. For all 6-digit dairy products, US and Australian exports reach on average 25 and 20 destinations respectively while Canadian and Brazilian exports reach only 5 and 7 destinations. Canada's statistic can be explained by its dairy supply management policy that discourages imports and exports.

The case of cocoa is particularly interesting. [4] Brazil is one of the largest cocoa producing country and it exports on average to 26 destinations across cocoa and chocolate products-year pairs. Cocoa beans can easily be imported and processed into exportable products and this is why Canada and the US are among the top exporting countries when it comes to cocoa and chocolate products. In 2014, Canada and US exports of cocoa and chocolate products were close ($1.22 billion vs $1.3 billion) and they had similar export composition (with 4 of the 11 HS products accounting for 97% and 86% of all cocoa and chocolate exports). However, the average number of US destinations for cocoa products exports is 33 while for Canada it is only 13. Canada exported chocolate and food containing cocoa HS180690 to 42 destinations, but exported cocoa paste HS180320 to only 2 destinations in 2014. Yet, for that year, 98.6% of Canada's exports of chocolate and cocoa products went to the US. Most

4. The US and New Zealand launched a WTO complaint in 1998 alleging that Canada's milk pricing system was an implicit export subsidy. The WTO ruled in favor of the plaintiffs and Canada had to change its milk pricing system. Canadian dairy exports are expected to decrease further with the elimination of export agricultural subsidies by WTO members.

of these exports originated from a single plant operated by Swiss multinational near Montreal. This suggests that once US orders are filled, the plant has little capacity left to serve other destinations, the firm serving these other markets from plants located in other countries. The US market is the fallback market for Canada's production of cocoa and chocolate products. US exports of chocolate and cocoa products are also highly concentrated, with Canada, Korea, Japan and Australia accounting respectively for 54%,5.9%, 4.2% and 4.2% of the total.

Figure 1.3 illustrates the number of terminated and new trade flows. The slope of the curve is consistent with increasing unit production costs and capacity constraints. Under constant average production costs, there should not be a proportional pattern between exits and entries because entries are independent of shocks in third countries, barring the effects of these shocks on multilateral resistance indices. While Figure 1.3 is suggestive, it does not control for other factors that might influence the emergence of new export flows. Table 1.2 provides regression results about the relationship between the size of foregone exports from terminated trade flows at $T-1$ and the size of exports from new trade flows at T, while controlling for other factors through product and time fixed effects. For Australia, Brazil and Canada, new export sales increase with the magnitude of terminated trade flows. The reverse is observed for the US. If larger more profitable markets are served first, an exporting country serving a large number of destinations is left with very small potential new markets when reallocating foregone sales from larger markets. This can best be illustrated by looking at the consequences of the recent US-China trade dispute on US soybean exports. US soybeans were exported to 30 countries in 2016. China was the largest market for US soybeans. The drop in US exports to China in 2018, triggered exports to 11 new destinations which, along with intensive margin adjustments in existing markets, could not prevent a substantial reduction in total exports. [5].

Forgone exports from terminated trade flows trigger intensive margin adjustments, the more so on "fallback" markets. Because the bulk of Canada's agricultural exports are headed to the US, it is not surprising to see in Table 1.3 that Canadian agricultural exports to the US increase by 0.712% when Canada's foregone sales from vanishing trade flows increase by 1%. A 1% increase in foregone exports from terminated agricultural trade flows originating from the US increases US exports to Mexico by 0.54%. The fallback market effect is strongest for Australian and Brazilian agricultural exports to China.

1.4 Export Survival

1.4.1 Specification and data

A multivariate analysis is used to evaluate the contribution of individual factors on the hazard rate of exports. The hazard function takes the form :

$$h_{ijk}(t) = f(h_0(t), X'_{ik,t-1}\beta, Z'_{ijk}\gamma) \tag{1.15}$$

5. see https ://www.fb.org/market-intel/u.s.-soybean-exports-to-china-fall-sharply

where $h_{ijk}(t)$ is the dependent variable, $X^k_{ik,t-1}$ is our variable of interest, which is the level of foregone sales of variety k and Z_{ijk} are control variables known to impact on the probability and conditional value of trade. $h_0(t)$ represents the baseline hazard. The novel element in our export survival specification is the level of foregone sales from exits in the previous year. Under increasing costs, selling a large quantity in a given market makes it harder to cover fixed export costs on several other destinations while this is not so when costs are linearly increasing with output. As argued earlier, this is consistent with the difference in the number of destinations between Canadian and US exports. However, another implication of increasing costs is that past exits should increase the survival of current flows. To test this hypothesis, we sum up foregone exports from flows terminated in the previous year and use it as an additional covariate. As argued above, a positive effect is consistent with decreasing returns a null of no effect indicates constant returns.

A few authors have investigated the survival of agri-food exports (e.g., Peterson et al. (2017) and Bojnec and Fertő (2009)). Generally, export survival specifications rely on covariates that impact trade at the extensive and intensive margins. Such covariates include market size proxies like GDP per capita and population, and trade costs proxies like tariffs, distance, common language, contiguity, whether the destination is landlocked, religious openness and the presence of livestock diseases. Other variables are usually included, like a multiple-spell indicator, to account for learning from past export spells, and exchange rate volatility, to account for risk.

Our dataset covers 235 product categories over the 2005-2014 period. The products defined at the 6-digit HS level can be classified into 6 groups (cereals, fruits and vegetables, meat, oilseeds, dairy products and cocoa). Exports originate from Canada, the US, Australia and Brazil and are shipped to 176 potential destinations. Using highly disaggregated data allows us to characterize more accurately the dynamics of trade because a successful export episode for one product can hide a multitude of failures when analyzing highly aggregated data. Import values and tariffs come from the website of World integrated Trade Solutions (WITS). The World Trade Organization (WTO)'s Tariff Analysis Online was used to obtain tariffs that were not in WITS. Most countries have an average agricultural tariff between 15 and 18 percent, but tariff peaks in excess of 100 percent are relatively common. Tariff increases are expected to reduce trade survival. In the estimation, the tarif variable is an ad valorem "ta". Data series on language, distances, colony and border were downloaded from the Centre d'études prospectives et d'informations internationales (CEPII)'s database. The religious openness index data primarily came from the CIA World fact-book. The Britannica Book for the year 2013 was used to replace missing observations. The Religious Openness Index (ROI) is expected to reduce the likelihood of export failure. Following Helble (2006), the ROI is defined as :

$$R_{ij} = \sum_{i=1}^{n} d_{mi} \sum_{j=1}^{n} d_{mj} \text{ with } i \neq j$$

where d_{mi} is unity if one of the five religions is present in country i and zero otherwise. So, R_{ij} is the product of the maximum number of world religions that one country can host by the corresponding number in trading partner j. It indicates the number of religions present in bilateral trading countries. The higher R_{ij} is, the more religions are present in both countries. Helble (2006) finds that the presence of different religions within a country is trade promoting.

Distance is expected to increase the likelihood of an export failure because it increases trade costs. Sharing a common language is expected to lower search costs just like sharing a border (contiguity). Rauch (1999) argue that the matching of sellers and buyers is the result of a search process that is less costly when when exporters and importers share a common language. In Frankel et al. (1998), common language is used as an indicator of taste similarity between trading countries. Landlocked destinations are associated with higher trade costs and with a higher probability of export failure.

As in Besedeš and Prusa (2006b), a multiple spell dummy is used to account for the incidence of trading experience on the hazard rate. The variable takes the value 1 if the exporter-importer-product triplet experiences multiple spells and is zero otherwise. On the one hand, exporters are expected to learn from past failures and this should increase export duration. On the other hand, search costs are expected to be lower after multiple spells and the lower fixed export costs favor ins and outs.[6] A descriptive analysis of our sample indicates that more than 30% of Canadian exporting flows feature multiple spells.

Real exchange rate volatility was constructed from the IMF's International Financial Statistics data on monthly nominal exchange rate and the Consumer Price Index (CPI). We follow the recent work of Héricourt and Nedoncelle (2018) in constructing a bilateral Real Exchange Rate (RER) volatility index for each of our exporting countries. The real exchange rate is defined as :

$$RER_{i,m,t} = e_{j,m,t} * \frac{p_{j,t}}{p_{dom,t}}$$

where $e_{i,m,t}$ denotes the nominal exchange rate of the domestic currency with respect to destination j's currency at the end of month m of year t. $p_{j,t}$ represents the Consumer Price Index (CPI) of country j in year t while $p_{dom,t}$ is the CPI of the domestic country in year t. We then compute the bilateral RER volatility index as the yearly standard deviation of monthly log differences in the real exchange rate.

$$RER_{volatility} = \sigma_t = \sqrt{\frac{\sum_{m=1}^{12}[(logRER_{i,m+1,t} - logRER_{i,m,t}) - \mu]^2}{11}}$$

where μ stands for the mean. The effect of exchange rate volatility on exports is notoriously ambiguous (e.g., McKenzie (1999) and Bonroy et al. (2007)).

Animal disease outbreaks often trigger temporary trade bans and induce the adoption of stricter regulations and standards that increase production costs permanently. According to the World Organization

6. We also ran our models with the number of previous spells and obtained similar results.

for Animal Health (OIE) guidelines, it takes three months for a country experiencing avian influenza to regain its disease-free status after the last infected poultry has been destroyed and all premises have been disinfected. Avian Influenza was found to reduce trade (Paarlberg et al., 2007; Johnson et al., 2015). Several countries have had to deal with Bovine Spongiform Encephalopathy (BSE). Canada implemented the Enhanced Feed Ban (EFB) initiative in 2007 even though it was dealing with just a few BSE cases. This and other BSE-related initiatives contributed to Canada being labelled "controlled BSE risk" country by the World Organisation for Animal Health. Our measure takes into account the dynamic process of disease outbreaks, that is the recovery period of country affected by animal diseases. To account for the recovery period, we constructed BSE and avian flu the variables still take the value 1 year after the last infected animal has been destroyed. Before presenting results from parametric discrete-time duration regressions, we report on semi-parametric export duration comparisons between Canada, the United States, Australia and Brazil.

1.4.2 Semi-parametric approach to export duration

Export survival cannot be analyzed with a linear regression because the error term is not normally distributed (Cleves, 2008). The semi-parametric the Kaplan-Meier estimator is appealing because it makes no assumption about the distribution of failure time. We denote by T the time to a failure event and t_i the realizations of T. The survival function defined as the probability of a successful export episode that last until time t is given by :

$$S(t) = Pr(T > t) = 1 - F(t) = \sum_{t_i > t} p(t_i), \tag{1.16}$$

with $p(t_i) = Pr(T = t_i)$, where p stands for the probability density and $F()$ is the cumulative distribution function (CDF).
The density function $p(t)$ is the derivative of the CDF, that is :

$$p(t) = \frac{dF(t)}{dt} = \frac{d(1 - S(t))}{dt} = -S'(t) \tag{1.17}$$

Given that the export of a specific product in country i has survived up to time t, the conditional probability density that failure occurs at t is defined as the hazard function and is given by :

$$h(t) = Pr(T = t | T \geq t) = \frac{p(t)}{S(t)} = \frac{p(t)}{1 - F(t)} \tag{1.18}$$

The cumulative hazard function is given by :

$$H(t) = \int_0^t h(u)du \implies H(t) = \int_0^t \frac{p(u)}{S(u)} du \tag{1.19}$$

$$H(t) = \int_0^t \frac{-S'(u)}{S(u)} = -\log(S(t)) \tag{1.20}$$

If the hazard can be loosely defined as the risk of failure at t given that the firm has survived this long, then the cumulative hazard function $H(t)$ is the accumulation of risk that trade fails between 0 and t.

We estimate the probability that trade flows survive up to a certain time as well as the median and mean survival lengths of agricultural exports from Canada, USA, Australia and Brazil using the Kaplan and Meier (1958) estimator :

$$\hat{S(t)} = \prod_{t_(i) \leq t} \frac{n_i - d_i}{n_i} \tag{1.21}$$

where n_i stands for the number of exporter episodes that have survived up to time t and d_i represents the number of sectors that stop exporting after t.

Our dataset contains multiple spells. One important modelling issue is the occurence of dependence between spells. To handle this issue we replace the time subscript by a spell subscript as suggested by Cameron and Trivedi (2005). A statistical summary of our dataset reveals that 31 percent of trade relationships originating from Canada experienced multiple spells, compared to 37 percent for the US, 34 percent for Australia and 30 percent for Brazil. The larger probability of multiple spells for the US is expected because of the much greater number of trade flows emanating from the US.

