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A Gravity Approach to Evaluate the Significance of Trade Liberalization in Vertically-Related Goods in The Presence of Non-Tariff Barriers[†]

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Abstract: A gravity-based model is developed to explain bilateral trade flows in primary and processed agri-food commodities. It innovates by explicitly accounting for the vertical production linkages between primary and processed agri-food products, tariffs, and subsidies and by estimating the restrictiveness of non-tariff barriers in the upstream sector. Our application focuses on cattle/beef trade flows between forty-two countries. The structural parameters of the model are used to simulate trade flows under various scenarios of import tariffs and domestic and export subsidies reductions. The United States and Australia emerge as the exporting countries that stand to benefit the most from cuts in tariffs and subsidies as bovine meat imports in the European Union and Japan significantly increase. A bootstrap procedure is used to generate confidence intervals around predicted trade liberalization outcomes.

Keywords: Gravity model, cattle/beef trade

JEL Classification: Q17, F13

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1. Introduction

Taking a long view of trade liberalization, it is apparent that the global trading system is in a critical transition period. Between the Great Depression and World War II, industrial tariffs averaged about 40% or roughly ten times the current average (OECD, 2003). In some sense, the work initiated in the 1940's to lower tariffs on industrial goods is nearly complete. However, the state of trade in agri-food commodities is comparable to that of industrial goods 60 years ago as it is still in its infancy. Gibson *et al.* (2001) estimated that the average tariff on agricultural products at the end of the Uruguay Round (UR) implementation period was about 60%.

Most of the lessons that were learned from liberalizing trade in industrial products still apply even though the distinguishing features of agri-food markets add a whole host of modeling issues. For instance, non-tariff barriers can be applied to various degrees to different, but vertically-related, products in a given marketing chain. In this context, comprehensive liberalization plans must recognize the vertical linkages between the upstream and downstream industries as farm policies impacts on the competitiveness of primary producers and processors alike. Agriculture has always been a politically sensitive sector and this is why it was for all practical purposes ignored in the General Agreement on Tariffs and Trade (GATT) prior to the UR and why it is so difficult for World Trade Organization (WTO) members to reach an agreement in the current Doha Round.

The objective of the paper is to develop a gravity-based model in the spirit of Anderson and van Wincoop (2003) to explain bilateral trade flows of processed agri-food commodities *and* primary agricultural products. Our theoretical framework yields empirically tractable bilateral trade flow equations that are estimated to analyze the impacts of trade liberalization scenarios in the cattle/beef markets. We chose these products for several reasons. First, the simultaneous import and export (or cross-hauling) of cattle and beef is common. Second, the trade position of a particular country in cattle is often different from its trade position in beef. Third, tariffs, and domestic and export subsidies vary a lot from one country to another. The European Union's (EU) tariff and export subsidy on bovine meat are both in excess of 100% while Australia does not intervene at all. Fourth, non-tariff barriers, like sanitary regulations, are notoriously disruptive. As a result, exporters have to tailor their products to meet the importers' regulations in the spirit of Grossman and Helpman (2005).

Our model features two important structural parameters: the elasticity of substitution for bovine meat and the cattle elasticity of transformation. The former elasticity measures the consumers' ability to substitute meats from different origins while the latter captures the ease with which an exporter can substitute one destination for another. Our elasticity of substitution estimate is lower than what has been reported for the aggregate manufacturing sector by Lai and Trefler (2004) and Anderson and van Wincoop (2004). This supports the hypothesis that there is significant product differentiation at the consumers' level with respect to the origin of beef. Even though explicit transaction costs (such as tariffs and transportation) are accounted for in the model, the estimate of the elasticity of transformation is quite low. This is consistent with the presence of significant impediments to substituting cattle exports across markets from the exporters' perspective. Simulations are performed to analyze the impacts of tariffs and/or subsidy reductions on trade flows of cattle and beef. As far as we know, we are the first to explicitly account for support policies and to propose a new approach to estimate the restrictiveness of non-tariff barriers in a gravity model.

The econometric studies pertaining to the liberalization of the cattle/beef sector are usually limited to a narrowly defined geographic area, like Wachenheim, Mattson and Koo (2004)'s analysis of the North American beef and cattle trade or Kim, Kim and Veeman (2004)'s study about the South Korean beef market. In contrast, gravity models are typically estimated on data sets involving a large number of countries. However, most of the empirical gravity applications have relied on highly aggregated manufacturing data (*e.g*. Eaton and Kortum, 2002; Anderson and van Wincoop, 2003; Lai and Trefler, 2004) and could not analyze the impact of trade liberalization in primary agricultural goods and in processed foods.