Duration across countries

The mean spell length increases over spells. This implies that the risk of an export failure decreases with the number of spells and that trade relationships face a higher hazard in initial years as shown in Figure 1.4. These results are consistent with findings reported several other studies including Besedeš and Prusa (2006a). Figure 1.4 plots the survival functions for the four exporting countries. Results show that approximately 60% of trade flows survive after the first year when they originate from Canada, compared to 70% for the US exports, 68% for Australian exports and 66% for Brazilian exports. The probabilities of exporting a product for more than 9 years is 0.22 for Canada, 0.29 for the US, 0.31 for Australia and 0.25 for Brazil. This means that Canadian export flows are less resilient on export markets compared to the U.S, Australia and Brazil and "ins" and "out" are more frequent for Canadian exporters. Table 1.4 reports median and mean export durations. Median durations for Canada and Brazil are respectively 2 years and 3 years which fall short of the 4-year median the US and Australia. The means are larger than corresponding medians which reflects the large number of trade flows that last one or two years.

Duration across products

Product perishability is also likely to impact on survival probabilities. Perishable items have a short period during which they must be marketed. This limits the capacity of exporting firms to search for new destinations and negative demand shocks in marginal destinations are likely to trigger greater intensive margin adjustments as exporting firms will price their goods more aggressively in fallback markets. Table 1.5 shows that export flows for oilseeds and cocoa have longer mean and median duration than exports flows for fruit and vegetables for Canada and the US. For Brazil, cocoa and dairy products have the longest and shortest mean survival.

The elasticity of substitution also plays a key role in models featuring CES preferences like ours. Because we do not have estimates for the elasticity of substitution for all of the 6-digit products in our dataset, we use Rauch (1999)'s classification system to analyze the relationship between export duration and product differentiation. Rauch (1999) defines three categories : homogeneous, reference-priced and differentiated goods. Homogeneous products are sold on organized exchanges. Quality variations for such products tend to be small and are handled through simple quality grids. Homogeneous products from different countries are often blended to minimize handling costs. As such they are very close substitutes and are expected to have the highest elasticities of substitution. Reference-priced goods are not traded on organized exchanges, but their price is set based on a reference price. When purchasing reference-priced products, consumers will know the source country, but this attribute does not impact very much on the purchasing decision (Besedeš and Prusa, 2006b). Differentiated products are not sold on organized exchanges and they have distinctive characteristics that make them unique in the eyes of consumers. As such their elasticity of substitution will be lower than that for the other two categories. Rauch (1999) argues that homogeneous products have lower search costs because they are sold on organized markets. Food processors relying on differentiated products might have higher switching costs which would tend to make trade flows of differentiated products more resilient.

The results in Table 1.6 reveal that the median survival time is longer for differentiated products than for homogeneous and reference-priced goods originating from Canada, USA, Australia, Canada and Brazil. The median export survival time is 3 years for differentiated goods and 2 years for both homogeneous and reference-priced products exported from Canada. The pattern is the same for the US, except that export flows of differentiated have a median survival time of 5 years while the median export survival time is 4 years for homogeneous and referenced goods. Half of Australia's export flows of differentiated goods survives at most 4 years, compared to 3 years for homogenous and reference-priced goods. These results are in line the ones reported in other studies pertaining to duration of exports of agri-food products (e.g., Bojnec and Fertő (2012)) .

1.4.3 Discrete-time multivariate analysis

The discrete-time hazard model requires some reorganization of our dataset as directed by Jenkins (1995). For each exporting country, we index each pair product-destination in our sample by variety $i = 1, I$ where $I = 41,360$. We observe each variety over ten years, from 2005-2014. Some of the trade flows (product-destination pair) are observed without any interruption until the end of the sample. These flows are referred to as (right) censored. Following common practice, left-censored observations are excluded to avoid a bias in the estimated hazard rate. The distribution of duration is modelled via the probabilities of ending a flow at each period t. More specifically we define the hazard rate as :

$$h_{ijk,t} := P(T_i < t+1 | T_i \geq t, X_{ijk}, Z_{ijk,t}) = F(\beta' X_{ik,t-1} + Z_{ijk,t}\gamma_t + \nu_t) \tag{1.22}$$

where $h_i jk,t$ is the probability that a particular trade relation terminates at a given time t. Our data are censored since some flows do not experience a failure event within their last spell. v_t is a function of time that allows the hazard rate to vary across periods (Hess and Persson, 2012). F(.) is a cumulative distribution function ensuring that $h_{ijk,t} \in [0,1]$. Given that, the contribution of the censored subjects to the sample likelihood equals the probability that the failure event occurs after 2014 (Willett and Singer, 1995) :

$$L_i(censored) = P[T > t] = S(t) \tag{1.23}$$

where $S(.)$ is the survivor function. For uncensored observations, their contribution to the likelihood is

$$L_i(uncensored) = Pr[T = t] = p(t) \tag{1.24}$$

The dichotomous censoring indicator can be defined as :

$$c_i = \begin{cases} 0 \text{ if censored or if trade flow is positive} \\ 1 \text{ if uncensored or trade flow is zero} \end{cases} \tag{1.25}$$

The contribution to the likelihood of both censored and uncensored is given by :

$$L_i = [p(t|X_{ik,t-1}, Z_{ijk,t}, \beta, \gamma)^{c_i} S(t|X_{ik,t-1}, Z_{ijk,t}, \beta)^{1-c_i}] \tag{1.26}$$

Then the log likelihood for the observed data is written as :

$$lnL = \sum_{i=1}^{N} [c_i \ln \text{ p}(t|X_{ik,t-1, Z_{ijk,t}}, \beta, \gamma) + (1-c_i) \ln \text{ S}(t|X_{ik,t-1}, Z_{ijk,t}, \beta, \gamma)] \tag{1.27}$$

This equation implies :

$$lnL = [\sum_{i=1}^{N} c_i \ln \frac{p(t)}{S(t)} + \ln S(t)] \tag{1.28}$$

Since the hazard ratio is $h(t) = \frac{p(t)}{S(t)}$ and the cumulative hazard ratio is equal to $H(t) = -\ln S(t)$, then the log likelihood can be defined in terms of the hazard rate and the integrated hazard functions which we assume independence over i :

$$lnL = [\sum_{i=1}^{N} c_i \ln h(t|X_{ik,t-1}, Z_{ijk,t}, \beta, \gamma) - H(t|X_{ik,t-1}, Z_{ijk,t}, \beta, \gamma)] \tag{1.29}$$

We tested three estimators for the hazard rate model : the complementary log-log (cloglog) model, the logit model and the probit model. Unlike the Cox proportional specification, these estimators have the advantage of taking into account multiple spells and unobserved heterogeneity (Hess and Persson, 2012). As in Hess and Persson (2011) we control for unobserved heterogeneity by using a random effects specification. The probit estimator defines the probability of an export failure through the standard normal distribution cumulative function denoted by Φ below :

$$Pr(h_{ijk,t}=1)=\Phi[\beta' X_{ik,t-1}+Z_{ijk,t}\gamma+\delta_t+\delta_j+\delta_k] \tag{1.30}$$

where X_{ikt} is a vector of covariates. The logit estimator relies instead on the cumulative of the logistic distribution :

$$Pr(h_{ijk,t}=1)=\frac{\exp(\beta' X_{ik,t-1}+Z_{ijk,t}\gamma)}{1+\exp(\beta' X_{ikt}+Z_{ijk,t}\gamma+\delta_t+\delta_j+\delta_k)} \tag{1.31}$$

The cloglog estimator models the probability of an export failure through :

$$Pr(h_{ijk,t}=1)=1-\exp[-\exp(\beta' X_{ikt}+\delta_t+\delta_j+\delta_k)] \tag{1.32}$$

where $h_{ijk,t}$ is a binary dependent variable which is equal to 1 if product k from country i fails to be exported to country j at time t and 0 otherwise.

The model specification for each estimator included the full set of covariates. The log likelihood values are quite similar across estimators for the four exporting countries in Tables 1.7 where only part of the results are reported. Still, the logit and cloglog perform slightly better than the probit. The tariff coefficients are inconsistent with our prior that tariff ought to increase the likelihood of exit. The negative tariff coefficients for Australia, Brazil and the US suggest that higher tariffs decrease the probability of an export failure. For Canada, higher tariffs increase the probability of an export failure, but the coefficients are not statistically significant. The signs of the tariff coefficients are robust across estimators. The wrong sign for tariff coefficients is not unusual in export duration studies. Besedeš and Prusa (2006b) and Hess and Persson (2012) try to rationalize it by arguing that higher tariffs reduce competition for incumbent firms, but reduced competition implies that some exporting firms have exited.

An alternative explanation for these wrong signs is tariff endogeneity. 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. Some countries have a large wedge between their applied and bound tariffs and can increase their tariffs without reneging on their WTO commitments. Countries with low bound tariffs typically resort to anti-dumping, countervailing or other safeguard measures to respond to rent-seeking lobbies. As pointed out by Trefler (1993), the theory of endogenous protection predicts that higher levels of import penetration will lead to greater protection. Accordingly, tariff endogeneity ought to be expected in export duration regressions. This is addressed in the next subsection.

Testing and correcting for tariff endogeneity

We apply the Two-Stage Residual Inclusion (2SRI) procedure developed by Terza et al. (2008) to test and correct for the presence of an endogenous regressor. The 2SRI estimator is consistent and easy to implement. In the first step, we regress the applied tariff on the observable factors impacting duration augmented by identifying instrumental variables and we store the residuals. In the second stage, the first stage residuals are included as an additional regressor in duration regressions which also include the tariff. The presence of the residuals as a regressor corrects the tariff coefficient and testing the significance of the residuals as a regressor constitute a test of endogeneity. Consider the following equation :

$$Pr(h_{ijk,t} = 1) = F[X_{ik,t-1}, Z'_{ijk,t}, t_{ijk,t}; \beta] \tag{1.33}$$

where vector $Z_{ik,t} = [Z'_{ik,t-1}, t_{ijk,t}]$, with $t_{ijk,t}$ a column vector of applied tariffs. This regressor is the one that is potentially endogenous. The above survival equation is our outcome regression. In the first stage, we implement the following auxiliary regression :

$$t_{ijk,t} = \alpha_T T_{jk,t} + \alpha_{TI} TI_{j,t} + \alpha_X X_{ik,t-1} + Z'_{ijk,t}\alpha_Z + x_{u,t} \tag{1.34}$$

where $x_{u,t}$ is a set of unobservable confounder latent variables (omitted variables) that influence the outcome of $h_{ijk,t}$ while being correlated to tariffs, but uncorrelated with the instruments.

We posit that a linear relation exists between applied tariffs and our instruments. We use the bound tariff $T_{jk,t}$ of country j 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 assumed that countries with high bound tariffs tend to have higher applied tariffs. [7] Countries that have high bound tariffs have more flexibility to make tariff adjustments in response to industry pressure and we also posit that countries with weaker institutions and plagued with corruption are more likely to maintain high tariffs. We use the transparency index, $TI_{j,t}$ of country j at year t as a second instrument to explain applied tariffs. The transparency index was downloaded from the website of Transparency International. [8] Let the residuals from the tariff first-stage regression be defined by $\hat{x}_{ut}$.

In the second stage, we re-estimate our duration regression, keeping the endogenous regressor, $t_{ijk,t}$ along with the other regressors, and including $\hat{x}_{ut}$ as an additional regressor. The estimated model can be depicted as :

$$Pr(h_{ijk,t} = 1) = F[X_{ik,t-1}, Z'_{ijk,t}, t_{kj,t}, \hat{x}_{u,t}; \beta] \tag{1.35}$$

where $t_{ijk,t}$ denotes applied tariffs levied by country j on product k at year t, and ε^{2sri} is the regression error term.

The 2SRI approach makes it easy to test for endogeneity because one need only check whether the estimated residual in the second-stage regression has a statistically significant effect. The likelihood

7. Buono and Lalanne (2012) correct for the spurious sign of tariffs on the extensive and the intensive margins of trade by using pre-Uruguay tariffs as instruments. This instrument did not work as well with agricutural tariffs as the bound tariffs.

8. The first-stage regression results are in appendix 2.

ratio test can be used for this purpose. Let $L(\beta)$ denotes the likelihood function with β representing the vector of parameters. Let $\hat{\beta}_u$ be the unrestricted estimates obtained by the 2SRI method and $\hat{\beta}_r$ be the restricted estimates obtained without including the residuals from the first stage. The likelihood ratio test is simply : $LR = 2[lnL(\hat{\beta}_u) - lnL(\hat{\beta}_r)] \sim \chi^2$. The null hypothesis of exogenous tariffs is rejected in all cases with corresponding p-values=0.000 below the usual 5%. Second-stage standard errors are corrected to account for first-stage errors following Terza et al. (2016).

1.5 Results and policy implications

The results for the endogeneity-corrected duration models are reported in Tables 1.9-1.13. t-statistics in the last column are corrected for the first-stage errors in the second-stage correction using the analytical approach developed by Terza et al. (2016). Consistent with our priors, we find that higher tariffs and vanished trade flows at T-1 respectively increase and decrease the probability of export failures. This is true for all exporting countries. Foregone trade flows have a particularly large decreasing effect on the probability of export failure for agri-food products originating from Brazil and Australia. Comparing the tariff coefficients across exporters, we find that Canada's export flows are much more susceptible to tariff hikes than export flows for the US, Australia and Brazil. Table 9 shows that Canada's export flows have a higher probability of being terminated for distant destination.

Our model specification has both tariffs and RTAs as explanatory variables. Once the tariff reductions of RTAs is removed, RTAs can influence export duration through reductions of non-tariff barriers and by simplifying the paperwork associated with exports and imports. While less restrictive non-tariff barriers is expected to increase export survival, lower fixed export costs make ins-and-out easier. Destinations for which Canada has a RTA, all else equal including tariffs, have a lower probability of experiencing an interruption. From Tables 1.9 and 1.10, one can see that the reducing effect of RTAs on export failure is larger for US agri-food exports than for Canadian exports. This suggests that US RTAs have potent non-tariff provisions, which is reflective of asymmetries in bargaining power amongst countries negotiating RTAs. In contrast, the RTA coefficient in Table 1.11 is positive, indicating that Australian firms find it easier to do "ins and outs" in countries participating in RTAs with Australia. The RTA coefficient for Brazil is not statistically significant, the incidence of RTAs being channelled only through tariff reductions.

Canadian exports to the US are particularly resilient, as suggested by the contiguity coefficient in Table 1.9. A glance at Table 1.10 reveals that US exports to Canada and Mexico are even more resilient. However, the contiguity coefficient for Brazil in Table 1.12 is about one-third of the ones for Canada and the US. These contiguity coefficients are consistent with large fallback markets and convex costs. Sharing a language increases export duration, particularly for Brazil, but not much for Australia. All else equal, exports to landlocked destinations have a higher probability of being terminated, especially for exports originating from Canada or the US. As expected, religious openness has a small negative impact on export failure, regardless of where exports originate. The theoretical effect of exchange rate volatility on exports is ambiguous (Bonroy et al., 2007) and our results reflects this with no significant effect for Canada and Brazil, an increasing (decreasing) effect on the probability of termination of US (Australian) export flows. As per our priors, animal diseases weakly increase the likelihood of an export termination. Confirming results from previous studies, firms seems to learn from past failures, whether it is from their own or that of national rivals, because the incidence of past spells is strong across exporting countries.

The importing countries' market size is a major determinant of trade. In models with consumers with homothetic preferences, increases in GDP due to increases in GDP per capita or due to population increases have the same effect. We allowed for different effects in our empirical export duration model. The sign of coefficients for GDP per capita and population is negative as expected and the magnitude of the coefficients is very close for Canada, the US and Brazil. For Australia, an increase in GDP per capita is twice as potent as a similar increase (in %) in population. Market size increases export survival most for US exports.

Figure 1.5 displays estimated survival probabilities showing the advantages for Canadian exporters to have trade partners with similar religions and languages. The probability plots exhibit a fair degree of non-linearity which cannot be conveyed by tables of coefficients.[9] The left panel of Figure 1.6 shows the survival probabilities of Canadian exports when subjected to a 25% tariff versus no tariff. The increase in the survival probability is essentially constant as years pass. This is not so in the right panel of Figure 1.6 which is about the effect of distance on export duration. The probability of surviving decreases more rapidly over time for export flows between distant trade partners.

Haaland and Venables (2016) show that the elasticity of substitution in monopolistic trade models with CES preferences has different trade policy implications depending on whether firms are symmetric or heterogenous and whether the labour supply is elastic or inelastic. Convex costs tend to soften the intensive margin effect of a tariff increase while the elasticity of substitution has the opposite effect. It follows that the effect of a tariff on the survival of export flows of goods with a higher elasticity of substitution may be the same as that for goods with a low elasticity of substitution if the latter are produced with technologies displaying less cost convexity. Therefore, it is pertinent to compare the incidence of various trade costs on export survival for flows of differentiated and homogenous products. Table 1.13 reports results for Canada's export flows of homogeneous and differentiated agricultural products. The effects of a tariff on the probability of export failure for homogenous goods and differentiated products are positive, significant and essentially the same. In contrast, the effect of GDP per capita is larger for differentiated products. The number of exits at T-1 has a significant negative effect on the probability of export failure for both differentiated and homogenous products. Finally, we ascertain the robustness of the results presented in Tables 1.9-1.13 by replacing the aggregate values of trade flows terminated at T-1 by the number of trade flows terminated at T-1. The results are

9. As in Hess and Persson (2011) we calculate the survival functions using different values for the covariate under scrutiny and mean values for all remaining covariates.

available upon request . Using a different variable to account for recent exits does not alter the results very much. For example, the coefficient for applied tariff about the export failure of Canadian export flows changes from 0.00275 to 0.00274.

1.6 Conclusion

We developed a theoretical model to analyse the effects of trade costs and other gravity model variables on the extensive and intensive margins of trade when firms face convex production costs. The introduction of convex costs modifies the standard sales equation of a firm selling to a specific destination through an index that aggregates the size and trade costs of all markets supplied by the firm. Thus, other markets have a direct influence on the firm's behaviour that goes beyond the indirect effect through multilateral inward and outward resistance indices. The interconnection of markets through costs has non-trivial implications for the relationship between productivity, export survival and the number of destinations. More productive firms or countries may sell to fewer, but larger destinations, than less productive ones. Thus, an increase in productivity may prompt a firm to abandon one or more profitable markets to enter one or more larger markets with high fixed costs. This behaviour is inconsistent with technologies exhibiting constant returns to scale (*CRS*). Under *CRS*, increases in productivity weakly increase the number of destinations. The proximity of large export markets makes "ins and outs" in smaller markets more likely.

Convex costs are particularly important in agriculture as supply is typically very inelastic in the short run and contracts between producers and processors make supply rather insensitive to shocks in export markets. Accordingly, our empirical application focusses on agri-food exports from Canada, the United States, Australia and Brazil.

Our findings confirm theoretical predictions about the ties between exits and entries. Exits, proxied by the aggregate value of export flows terminated at T-1, have a strong negative impact on the probability of export failure. This is true for all exporting countries and over samples with more or less differentiated products.

As in Besedes and Prusa (2006), applied tariffs seem to decrease the likelihood of an export failure when treated as exogenous. Once corrected for endogeneity with Terza et al. (2008)'s two-stage residual inclusion procedure, the duration models show that tariffs adversely affect the survival of agri-food export flows. Discriminating tariff reductions are an important component of regional trade agreements (RTAs), but RTAs have non-tariff provisions that can influence export survival. Non-tariff barriers are notorious for their reducing effect on agri-food trade and to the extent that RTAs encourage some regulatory harmonization, then one would expect RTAs to increase export survival. Another channel through which RTAs may influence export survival is by reducing the bureaucratic load on firms engaged in exporting and importing. RTA-induced reductions in fixed costs favour ins and outs and hence increase the likelihood of export failure. Therefore, once the tariff reduction effect of RTAs is removed, the incidence of RTA on export failure is ambiguous. RTAs significantly reduce the risk of an export failure for Canadian and US exports. This is consistent with the findings of Ghazalian et al. (2011) who argue that NAFTA's non-tariff provisions were most important in promoting regional trade in meats. As per our priors, GDP per capita, the population of the destination country and contiguity lower the probability that a flow will be terminated. Similarly, multiple spells exert a negative effect on the hazard of exit. This is typically interpreted as evidence that firms learn from export failures or that fixed export costs, including search costs, get smaller each time a firm re-integrate a market.

In terms of policy implications, governments must not automatically equate reliance on a few export markets and frequent "ins and outs" as the symptoms of a productivity problem. In Vannoorenberghe (2012)'s 2-country model, the domestic market is a buffer against trade shocks. Because of the relative importance of exports in the marketing of many agricultural products, trade shocks in some exports markets are likely to be buffered through adjustments in other export markets, especially in large export markets that are close by. Foregone exports from terminated flows increase exports to fallback markets. Empirical evidence confirms a strong fallback market effect between Canada and the US. For Australia and Brazil, the fallback market is China. Strong fallback market effets make for average shorter export duration and fewer trade partners, all else, including productivity, constant. The presence of a fallback market makes it easier to deal with production rigidities and may facilitate risk management along supply chains to the extent that risk-sharing arrangements and government intervention through insurance programs make domestic production more rigid. Governments should pursue trade liberalization widely through RTAs and the WTO to boost export survival in as many destinations as possible and to insure that their firms have a secured access to their fallback markets. This is particularly important for small trade-dependant countries and one can understand the urgency that Canada and Mexico felt during the negotiations of the US-Mexico-Canada trade agreement. The same applies to African countries seeking a preferential access to the EU market and to neighbours of China and Japan.