The impact of trade liberalization is often analyzed with Computable General Equilibrium (CGE) models (*e.g.*, Fabiosa *et al*, 2005; Hertel and Martin, 2001). While in principle they could be highly disaggregated, they too usually rely on highly aggregated products. CGE models are sometimes criticized on the ground that the value of the parameters are either borrowed from other studies or are based on educated guesses. The fact that the parameters are not jointly estimated means that they may not be mutually consistent with one another. Calibration techniques can be used to attenuate this problem as some coefficients can be adjusted to better replicate a period of reference, but the CGE modeller often does not know the confidence interval around each parameter and hence does not know what constitute a "reasonable" adjustment. The lack of statistical support is also problematic because it prevents the construction of confidence intervals around simulated trade flows.[1] We address this issue by building confidence intervals around predicted trade flows using bootstrap methods. This allows us to test hypotheses about changes in trade positions induced by trade liberalization.

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[1] Abdelkhalek and Dufour (1998) propose a method to bring "statistical objectivity" in assessing the uncertainty about simulation results of CGE models, but their approach has not been widely used in practice.

Two issues had to be addressed for the successful estimation of the empirical specification of our model. First, there is a significant number of zeros in trade flows for many country pairs due to the disaggregate nature of the data. Ideally, the estimator must prevent the occurrence of simulated negative trade flows.[2] Second, there is a simultaneity issue associated with the cattle bilateral export supply functions and meat import demand schedules. Ignoring this issue would result in biased parameter estimates and hence unreliable trade flow predictions. As a result, a type 1 Tobit model is used to address the corner solution outcomes in the data and the potential simultaneity bias is tackled with instrumental variable estimation techniques.

The remainder of the paper is structured as follows. The next section presents the theoretical foundations of our gravity model. It highlights the vertical linkages between the cattle and beef sectors. The third section describes the data and the econometric procedure used to estimate the structural parameters of the model. The fourth section presents results from various liberalization scenarios and discusses their policy implications. The United States (US) and Australia emerge as the exporting countries that stand to benefit most from trade liberalization as the EU and Japan significantly increase their imports of beef. Canada's trade position in the beef sector would deteriorate while Argentina's trade position would improve. The last section reviews the main results and their implications in the context of the troubled Doha Round.

2. The Theoretical Model

Consider a world with Z countries and S processing sectors producing consumer-ready goods. The S sectors are characterized by differentiated varieties and increasing returns to scale in production. We assume that each variety is produced by one firm and that there are a total of n_{sz}^{M}

[2] The modeling of zeros is insightful in its own right because some of the factors conditioning the probability of export are influenced by policies.

firms in sector s of country z. A two-tier consumer preference structure is assumed as in Lai and Trefler (2004). The upper tier is a Cobb-Douglas function over goods and the lower tier is a Dixit-Stiglitz Constant Elasticity of Substitution (CES) function over varieties. The logarithm of the utility function for a representative consumer in country i is:

$$\ln U_i = \sum_s \mu_s \sigma_s / (\sigma_s - 1) \ln \left(\sum_z \int_0^{n_{sz}^M} m_{siz}(v)^{(\sigma_s - 1)/\sigma_s} dv \right) \tag{1}$$

where μ_s is the constant share of income spent on goods produced by sector s with $\sum_s \mu_s = 1$, σ_s is the elasticity of substitution between varieties specific to sector s, m_{siz} measures consumption of variety v of sector s of country z. Weak separability implies that the representative consumer maximizes the lower tier utility function subject to the budget constraint, $\mu_s Y_i = \sum_z \int_0^{n_{sz}^M} p_{sz} \tau_{siz}^M \varepsilon_{sz}^M m_{siz}(v) dv$, where Y_i represents total income of the representative consumer in country i, p_{sz} is the seller's price in country z, $\tau_{siz}^M \geq 1$ is the *ad valorem* equivalent of trade costs associated with shipping goods from country z to country i, $\varepsilon_{sz}^M \leq 1$ measures support policies on an *ad valorem* basis (*e.g.* production subsidy, export subsidy) for country z and it is invariant across destinations. Total imports of country i coming from country j in sector s are:

$$M_{sij} = n_{sj}^M m_{sij} = \mu_s Y_i \frac{\left(p_{sj} \tau_{sij}^M \varepsilon_{sj}^M \right)^{-\sigma_s} n_{sj}^M}{\sum_z \left(p_{sz} \tau_{siz}^M \varepsilon_{sz}^M \right)^{1-\sigma_s} n_{sz}^M}. \tag{2}$$