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Figures

FIGURE 1.1 – Cost linkages and ins and outs

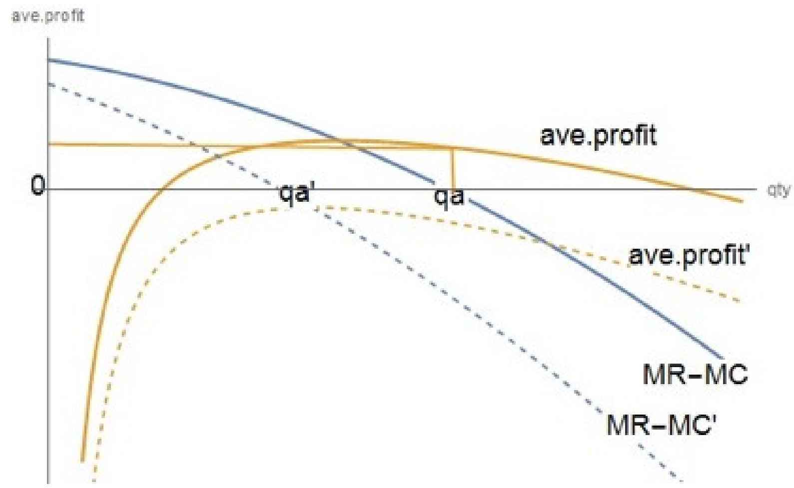


FIGURE 1.2 – Change in the productivity and ins and outs

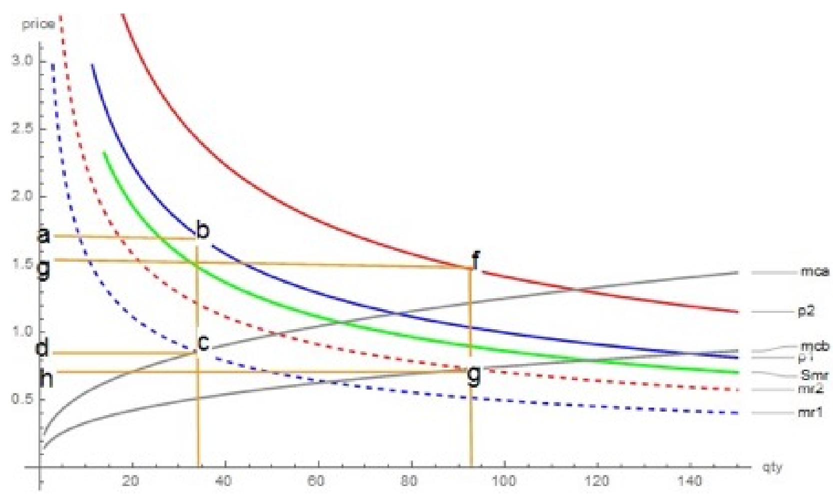


FIGURE 1.3 – Terminated and new US export flows

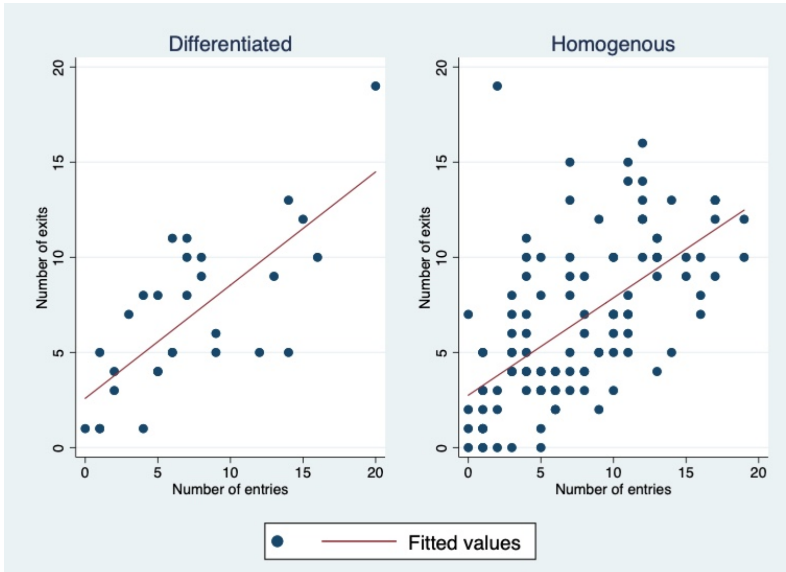


FIGURE 1.4 – Kaplan-Meier estimates for spells of different lengths

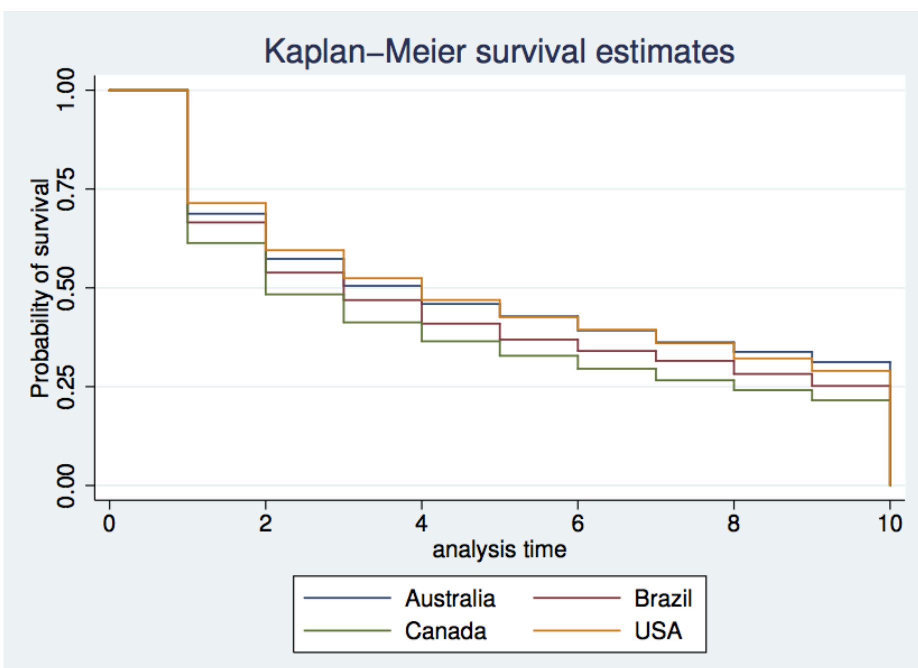


FIGURE 1.5 – The effects of religion and language on Canada's export survival probabilities

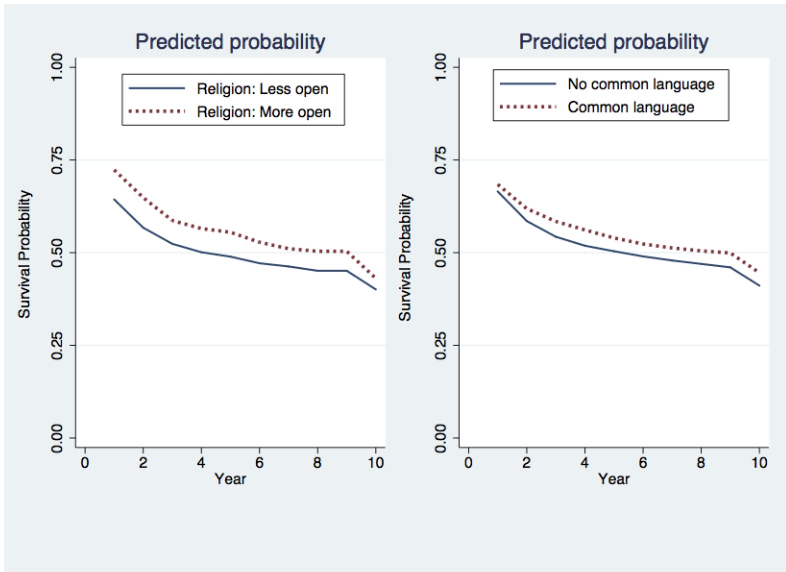


FIGURE 1.6 – The effectss of tariffs and distance on Canada's export survival probabilities

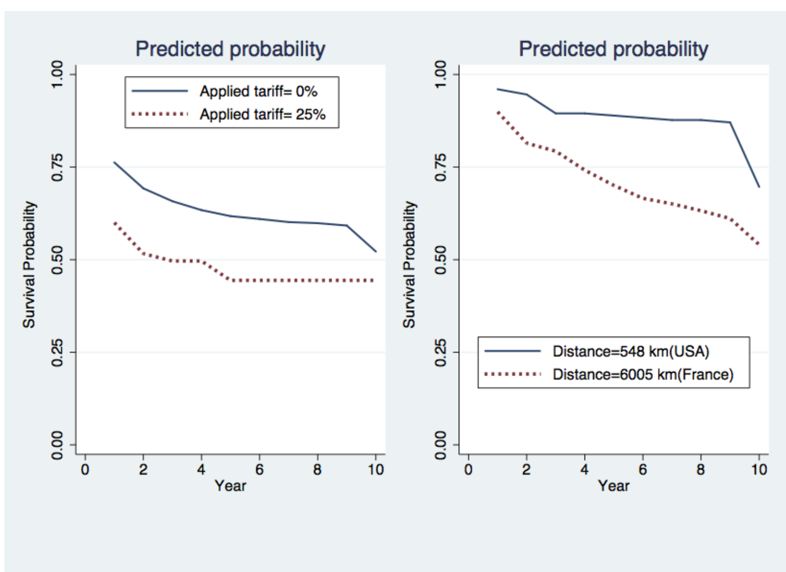


FIGURE 1.7 – Duration across product-types

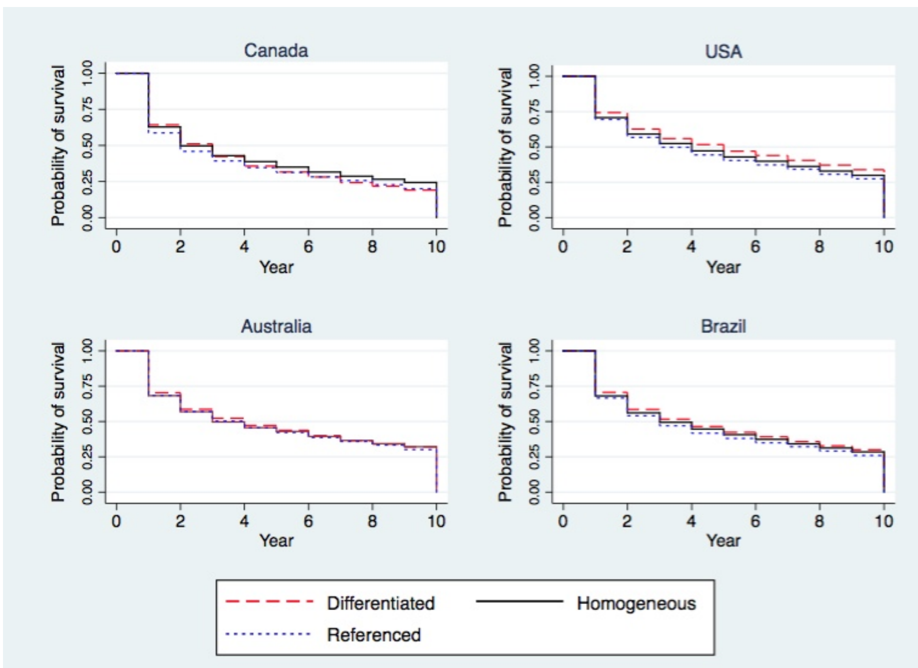


TABLE 1.1 – Average number of destinations by exporting countries and matched-pair difference test relative to US

	USA	Canada	Australia	Brazil
All products	19.825	7.280	10.471	8.949
P-Value		(0.0000)	(0.0000)	(0.0000)
Meats	20.403	9.398	16.123	12.142
P-Value		(0.0000)	(0.0000)	(0.0000)
Dairy	25.423	5.017	20.717	6.817
P-Value		(0.0000)	(0.0000)	(0.0000)
Fruits and Veg	18.758	2.627	9.813	10.365517
P-Value		(0.0000)	(0.0000)	(0.0000)
Cereals	30.464	14.241	7.647	10.035
P-Value		(0.0000)	(0.0000)	(0.0000)
Oilseeds	20.595	8.688	8.14	5.96
P-Value		(0.0000)	(0.0000)	(0.0000)
Cocoa	32.955	11.827	13.018	26.218
P-Value		(0.0000)	(0.0000)	(0.0000)

TABLE 1.2 – The effect of lost exports from vanishing trade flows on the size of new trade flows

	Canada	Australia	Brazil	U.S
Exit flows at T-1	0.791***	0.169	0.121**	-0.180***
	(36.19)	(1.42)	(2.72)	(-6.54)
Product fixed effects	YES	YES	YES	YES
Time Fixed effects	YES	YES	YES	YES

t statistics in parentheses

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

TABLE 1.3 – Losts exports from terminated trade flows and exports to fallback markets

	Canada US	US Mexico	Australia China	Brazil China
Exit flows at T-1	0.712***	0.541**	1.057**	0.762
	(9.48)	(2.38)	(3.22)	(0.08)
Product fixed effects	YES	YES	YES	YES
Time Fixed effects	YES	YES	YES	YES

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE 1.4 – Mean and median survival time of exports with multiple spells

Exporter	No of trade flows	Median	Mean
Canada	8480	2 *	4.2
Brazil	7784	3*	4.6
Australia	9348	4 *	5
USA	20272	4 *	5.1

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE 1.5 – Mean and (median) survival time by group of products

Category	Canada	USA	Australia	Brazil
Oilseeds	4.7 (3)	5.3 (4)	4.6 (3)	4.4 (3)
Cocoa	4.1 (3)	5.7 (6)	4.7 (3)	5.3 (4)
Dairy	3.5 (2)	5.2 (5)	5.8 (6)	3.7 (2)
Fruits and Veg	3.1 (2)	5.3 (4)	5.1 (4)	4.8 (3)
Meats	4.2 (2)	4.7 (3)	5.2 (4)	4.9 (3)
Cereals	4.3 (2)	5 (4)	4.5 (3)	4.1 (3)

TABLE 1.6 – Mean and (Median) survival time across product-types

Category	Canada	USA	Australia	Brazil
Homogeneous	4.3 (2) yrs	5.1 (4) yrs	5.0 (3) yrs	4.9 (3) yrs
Referenced	4.0 (2) yrs	4.9 (4) yrs	5. 0 (4) yrs	4.7 (3) yrs
Differentiated	4.2 (3) yrs	5.5 (5) yrs	5.2 (4) yrs	5.0 (4) yrs

TABLE 1.7 – Partial results about the decomposition of the probability of failure with exogenous tariffs

		Probit	Cloglog	Logit
Canada	Applied tariffs	0.00102	0.000805	0.00182
	(1.85)	(1.64)	(1.72)	
	Log Likelihood	-31210.184	-31209.043	-31189.349
US	Applied tariffs	-0.000851*	-0.000608	-0.00174*
	(-2.16)	(-1.40)	(-2.45)	
	Log Likelihood	-65892.865	-65752.94	-65797.823
Australia	Applied tariffs	-0.00235***	-0.00204***	-0.00464***
	(-4.66)	(-4.01)	(-4.98)	
	Log Likelihood	-32264.886	-32207.755	-32254.034
Brazil	Applied tariffs	-0.00105*	-0.000771	-0.00214*
	(-1.96)	(-1.57)	(-2.14)	
	Log Likelihood	-31364.27	-31361.673	-31378.528

t statistics in parentheses

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

TABLE 1.8 – First-stage regressions about tariffs in the 2SRI approach

	Canada	U.S	Australia	Brazil
Bound tariffs	0.0822***	0.115***	0.13***	0.128***
	(4.96)	(3.73)	(4.25)	(3.96)
Transparency index	0.0372***	0.0289***	0.0594***	0.0529***
	(4.17)	(3.85)	(7.88)	(7.02)
Num. of exits	-0.0628***	-0.0340***	-0.0186*	-0.0767***
	(-5.16)	(-5.74)	(-2.01)	(-7.59)
Distance	-4.539***	-3.624***	3.881***	4.522***
	(-10.48)	(-7.15)	(5.36)	(6.14)
Contiguity	-23.73***	-4.549*		0.319
	(-13.38)	(-2.29)		(0.46)
Common off. language	0.130	-3.918***	-5.36***	-2.032***
	(0.28)	(-3.90)	(-5.41)	(-3.69)
Landlocked	-1.807***	-2.37***	-4.039***	-3.60***
	(-4.92)	(-5.31)	(-9.41)	(-8.72)
Religious openness	-0.0791***	0.00405	-0.0277	-0.488***
	(-3.37)	(0.11)	(-0.81)	(-5.59)
Exchange rate volatility	3.549***	3.736***	2..862***	4.323***
	(6.66)	(6.67)	(5.31)	(7.68)
BSE disease	1.189***	1.488***		-1.94***
	(6.69)	(10.29)		(-8.05)
Avian	2.148***	1.844 ***		2.455***
	(4.68)	(3.44)		(4.11)
GDP per capita	-0.492***	-0.513**	-1.169***	-0.874***
	(-3.89)	(-3.17)	(-7.00)	(-5.20)
Population	0.953***	0.627***	0.373***	0.584***
	(13.36)	(6.64)	(4.69)	(7.64)
Multiple spells	1.132	0.611	4.024***	0.802
	(1.19)	(1.27)	(3.84)	(1.12)

t statistics in parentheses

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

TABLE 1.9 – Decomposition of the probability of export exit :Canada

Variable	Estimate	Uncorrected t-statistic	Corrected Corrected t-statistic	Estimates with FE
Volume of exits at t-1	-0.040***	-12.49	-12.48	-0.039***
Applied tariffs	0.00275***	4.051	3.95	0.00166***
Distance	0.6512***	13.79	13.78	
RTA	-0.0345*	-0.680	-0.679	
Contiguity	-0..985***	- 4.724	-4.722	
Common off. language	-0.5073***	-13.33	-13.31	
Landlocked	0.8246***	12.033	12.030	
Religious openness	-0.0126***	-3.69	-3.68	
Exchange rate volatility	0.0585	0.1508	0.1505	
BSE disease	0.00270	0.0947	0.0947	0.0710**
Avian flu	0.412 ***	7.31	7.30	0.504***
GDP per capita	-0.2469***	-19.19	-19.16	
Population	-0.2308***	-20.97	-20.95	
Multiple spells	-2.8618***	-52.69	52.68	-0.872***
1st-stage residuals	-0.003867***	-3.40	-3.36	
Constant	3.731***	8.42	8.40	
Random Effect Yes	Yes	Yes		
Importer-Time FE				Yes
Product FE				Yes

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

TABLE 1.10 – Decomposition of the probability of export exit : USA

Variable	Estimate	Uncorrected t-statistic	Corrected Corrected t-statistic	Estimates with FE
Volume of exits	-0.0075***	-3.015	-3.013	-0.0299***
Applied tariffs	0.0012***	2.10	2.085	0.00116***
Distance	0.998***	27.75	27.75	
RTA	-0.4418***	-14.222	-14.218	
Contiguity	-1.11***	-7.94	-7.93	
Common off. language	-0.563***	-15.10	-15.09	
Landlocked	1.206***	22.90	22.80	
Religious openness	-0.022***	-6.30	-6.30	
Exchange rate volatility	1.094**	3.022	3.020	
BSE disease	0.1758 ***	7.705	7.705	0.112***
Avian flu	0.6972***	14.29	14.29	1.043***
GDP per capita	-0.30***	-28.48	-28.46	
Population	-0.358***	-34.79	-34.77	
Multiple spells	-1.771***	-44.99	-44.97	-0.37***
1st-stage residuals	-0.00188**	-2.21	-1.877	
Constant	1.746***	5.032	5.031	1.890***
Random Effect Yes	Yes	Yes		
Importer-Time FE				Yes
Product FE				Yes

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

TABLE 1.11 – Decomposition of the probability of export failure : Australia

Variable	Estimate	Uncorrected t-statistic	Corrected Corrected t-statistic	Estimates with FE
Volume of exits at t-1	-0.142***	-24.76	-24.70	-0.111***
Applied tariffs	0.00067*	2.366	2.159	0.00125***
Distance	0.963 ***	27.135	26.873	
RTA	0.151***	3.71	3.69	
Common off. language	-0.0631***	-2.126	-2.11	
Landlocked	0.464***	8.706	8.69	
Religious openness	-0.0184***	-8.172	-8.13	
Exchange rate volatility	-2.05**	-12.81	-12.80	
GDP per capita	-0.142***	-17.99	-17.81	
Population	-0.1285***	-19.047	-22.16	
Multiple spells	-2.528***	-86.306	-85.21	-1.747***
1st-stage residuals	-0.00615***	-6.34	-6.32	
Constant	-2.302***	-2.11	-2.10	
Random Effect Yes	Yes	Yes		
Importer-Time FE				Yes
Product FE				Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

TABLE 1.12 – Decomposition of the probability of export failure : Brazil

Variable	Estimate	Uncorrected t-statistic	Corrected Corrected t-statistic	Estimates with FE
Volume of exits	-0.160***	-51.49	-51.43	- 0.099***
Applied tariffs	0.00132*	1.973	1.92	0.00201***
Distance	1.040***	21.16	21.01	
RTA	0.0136	0.112	0.112	
Contiguity	-0.343***	-3.86	-3.83	
Common off. language	-1.065***	-15.428	-15.40	
Landlocked	0.336***	5.94	5.92	
Religious openness	-0.0368***	-4.80	-4.79	
BSE disease	1.026***	22.77	22.70	0.157***
Avian flu	-0.0584	-1.686	-1.667	1.431***
Exchange rate volatility	-1.217***	-4.07	-4.06	
GDP per capita	-0.302***	-23.92	-23.89	
Population	-0.243***	-21.60	-21.59	
Multiple spells	-2.244***	-44.37	-44.22	-0.854***
1st-stage residuals	-0.00533***	-4.32	-4.29	
Constant	1.004**	2.37	2.35	5.364
Random Effect Yes	Yes	Yes		
Importer-Time FE				Yes
Product FE				Yes

* $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$

TABLE 1.13 – Decomposition of the probability of a Canadian export failure across product-types

Variable	Homogenous	Differentiated
Volume of exits at t-1	-0.0359*** (-10.37)	-0.0511***(-7.49)
Applied tariffs	0.00205** (2.97)	0.00203*(2.78)
Distance	0.717*** (14.27)	0.480***(5.92)
RTA	0.0341(0.59)	0.0236 (0.24)
Contiguity	-0.408 (-1.94)	-0.366 (-0.98)
Common off. language	-0.430*** (-10.60)	-0.476***(-6.51)
Landlocked	0.891***(11.72)	0.610***(5.31)
Religion openness	-0.0114** (-3.21)	-0.0244***(-3.88)
Exchange rate volatility	-0.445 (-1.15)	-0.891 (-1.55)
GDP per capita	-0.125*** (-9.34)	-0.293***(-12.94)
Population	-0.172***(-14.77)	-0.201***(-10.42)
Multiple spells (dummy)	-2.510***(-44.40)	-1.906***(-21.78)
1st-stage residuals	-0.00815***(-6.57)	-0.0129***(-3.80)

t statistics in parentheses

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

Chapitre 2

Animal Disease Outbreak and Border Closure

2.1 Résumé

Le commerce international des animaux vivants et des produits d'origine animal est très souvent entravé par les épidémies animales qui se propagent très vite entre pays. Nous nous appuyons sur un cadre empirique fondé sur le modèle de sélection multivariés pour examiner l'impact des maladies spécifiques aux animaux sur les marges extensives et intensives des flux commerciaux dans le temps. Les résultats montrent que la fièvre aphteuse ont un impact négatif sur les marges extensives et intensives du commerce des bovins et du bœuf et ce, pendant approximativement sept années. Contrairement au cas des accords d'intégration économique (EIE) étudié par Baier et al. (2014), nos résultats suggèrent que les effets des maladies animales sur la marge extensive sont plus grands que leur effets correspondants sur la marge intensive. En ce qui concerne les effets inter-espèces, la grippe aviaire et la peste porcine réduisent la probabilité et le niveau des échanges de bovins et de bœufs.

2.2 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) 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. Regarding cross-species effects, the avian flu and swine fever reduce the probability and the level of trade in cattle and beef.

2.3 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. As an illustration, 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).

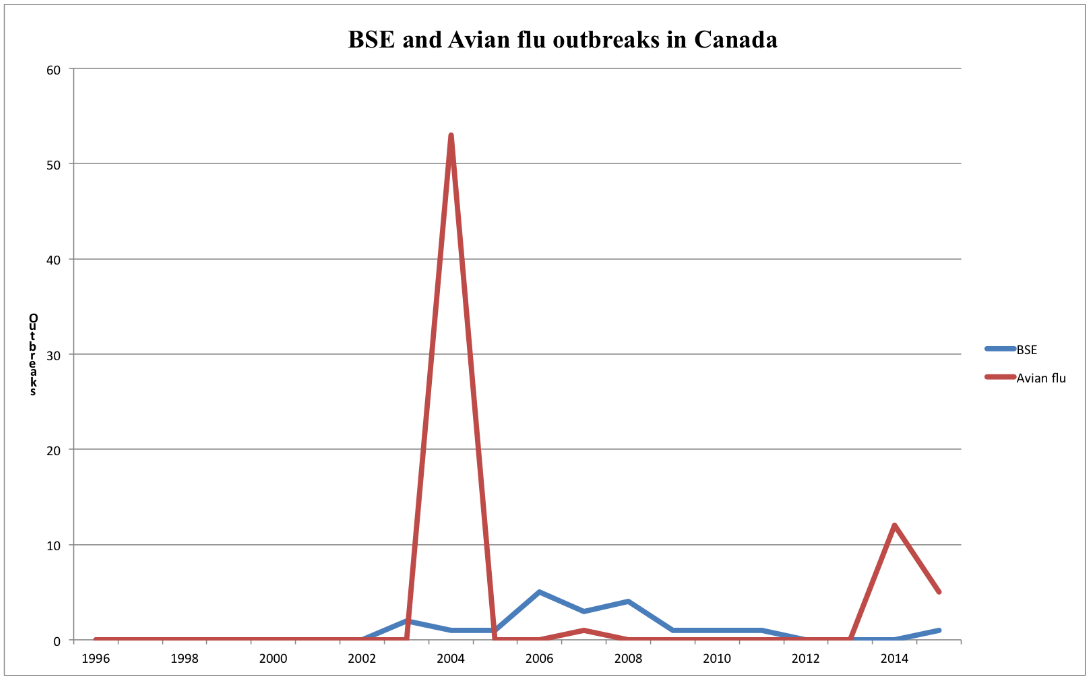
The rest of this paper is organized as follows. The next section is about disease outbreak management, with an emphasis on Canada's protocols. This is followed by a methodology section in which the model is presented along with data sources. The last section summarizes our results and dwells on their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

2.4 The disease outbreak management in the livestock market in Canada

Canada has an export-oriented livestock industry as it exports nearly 70 percent of its hogs and pork products and nearly 50 percent of its cattle and beef products. However the livestock sector is prone to numerous risks such as animal disease outbreaks that can have adverse impacts not only on the premises where disease is discovered but also on the entire value chain. Figure 2.1 illustrates the evolution of FMD and BSE occurrences over time. It is evident that despite significant efforts to eradicate for good these diseases the reoccurrence do happen.