Let Q_{sj}^M represent total output of commodity s in country j. For future reference, we define the following identity which expresses trade flows as a fraction of total output in the processing sector:

$$M_{sij} = \left(M_{sij} \Big/ \sum_z M_{szj} \right) Q_{sj}^M \quad (3)$$

where $\sum_z M_{szj} = \sum_z \mu_s Y_z \frac{\left(p_{sj} \tau_{szj}^M \varepsilon_{sj}^M \right)^{-\sigma_s} n_{sj}^M}{\sum_{z'} \left(p_{sz'} \tau_{szz'}^M \varepsilon_{sz'}^M \right)^{1-\sigma_s} n_{sz'}^M}$.

The key assumption in the consumers' utility maximization problem is that processed goods are differentiated. In contrast, we assume that primary goods are not differentiated on the basis of their intrinsic qualities. This is not a heroic assumption because commodities are often blended and priced based on a benchmark quality. This can only be done when differentiation is limited. From an analytical standpoint, the assumption that primary agricultural goods are homogenous from the buyers' perspective is most convenient because it drastically reduces the number of consumption possibilities.

Non-tariff barriers and sanitary regulations are notorious impediments to agricultural trade. Accordingly, we posit that destinations are not perfectly substitutable for exporters of primary agricultural goods.[3] Imperfect substitutability across destinations for exports of primary products is modeled through a constant elasticity of transformation. This concept was first introduced by Powell and Gruen (1968) and was more recently used by Bergstrand (1985, 1989) and Baier and Bergstrand (2001). To gain some insights regarding this concept, consider the following heuristic interpretation. Let us assume that that the production process can be decomposed into two different stages. First, each firm produces an aggregate output (denoted $\overline{\iota}_{sj}$) which is subsequently tailored to each particular market according to the constant elasticity of transformation (CET) function:

[3] The most publicized dispute about a sanitary regulation is perhaps the EU ban on hormone-treated cattle/beef (Bureau, Marette and Schavina, 1998; Wilson, Otsuki and Majumdsar, 2003). Canada and the US challenged the EU ban on imports of hormone-treated cattle/beef, but the ban remained in effect even when WTO dispute settlement panels ruled that it ought to be lifted. The EU chose to be subject to retaliatory measures by the US and Canada. The impact of the embargo on hormone-treated cattle/beef in the empirical model will be discussed below.

$$\bar{\iota}_{sj} = \left(\sum_z \iota_{szj}^{(1+\gamma_s)/\gamma_s}\right)^{\gamma_s/(1+\gamma_s)} \quad (4)$$

where γ_s represents the elasticity of transformation in sector *s* that takes the lower value of zero if products are not substitutable and a value of infinity for the case of perfect substitutability across destination countries, and ι_{sij} is the production by country j exported to country i.

The technology to produce primary goods is homothetic and is summarized by the cost function $\rho_{sj}^{\alpha_s}\bar{\iota}_{sj}^{\beta_s}$, where ρ_{sj} is a cost indicator specific to country *j* and sector *s* and $\alpha_s, \beta_s > 0$. In our study, ρ_{sj} is interpreted as land rents. The bilateral export supply functions of a producer in sector *s* are determined by maximizing the profit function:

$$\pi_{sj}^I = \sum_z h_{sz}\tau_{szj}^I\varepsilon_{sj}^I\iota_{szj} - \rho_{sj}^{\alpha_s}\bar{\iota}_{sj}^{\beta_s} \quad (5)$$

where h_{sz} is the price of the primary good used by processing firms in sector s; $\varepsilon_{sj}^I \geq 1$ is the support offered by country j, and $\tau_{szj}^I \leq 1$ is the trade cost. Profit maximizing conditions yield the bilateral export supply functions:

$$\iota_{sij} = \beta_s^{-\frac{1}{\beta_s - 1}}\rho_{sj}^{-\frac{\alpha_s}{\beta_s - 1}} \frac{\left(h_{si}\tau_{sij}^I\varepsilon_{sj}^I\right)^{\gamma_s}}{\left[\sum_z\left(h_{sz}\tau_{szj}^I\varepsilon_{sj}^I\right)^{1+\gamma_s}\right]^{\xi_s}} \quad (6)$$

where $\xi_s = \left[\gamma_s(\beta_s - 1) - 1\right]/(1+\gamma_s)(\beta_s - 1)$ and $\gamma_s > 1/(\beta_s - 1) > 0$ for the second order conditions to be respected. Let the number of identical producers of the primary agricultural product s in j be represented by n_{sj}^I. Aggregate exports from j to i are:

$$I_{sij} = n_{sj}^I\beta_s^{-\frac{1}{\beta_s - 1}}\rho_{sj}^{-\frac{\alpha_s}{\beta_s - 1}} \frac{\left(h_{si}\tau_{sij}^I\varepsilon_{sj}^I\right)^{\gamma_s}}{\left[\sum_z\left(h_{sz}\tau_{szj}^I\varepsilon_{sj}^I\right)^{1+\gamma_s}\right]^{\xi_s}}. \quad (7)$$