The control and the eradication of a disease outbreak largely depends on the country and the disease itself. BSE has been eradicated in mostly developed countries. BSE or mad cow disease is a neuro-degenerative disease caused by a misfolded protein. The infectious agent is most highly concentrated in the nervous tissue, but it can also be found in virtually all tissues throughout the body, including blood. It has an extremely long incubation period and therefore the symptoms are not seen immediately. The disease can be easily transmitted to humans who have eaten infected flesh. FMD is more difficult to control because it spreads by aerosol. FMD is fatal viral disease that affects cloven-hoofed

FIGURE 2.1 – BSE and Avian flu outbreaks in Canada



animals. The disease causes high temperature and sores inside the mouth, and an excessive production of frothy saliva. Adult animal loose weight and we observe an important decrease of milk production. Susceptible animals include cattle, water buffalo, sheep, goats, pigs. FMD is not transmitted to humans but it quickly spread between animals. Swine fewer is transmissible by feeding. The swine fever is endemic in part of Asia, South and Central America and on some Caribbean Islands. The disease has been eradicated from a number of countries, including the U.S, Canada and New Zealand. Animals can acquire avian influenza through direct contact with other infected animals or contaminated environments. While avian influenza is a zoonotic disease, as it can be transmitted from animals to humans, there is no evidence that swine fever is zoonotic. The foot and mouth disease affects both cattle, swine, sheep and goats. In order to limit the disastrous effects that animal outbreaks may have on bilateral trade, the OIE allows the possibility of zoning arrangement, under which both countries would recognize each others free areas, outside of the areas under control, and resume trade from these free areas. The containment zone is the only concept of zoning strategy that is accepted by the OIE under small outbreaks. However, there are six diseases whose recognition of containment zone must be approved by the World Assembly of Delegates of the OIE. These six diseases include the foot and mouth disease, the African horse sickness (AHS), the classical swine fever, the contagious bovine pleuropneumonia (CBPP), the peste des petits ruminants (PPR) and the bovine spongiform encephalopathy. For these diseases, the OIE allows the establishment of a containment zone only for limited outbreaks.

2.5 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 :

$$
\begin{aligned}
\log y_{ij,t}^{k} = x'\beta_k + v_{k,t} \quad \text{if} \quad z'\alpha_k + u_{k,t} > 0 \\
y_{ij,t}^{k} = 0 \quad \text{if} \quad z'\alpha_k + u_{k,t} < 0 \\
k = 1,2
\end{aligned}
\tag{2.1}
$$

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 :

$$
\Sigma = \begin{bmatrix} \Sigma_{uu} & \Sigma_{uv} \\ \Sigma_{vu} & \Sigma_{vv} \end{bmatrix}
\tag{2.2}
$$

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) :

$$
\begin{aligned}
L_1 &= \int_{-\infty}^{-z'\alpha_1} \int_{-\infty}^{-z'\alpha_2} f(u_1,u_2)du_2du_1 \\
&= \Phi_2(-z'\alpha_1, z'\alpha_2; \rho_{21}^{uu})
\end{aligned}
\tag{2.3}
$$

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

$$
\begin{aligned}
L_2 &= \int_{-z'\alpha_1}^{-\infty} \int_{-\infty}^{-z'\alpha_2} h(u_1,u_2|v_1)du_2du_1 \\
&= (y^1)^{-1}\sigma_1^{-1}\phi_1(h_1)\Phi_2(r_1,-r_2;-\tau_{12})
\end{aligned}
\tag{2.4}
$$

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 :

$$
\begin{aligned}
L_4 &= g(v_1,v_2)\int_{-z'\alpha_1}^{-\infty} \int_{-z'\alpha_2}^{-\infty} h(u_1,u_2|v_1,v_2)du_2du_1 \\
&= (y^1)^{-1}(y^2)^{-1}\sigma_1^{-1}\sigma_2^{-1}\phi_2(h_1,h_2;\rho_{21}^{vv})\Phi_2(q_1,q_2;\tau_{12}')
\end{aligned}
\tag{2.5}
$$

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 $\tau'_{12} = \omega_{12}/(\omega_1, \omega_2)$

2.5.1 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

2.5.2 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 **x** and **z** using the following formula :

$$e_i^p = \lambda(\mathbf{z}\alpha_i)\alpha_{ij} \tag{2.6}$$

$$e_i^c = [\beta_{ij} + [\lambda(\mathbf{z}\alpha_i + \rho_{ii}^{vu}\sigma_i) - \lambda(\mathbf{z}\alpha_i)]\alpha_{ij}]x_j \tag{2.7}$$

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 :

$$e_{ij}^u = [\beta_{ij} + \lambda(\mathbf{z}\alpha_i + \rho_{ii}^{vu}\sigma_i)\alpha_{ij}]x_j \tag{2.8}$$

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.

2.6 Data and descriptive statistics

2.6.1 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.

2.6.2 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.

2.7 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.

2.7.1 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 holdings (Knight-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.

2.7.2 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.

2.8 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 2.2 – Illustration of BSE effect in data on the U.S beef exports

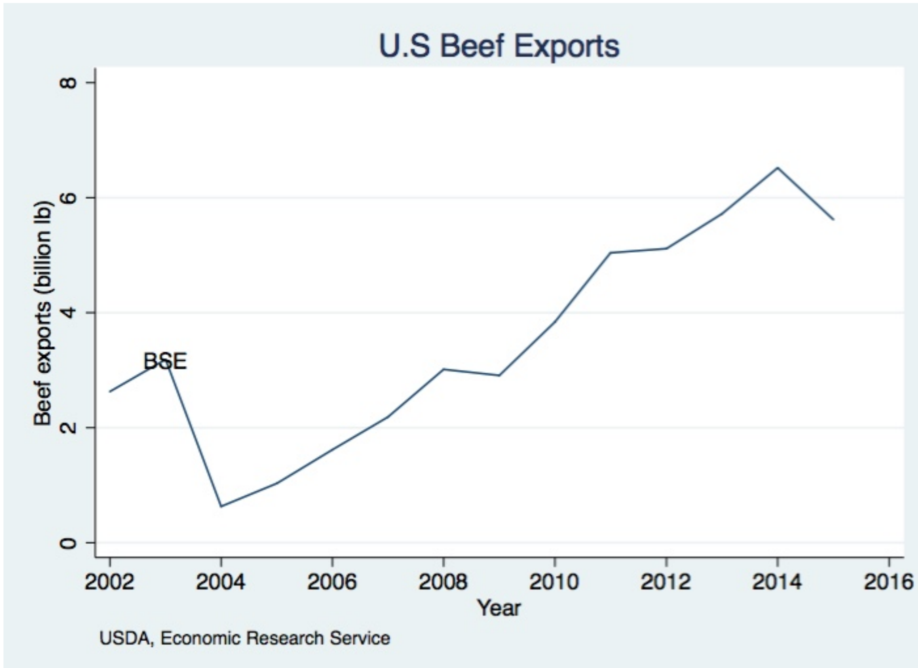

TABLE 2.1 – Waiting period

	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 2.2 – 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 2.3 – 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 2.4 – 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 2.5 – 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 2.6 – 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 2.7 – 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 2.8 – 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 2.9 – 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 2.10 – 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 2.11 – 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 2.12 – 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 2.13 – 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

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

Chapitre 3

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

3.1 Résumé

En réponse aux alertes d'épidémies dans les pays exportateurs, les pays importateurs imposent généralement des interdictions d'importations qui varient en termes de couverture des produits et de durée. Nous servant d'une base de donnée panel unique, couvrant des produits bovins désagrégés à 4 chiffres sur la période 1996-2013, nous estimons l'effet d'une élimination hypothétique des maladies animales sur les flux commerciaux. Plus spécifiquement, nous examinons comment l'encéphalopathie spongiforme bovine (ESB) et la fièvre aphteuse impactent les flux commerciaux de viande bovine. Le modèle de gravité structurelle sectorielle est utilisé pour mésurer les effets directs, conditionnels et globaux, en permettant ainsi aux indices de résistance multilatéraux entrants et sortants, aux dépenses et aux prix à la production de s'ajuster à l'éradication des maladies animales. Les canaux indirects par lesquels l'ESB et la fièvre aphteuse influent sur le commerce sont importants. Notre expérience contrefactuelle suggère que le Canada serait l'un des pays tirant le meilleur parti de l'éradication de l'ESB et de la fièvre aphteuse.

3.2 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 products 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, expenditures 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.

3.3 Introduction

In 2017, world beef exports amounted to US$ 52 billion (WITS, 2018). Canada's beef exports contributed $2.4 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 main cattle exporting countries are Mexico, the European Union, Australia, Brazil and Canada. 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 tendency 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 a FMD outbreak in May of 2001, the UK Ministry of 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

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

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 slaughtering 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). Accordingly, we rely on two different livestock disease alert specifications : one that assumes that domestic and export markets react similarly to livestock disease alerts and one that assumes that only export markets react. The second livestock disease alert specification makes it necessary to have data on international and intra-national flows, even if one is interested in measuring only the partial effects of livestock disease alerts on trade flows. It has been known for several years that distance effects cannot be precisely estimated if intra-national trade flows are missing (Yotov, 2012). Clearly the same logic applies about the assessment of livestock disease alerts on trade flows.

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

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

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 livestock 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 four 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 specifications on consecutive observations separated by 1 and 3 years respectively. We rely on a fourth specification to assess the implication of having disease outbreaks influence only international flows as opposed to all flows. This specification is in line with the usual definition of border variables aimed at measuring the additional friction due to border crossings after controlling for distance and market size (Bergstrand et al., 2015; Anderson et al., 2018). After selecting a preferred specification, we use recent breakthroughs in structural gravity modelling 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, expenditures and factory-gate prices. The full effects of a hypothetical removal of livestock 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 livestock 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 extensive 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 four 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 highlights the main results and their policy implications

3.4 Sectoral Structural Gravity and Livestock 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. Put differently, there is no substitution in production across sectors. 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. In our study, substitution is limited as consumers can only reallocate beef expenditures across sources.

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] Trade and other variables like production do indeed change over time, and in some cases at a slow pace. One way to deal with this is by explicitly modelling the adjustment process. For example, Olivero and Yotov (2012) introdu-

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.

ced dynamics in production through capital accumulation to explain sluggish trade flow adjustments. Another way is to estimate the gravity model on panel data with intervals, skipping years between two observations within a panel. Yotov et al. (2016) contend that gravity estimates obtained that way are as reliable as the one from the dynamic model of Olivero and Yotov (2012). By skipping years, the model jumps from one trade equilibrium with predefined production capacities to another, with adjusted production capacities, without having to specify an adjustment process. This is a huge advantage because modelling explicitly the beef supply response would require data on calves on feed, inventories and assumptions about price expectations. 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), Yang et al. (2013)). 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 adjustments in counterfactual experiments. BSE and FMD outbreaks can be likened to the challenge of modelling non-discriminatory trade policies in a gravity framework. This is why we rely on two specifications to define BSE and FMD variables. If BSE and FMD outbreaks impact international and intra-national flows indiscriminately, then variables capturing BSE and FMD alerts in exporting and importing countries are exporter-time and importer-time specific variables. This precludes the use of exporter-time and importer-time fixed effects to capture the effects of all of the variables specific to exporting and importing that vary with time such as beef production, national income and expenditures. to be replaced by exporter, importer and year fixed effects. If BSE and FMD outbreaks affect only international flows, then exporter-time and importer-time fixed effects can be used as controls.

We rely on a balanced panel dataset about trade in beef (cattle and meat) 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.

3.4.1 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 Inward Multilateral Resistance (IMR) and Outward Multilateral Resistance (OMR) indices, expenditures, factory-gate prices and trade flows. The model rests on specific assumptions that are common in the literature. The IMR term is a weighted average of all bilateral trade costs that fall on the consumers in each region. Consumers use the IMR to assess the height of a trade cost specific to a given exporting country in relation to trade costs from all sources. The IMR is the channel through which information from other markets influence consumption decisions about products from specific sources. Similarly, the OMR term is defined as a weighted-average aggregating all bilateral trade costs faced by producers of goods in each country (Yotov et al., 2016). Producers can then compare the trade cost associated to a specific destination to the OMR to gauge the relative potency of the hurdle it faces in the specific destination.

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 $U_j = [\int_{\omega \in \Omega_j} [q(\omega)]^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}]^{\frac{\varepsilon}{\varepsilon-1}}$ where Ω_j represents the set of available varieties 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.

Consumers in country j purchase from different sources, including domestic ones when $i = j$, at delivered prices $p_{ij}(\omega) = p_i(\omega)\tau_{ij}T_{ij}$, where $p_{ij}(\omega)$ is the price observed in country j of variety ω 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} is the tariff applied by destination country j to imports from country i.[6] To simplify we define $t_{ij} = \tau_{ij}T_{ij}$. In most studies, τ_{ij} is approximated by a vector of variables such as distance, colonial links, common language and religious proximity. In beef trade, the presence of BSE and FMD diseases in exporting and importing countries is likely to impact on trade costs in a non-trivial manner as changes in domestic regulations will likely increase variable and possibly fixed trade costs as in Gaigné and Larue (2016b) and Gaigné and Larue (2016a). 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 :

$$X_{ij}(\omega) = E_j P_j^{1-\varepsilon} [p_{ij}(\omega)]^{1-\varepsilon} \tag{3.1}$$

6. 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. In our one-sector model, tariff revenue are not likely to have much of an incidence on GDPs.

where $P_j = [\int_{\omega \in \Omega_j} p_{ij}(\omega)^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}$ is the aggregate consumer price index. E_j denotes expenditures in country j. Consumers allocate beef expenditures across sources according to their CES preferences. Expenditures enter linearly in the above expression which facilitates the link between individual consumer demands and aggregate demand.

On the supply side, we have an endowment economy with an exogenous quantity Q_i. The value of sectoral output at the factory gate price is given by $p_i Q_i = Y_i$. The fixed-endowment model is consistent with the short run production rigidities observed for agricultural products with long production cycles. Thus, Q_i can be seen as the outcome of a production capacity choice made in the past. In an endowment model, supply is zero-elastic in the short run and variations in the value of production stem from changes in factory-gate prices. Most gravity models rests on simple technological assumptions to facilitate the computations of multi-resistance indices that aggregate information about many trade partners.[7] To accommodate the possibility that trade and explanatory variables do not adjust immediately to trade shocks, one can explicitly specify the manner with which dynamics operate in the model, like Olivero and Yotov (2012), or conduct the estimation on a panel with observations separated by a few periods, as advised by Trefler (2004) and Yotov et al. (2016). This allows the output quantity, trade and other variables to change over time without having to specify a complex dynamic beef supply response model. In essence, the estimation assumes that each observation is a short run equilibrium that triggers an adjustment process over a given number of years. By skipping this number of years between two observations, the estimated coefficients reflect the long run adjustments of all variables. The disadvantage of this approach is that nothing is learned about dynamic adjustment processes.

Market clearing implies :

$$Y_i = \sum_j X_{ij} \tag{3.2}$$

$$= \sum_j E_j P_j^{1-\varepsilon} [p_{ij}(\omega)]^{1-\varepsilon} \tag{3.3}$$

The above identity highlights the need to account for intra-national sales in the modeling of trade flows. Internal consistency requires that all sales add up to production. Define $Y \equiv \sum_i^N Y_i$ where N is the number of countries and divide equation (3) by Y it can be shown that :

$$(p_i \Pi_i)^{1-\varepsilon} = \frac{Y_i}{Y} \tag{3.4}$$

Inserting equation 4 in equation 3 gives the outward multilateral resistance index (OMR) :

$$(\Pi_i)^{1-\varepsilon} = \sum_j (\frac{\tau_{ij} T_{ij}}{P_j})^{1-\varepsilon} \frac{E_j}{Y} \tag{3.5}$$

7. Demand-side gravity is the simplest with an exogenous output quantity. Supply-side gravity rests on a Ricardian foundation with a single factor, labor, with constant productivity. Gravity based on heterogeneous firms, as in Helpman et al. (2008), assumes constant returns technologies with a single factor.

Rearranging equation 3.4 in terms of p_i and inserting this in the price index of equation 1 gives the inward multilateral resistance (IMR) :

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 importing countries. The OMR captures the incidence of BSE and FMD outbreaks in the various destinations supplied by firms based in country i. Rearranging equation 4 in terms of p_i and inserting this in the price index of equation 1 gives the inward multilateral resistance (IMR) :

$$(P_j)^{1-\varepsilon} = \sum_i \left(\frac{\tau_{ij}T_{ij}}{\Pi_i}\right)^{1-\varepsilon}\frac{Y_i}{Y} \tag{3.6}$$

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, particularly when they fall on large exporting countries. The IMR may not be interpreted as a consumer price index (CPI) if the purchases are made by intermediate goods users. In the case cattle and beef products, it is safe to assume that imported cattle are either slaughtered or used for genetic improvements as breeding stock. Similarly, meat carcasses are likely to be processed before the meat is purchased by consumers. BSE and FMD outbreaks in various exporting countries tend to increase the IMR, making imports from a disease-free country i relatively cheaper. The structural gravity export equation can be rewritten in terms of the OMR and IMR indices :

$$X_{ij} = \frac{Y_i E_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\varepsilon} \tag{3.7}$$

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

$$p_i = \left(\frac{Y_i}{Y}\right)^{\frac{1}{1-\varepsilon}}\frac{1}{\alpha_i \Pi_i} \tag{3.8}$$

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) to construct the IMR and OMR indices. [8] 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 :

$$(\Pi_i)^{1-\varepsilon} = \frac{Y_i}{exp(FE_i)}E_r \tag{3.9}$$

$$(P_j)^{1-\varepsilon} = \frac{E_j}{exp(FE_j)}\frac{1}{E_r} \tag{3.10}$$

8. This is another appealing property of the PPML estimator which delivers consistent estimates in the presence of zeros and heteroskedasticity (Silva and Tenreyro, 2006).

where FE_i designates the exporter-time fixed effects associated with exporter i and E_r 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 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 :

$$\Delta p_{i,t}^{CFL} = \frac{p_{i,t}^{CFL}}{p_{i,t}} = \frac{\exp(\hat{\pi}_i{}^{CFL})/E_{R,t}^{CFL}}{\exp(\hat{\pi}_i)/E_{R,t}} \tag{3.11}$$

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.

3.5 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 lengths. 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 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. [9] We consider two cases. The first one assumes that domestic and export markets react similarly to outbreaks. Thus, the BSE and FMD binary variables equal 1 whether the buyer is domestic or foreign. The second case assumes that domestic regulators and consumers remain confident in the safety of domestic beef in spite of BSE and/or FMD cases. The latter condition is motivated by the fact that domestic authorities

9. Alternative specifications involving the number of infected animals, which embody more information, did not perform as well probably because one is a big number when one consider importing countries' reaction to BSE and FMD cases reported in exporting countries.

typically do not impose bans on beef originating from domestic sources. The second case is representative of Canada's experience with BSE. In other countries where the number of infected animals was much higher, domestic consumers temporarily changed their behavior. Lagged BSE and FMD effects must also be introduced to capture the dynamics of BSE and FMD outbreaks. Having differential reactions to BSE and FMD outbreaks between domestic and foreign markets makes it possible to rely on exporter-year and importer-year fixed effects to compute multilateral resistance indices. When domestic and foreign markets are assumed to react similarly to BSE and FMD outbreaks, non-time varying exporter and importer fixed effects must be used to permit the identification of BSE and FMD effects. In this case, additional variables about exporters and importers must be introduced in the gravity equation, like sectoral expenditures and output. The price of relaxing the differential reaction assumption is that multilateral indices are not measured as precisely. Comparing coefficients estimated under the two approaches tell us about the significance of the differential reaction assumption and about the bias introduced by the computation of multilateral indices with non-time varying exporter and importer fixed effects. We use the PPML estimator to obtain benchmark coefficient estimates. The two empirical versions of export equation (8) are :

$$X_{ij,t} = exp(\Gamma_{ij,t}\beta + \Lambda_{it}\theta + \Sigma_{jt}\gamma + \Delta_{ij}\alpha + \tau_i + \chi_j) + \varepsilon_{ij,t} \tag{3.12}$$

$$X_{ij,t} = exp(\Gamma_{ij,t}\beta + \Lambda'_{it}\theta + \Sigma'_{jt}\gamma + \Delta_{ij}\alpha + \tau_{it} + \chi_{jt}) + \varepsilon_{ij,t} \tag{3.13}$$

where $X_{ij,t}$ is the bilateral trade flow (in levels) between countries i and j at time t. τ_i represent non-time varying exporter fixed effects while τ_{it} stands for exporter-year fixed effects which will be used to recover the (log of) outward multilateral resistance index. Similarly, χ_j and χ_{jt} represent non-time varying importer fixed effects and importer-year fixed effects, 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 : $SPSijt = 0.6 * SPSIR_t + 0.3 * SPSIR_{t-1} + 0.1 * SPSIR_{t-2} + 0.6 * SPS_IT_t + 0.3 * SPS_IT_{t-1} + 0.1 * SPS_IT_{t-2}$, where SPSIR is the number of SPS issues raised by the exporting country in the pair times an international trade flow indicator and 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 tendency 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). dBSE and dFMD variables with a $'$ indicate when BSE and FMD cases do not impact on the domestic market. 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 11. 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. We presume that BSE and FMD will have similar impacts on all the exporting firms so

$$WS_i = \frac{W_i^{CFL}}{W_i^{BLN}} = (\frac{\lambda_{ii}^{CFL}}{\lambda_{ii}^{BLN}})^{\frac{1}{1-\varepsilon}} \tag{3.14}$$

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 intra-national flows in total expenditures without and with BSE and FMD diseases elevated to the power one minus the elasticity of substitution :

3.6 Data and descriptive statistics

3.6.1 Data

Our data come from several sources. The product definition is a pooling of 4-digit HS classification codes 0102,0201,0202 and 0206 into a beef aggregate that includes cattle, fresh and frozen meat and offals. 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.

3.6.2 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 (3.2) 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%. During the same period BSE and FMD free countries located in Australia, Chile, Mexico, New-Zealand and Norway see their exports increase by 30%.

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 3.3 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 3.4 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.

3.7 Results

3.7.1 Partial effects of BSE and FMD disease outbreaks

Table (3.4) reports the results from the PPML estimation of four 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 first three models are estimated with importer, exporter, and time fixed effects. The time fixed effects are included to account for macro shocks while the exporter and importer fixed effects are meant to capture all time-invariant country-specific variables. In these models, the disease variables time-varying and specific to exporting and importing countries, which precludes the inclusion of exporter-year and importer-year fixed effects. The fourth model is based on our second specification which posits that intra-national trade flows are not impacted by livestock disease alerts. The disease variables being time-varying pair-specific, it is possible then to includes exporter-year and importer-year fixed effects.

For all four models, the R^2s 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. The estimated coefficients can be used to assess the magnitude of partial trade effects that treat the IMR and OMR indices, expenditures 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% according to the estimate reported in the first column of table 3.5. This is low relative to the estimate reported in the fourth column. The estimates for the tariff variable vary much less across models. 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. 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 for the first model 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 too. 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. The null hypothesis 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 $\exp(dBSE-origin)-1$.[10] The immediate trade reduction caused by a BSE outbreak according to model 1 is 43%, a highly significant reduction considering that our data is annual and BSE outbreaks can happen early or late in any given year. For model 4 whose specification includes time-varying exporter and importer fixed effects, the short run BSE-induced trade reduction is also quite large at 33%. 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% when coefficient estimates from model 1 are used. Model 4 produces a long run BSE-induced drop in trade of 96% which is very close to the long run elasticities of the other three models. For dFMD-origin, the short run elasticity is larger than for BSE at -82%. This might have more to do with the timing of the outbreaks than the importing countries' policy response. The long run FMD 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 favour 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

10. Standard errors around elasticity estimates can easily be computed with Stata's NLCOM command.

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. 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.

3.7.2 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 in Bergstrand et al. (2015) and Anderson et al. (2018). Our partial results above suggest that BSE and FMD diseases have tremendous effects on trade costs. Our counterfactual experiment is conducted with model 1. The full effects computed from the counterfactual experiment are presented in Tables 3.6-3.7. The first column shows that the elimination of BSE and FMD diseases would substantially boost trade in most countries. Canadian beef exports would increase by roughly 62% which is similar to the increase for Argentina and Mexico, but much smaller than the 87% increase for US exports, the 101% increase for Brazil and the 131% increase for India. Some small exporters would see their exports being multiplied severalfold. This is especially true for Japan, Korea and China. In contrast, Malaysia, 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-fourth the size of the full export change. It is approximately one-fith for the U.S. This suggests that this channel matters when trying to gauge the incidence of trade costs on trade flows. The outward multilateral resistance indices for all countries decrease a lot, suggesting that the removal of BSE and FMD would induce significant improvement in market access from an exporter perspective. If trade costs specific to an importing country remain constant, they will be perceived as relatively more trade restricting by an exporting country whose OMR fall. The OMR aggregates trade costs faced by an exporting country across all destinations and the elimination of cattle diseases would enormously reduce trade costs faced by Canadian exporters.

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.

Factory-gate prices would increase in most countries. For Canada, the increase would be almost

13.2%. 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 important in most countries because their IMR increases. Finally, the welfare results in the column labelled real (sectoral) GDP indicates that Canada would gain 16%, from the elimination of BSE and FMD. Other countries like Uruguay, Paraguay, Ireland, Bolivia, New-Zealand and Thailand would also be in the set of countries gaining most. Finland and Norway and Korea would gain very little and Sweden, Greece, Chile and Malaysia would experience a small loss.

For robustness purposes, we implemented a counterfactual scenario about the disappearance of BSE and FMD that relaxed the zero elastic beef supply assumption and allowed increases not only in the value of domestic production but also in the quantities of beef produced in each country. We modelled domestic beef production in terms of lagged factory-gate prices, putting more weights on recent prices and lower weights on more distant ones. The results are presented in tables 3.8-3.9. The trend in terms of gains remain the same across the two specifications.

3.8 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 countries 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 3.1 – 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 3.2 – Exports growth of countries with BSE and FMD status over 6 consecutive years

Group of countries	Exports 1997	Exports 2003	Growth rate
BSE countries	$2.9E+10	$2 E+10	-50%
FMD countries	$2.6 E+10	$1.25 E+10	-55%
BSE & FMD free countries	$0.79 E+07	$1.02 E+07	30%

TABLE 3.3 – 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 3.4 – 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 3.5 – Estimation results

	(1) PPML 1	(2) PPML 2	(3) PPML 3	(4) PPML 4
Applied tariffs	-1.3009***	-1.7164***	-1.9369***	-1.546***
Distance	-0.2746***	-0.1801***	-0.1876*	-0.851***
dBSE origin	-0.5650***	-0.8630***	-2.7511***	-0.388
$dBSE_{t-1}$ origin	-0.6725***			
$dBSE_{t-2}$ origin	-0.3727***	-1.1551***		-0.727**
$dBSE_{t-3}$ origin	-0.3860***			
$dBSE_{t-4}$ origin	-0.4222***	-0.9240***		-1.185***
$dBSE_{t-5}$ origin	-0.1235			
$dBSE_{t-6}$ origin	-0.3127***	-0.7960***		-1.014**
$dBSE_{t-7}$ 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***	-1.632***
$dFMD_{t-1}$ origin	-1.4765***			
$dFMD_{t-2}$ origin	-1.0369***	-1.1073***		-2.933***
$dFMD_{t-3}$ origin	-0.7243***			
$dFMD_{t-4}$ origin	-1.3820***	-2.3100***		-2.940***
$dFMD_{t-5}$ origin	-2.6433***			
$dFMD_{t-6}$ origin	-2.3021***	-2.3023***		-6.129***
$dFMD_{t-7}$ 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***	-2.131***
SPS_{ijt}	-0.0859***	-0.1038***	-0.1577***	-0.515***
N	17600	9600	6400	9600
r2	0.9734	0.9451	0.9304	.994
ll	-6.428e+05	-4.073e+05	-3.275e+05	-2.215e+05

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

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

TABLE 3.6 – Full effects from the eradication of BSE and FMD

Country	Exports FULL	Real GDP	Gate prices	Full IMRs	Full OMRs	Exports CDL
Argentina	61.47	20.26	14.71	12.54	-98.41	10.38
Australia	44.96	28.27	13.23	1.62	-98.40	0.94
Austria	35.89	13.67	16.36	52.44	-98.70	1.87
Belgium	43.45	25.40	15.95	15.06	-98.64	2.32
Bolivia	33.20	30.82	18.34	30.71	-98.78	3.04
Brazil	100.53	12.24	13.18	22.90	-98.03	22.09
Canada	61.54	15.86	13.18	20.25	-98.44	13.77
Switzerland	55.56	23.43	16.28	21.45	-98.61	9.69
Chile	40.54	-2.97	15.04	133.63	-98.69	4.35
Colombia	118.17	8.01	14.63	59.62	-98.40	39.38
Germany	58.61	16.74	14.66	21.70	-98.42	8.32
Denmark	41.04	14.12	16.40	51.23	-98.69	2.83
Ecuador	259.04	8.60	21.43	126.40	-98.66	146.12
Spain	51.76	14.99	16.95	46.56	-98.66	10.26
Finland	30.31	6.48	16.48	93.13	-98.82	0.32
France	73.13	15.60	14.28	20.03	-98.34	16.40
United Kingdom	82.94	20.40	15.48	16.87	-98.45	24.01
Greece	27.42	-9.38	16.95	222.51	-98.82	0.84
Indonesia	72.58	23.19	13.45	12.00	-98.46	13.39
India	131.36	21.76	21.84	20.23	-98.41	43.79
Ireland	46.27	32.39	17.14	6.33	-98.54	2.64

TABLE 3.7 – Continued

Country	Exports FULL	Real GDP	Gate prices	Full IMRs	Full OMRs	Exports CDL
Italy	66.13	12.59	14.34	32.54	-98.44	13.60
Japan	269.87	22.60	8.11	-0.89	-98.04	87.89
Korea	206.55	8.26	10.44	34.54	-98.31	68.60
Morocco	45.55	14.20	13.98	34.73	-98.48	5.29
Mexico	58.86	11.89	12.00	27.18	-98.48	18.45
Malaysia	-107.12	-26.87	22.86	724.78	-98.95	-380.93
Netherlands	56.80	14.92	15.34	29.27	-98.48	8.33
Norway	30.17	4.83	15.98	94.23	-98.73	1.09
New-Zealand	41.88	31.05	14.00	2.53	-98.52	0.55
Peru	40.79	32.02	16.34	17.01	-98.67	3.69
Poland	47.31	26.41	16.87	18.72	-98.61	3.76
Portugal	53.83	9.50	17.72	81.25	-98.73	13.36
Paraguay	46.02	32.26	15.89	15.32	-98.59	0.76
Sweden	29.61	-11.18	16.55	234.63	-98.79	0.52
Thailand	49.82	31.52	16.43	13.60	-98.77	7.41
Turkey	386.02	18.90	18.80	31.01	-98.36	232.91
Uruguay	34.02	26.25	15.15	17.07	-98.65	0.22
USA	87.13	10.82	8.46	11.52	-97.93	14.27
China	148.10	19.13	12.82	5.40	-97.95	42.56

TABLE 3.8 – Full effects from the eradication of BSE and FMD

Country	Exports FULL	Real GDP	Gate prices	Full IMRs	Full OMRs	Exports CDL
Argentina	46.95	8.90	15.13	47.27	-97.63	10.42
Australia	30.37	13.53	13.44	23.82	-97.62	0.95
Austria	22.33	3.36	16.62	105.56	-98.13	1.89
Belgium	25.76	6.05	16.59	84.02	-98.08	2.39
Bolivia	13.89	13.99	18.86	79.10	-98.32	3.08
Brazil	77.41	12.16	14.52	25.22	-97.35	22.08
Canada	45.91	6.89	13.62	50.56	-97.73	13.70
Switzerland	34.39	42.63	17.10	-1.19	-98.08	9.71
Chile	18.26	13.44	15.44	48.19	-98.13	4.32
Colombia	84.86	34.57	15.94	1.23	-97.94	39.54
Germany	41.14	11.26	15.69	41.24	-97.83	8.34
Denmark	22.47	1.51	17.21	128.10	-98.22	2.88
Ecuador	201.77	1.55	22.21	216.56	-98.21	143.38
Spain	35.68	3.60	17.29	109.42	-98.08	10.32
Finland	6.97	-10.16	16.99	239.53	-98.35	0.32
France	56.31	12.43	15.24	30.89	-97.69	16.39
United Kingdom	61.78	18.25	16.55	22.79	-97.88	23.92
Greece	11.34	40.24	16.86	7.68	-98.26	0.85
Indonesia	47.38	46.41	14.02	-5.84	-97.78	13.18
India	102.74	9.40	22.89	95.73	-97.88	43.77
Ireland	31.73	17.25	17.75	33.54	-97.99	2.64

TABLE 3.9 – Continued

Country	Exports FULL	Real GDP	Gate prices	Full IMRs	Full OMRs	Exports CDL
Italy	47.49	12.02	15.25	36.32	-97.83	13.53
Japan	210.00	26.09	9.99	-2.56	-97.46	87.50
Korea	156.36	35.39	11.56	-3.72	-97.77	68.42
Morocco	29.41	3.60	15.06	86.31	-97.96	5.36
Mexico	52.31	19.67	11.92	8.36	-97.66	18.46
Malaysia	-401.50	61.38	22.21	7.60	-98.42	-378.98
Netherlands	40.16	11.03	16.26	45.82	-97.90	8.37
Norway	17.54	8.20	16.55	78.63	-98.25	1.10
New-Zealand	25.97	8.22	14.15	50.28	-97.78	0.55
Peru	13.83	-7.03	17.23	213.97	-98.22	3.72
Poland	29.38	24.03	17.62	22.47	-98.09	3.76
Portugal	34.20	34.91	18.11	8.95	-98.18	13.31
Paraguay	20.81	18.58	16.84	43.83	-98.08	0.99
Sweden	3.67	-10.26	16.95	248.30	-98.33	0.53
Thailand	21.32	-7.06	16.65	208.37	-98.18	7.67
Turkey	347.38	33.31	20.04	2.23	-97.89	231.50
Uruguay	20.26	6.68	15.05	70.34	-97.96	0.22
USA	67.77	12.72	9.87	9.23	-97.15	14.31
China	114.71	19.78	14.51	5.38	-97.30	42.41

Conclusion

The present thesis addresses three important and different questions about agricultural trade. Through three essays, we contribute to the literature on export survival and on the effects of tariffs and non tariffs barriers on trade flows. First of all, the novelty of the first paper lies in the development of a theoretical framework to explain the frequent "ins" and "outs" by exporting countries engaged in agricultural trade. By introducing convex marginal costs into the cost structure of the firms, our model provides important insights about the very short survival time of export flows. At the intensive margin level, our model results in an export equation that features an index that aggregates trade costs adjusted for the size of markets supplied by firms. More importantly, at the extensive margin level, we found that the cut-off profits depend on fixed costs and price indices from all destinations. Therefore, the firm's decision in any given market is directly tied to sales in other markets. This exacerbates the effets that fixed and variable costs have on market exits. As a result while firms with high productivities have more scope to increase output, this does not necessarily translate into exporting to more destinations. Largest and closest importing markets are likely to be chosen and to serve as fallback markets. Interestingly, this theoretical postulate of cost convexity is thereafter supported by a rigorous and robust econometric analysis. We showed that lagged foregone exports from terminated flows increase exports to "fallback markets" and reduce the probability of export failure. One special feature of our empirical framework is that it addresses tariff endogeneity, an issue that might be responsible for some the peculiar tariff coefficients reported in previous export survival studies.

The second essay fills a gap about the dynamic effects of animal diseases. The reporting of an animal disease outbreak triggers immediate import bans. The return to normal trade can be slow-coming, even uncertain, as countries have heterogenous ways responding to outbreaks. This chapter takes advantage of the multivariate sample selection model that allows us to account for the vertical production linkage between cattle and beef. By allowing the infectious animal diseases to have different impacts on trade flows over time, we found that the return to normal trade in the beef sector takes on average 7 years.

The last essay, explores the implications of a counterfactual scenario showcasing the elimination of BSE and FMD outbreaks. To the best of our knowledge, this paper is the first to implement a counterfactual experiment about animal diseases. Previous studies have only reported partial trade effects that assumes that disease outbreaks do not impact on multilateral trade resistance indices, expenditures and factory-gate prices. Our results suggest that 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 are an important trade liberalization channel. Our results also show much heterogeneity in welfare changes across countries, but large gains for Canada.

Relevant policy messages emerge from these three chapters of the thesis. First of all, governments must not automatically equate reliance on a few export markets and frequent "ins and outs" as symptoms of a productivity problem. The domestic market and key export markets are buffers against trade shocks in third export markets. Because of the relative importance of exports in the marketing of many agricultural products, trade shocks in some exports markets are likely to be buffered through adjustments in other export markets, especially in large export markets that are close by. Foregone exports from terminated flows increase exports to fallback markets. The presence of a fallback market makes it easier to deal with production rigidities and may facilitate risk management along supply chains to the extent that risk-sharing arrangements and government intervention through insurance programs make domestic production more rigid. Governments should nevertheless pursue trade liberalization widely through RTAs and the WTO to boost export survival in as many destinations as possible and to insure that their firms have a secured access to their fallback markets. This is particularly important for small trade-dependant countries. One can understand the urgency that Canada and Mexico felt during the negotiations of the US-Mexico-Canada trade agreement. The same applies to African countries seeking a preferential access to the EU market and to neighbours of China and Japan.

As for animal disease outbreaks, 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 outbreaks, or outbreaks 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. Because almost all countries would gain from the elimination of BSE and FMD, one can only hope that countries will collaborate to eradicate these diseases.

3.10 Bibliographie

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