For future reference, we define an identity that relates bilateral exports in (7) to total output of the primary commodity *s* in country *j*:

$$I_{sij} = \left(I_{sij} \Big/ \sum\nolimits_z I_{siz} \right) Q_{si}^{I^d} \tag{8}$$

where $Q_{si}^{I^d}$ is the total demand of the primary commodity in country *i*.

Vertical linkages between the primary and processing sectors constrain price linkages. Under the assumption of monopolistic competition in the production of consumer-ready goods and constant average variable costs, profit maximization implies a constant mark-up pricing rule in the processing sector:

$$p_{sj} = \frac{\sigma_s}{\sigma_s - 1} h_{sj}^{\theta_{sh}} w_j^{\theta_{sw}} r_j^{\theta_{sr}} \tag{9}$$

where w_j and r_j are the wage and capital rent (exogenous to sector *s*) and θ_{sh}, θ_{sw} and θ_{sr} are the cost parameters associated with their corresponding production factors such that $\theta_{sh} + \theta_{sw} + \theta_{sr} = 1$. A world trade equilibrium condition implies that total sales of the processed commodity *s* are related to total production of the primary good.

$$\sum\nolimits_z M_{szj} = \eta_{sj} \sum\nolimits_z I_{sjz} \tag{10}$$

where $\eta_{sj} = \left(\theta_{sh} h_{sj}^{\theta_{sh}-1} w_j^{\theta_{sw}} r_j^{\theta_{sr}} \right)$ is the conversion factor between primary and processed goods. Substituting the pricing rule in (9) into the import demand function defined in (2) and using the export supply function in (7) yields the equilibrium price for the primary good in each country:

$$h_{sj} = \varphi_{sj}(\cdot) \equiv \left[\eta_{sj}^{-1} \frac{\sum_z \mu_s Y_{sz} \left(\frac{\sigma_s}{\sigma_s - 1} w_j^{\theta_{sw}} r_j^{\theta_{sr}} \right)^{-\sigma_s} \frac{\left(\tau_{szj}^M \varepsilon_{sj}^M \right)^{-\sigma_s} n_{sj}^M}{\sum_{z'} \left(\frac{\sigma_s}{\sigma_s - 1} h_{sz'}^{\theta_{sh}} w_{z'}^{\theta_{sw}} r_{z'}^{\theta_{sr}} \tau_{szz'}^M \varepsilon_{sz'}^M \right)^{1-\sigma_s} n_{sz'}^M}}{\sum_z n_{sz}^I \beta_s^{-\frac{1}{\beta_s - 1}} \rho_{sz}^{-\frac{\alpha_s}{\beta_s - 1}} \frac{\left(\tau_{sjz}^I \varepsilon_{sz}^I \right)^{\gamma_s}}{\left[\sum_{z'} \left(h_{sz'} \tau_{sz'z}^I \varepsilon_{sz}^I \right)^{1+\gamma_s} \right]^{\xi_s}}} \right]^{1/(\theta_{sh}\sigma_s + \gamma_s)} \quad \forall j \quad (11)$$

3. Data and Estimation Strategy

In what follows, the subscript s is dropped because the empirical application focuses exclusively on the bovine meat and cattle sectors. Inserting (11) into the logarithm transformations of the identities of the bilateral trade functions in (3) and (8), and rearranging yields the empirical bilateral trade flows:

$$\ln M_{ij} = \ln Y_i + \ln Q_j^M + \ln \delta_{ij}^M(.) - \ln \lambda_j^M(.) - \sigma \ln \varphi_j(.) + k^M + e_{ij}^M \quad (12)$$

$$\ln I_{ij} = \ln Q_i^{I^d} + \ln Q_j^I + \ln \delta_{ij}^I(.) - \ln \lambda_i^I(.) + \gamma \ln \varphi_i(.) + k^I + e_{ij}^I \quad (13)$$

where

$$\delta_{ij}^M(\cdot) \equiv \frac{\left(\frac{\sigma}{\sigma - 1} w_j^{\theta_w} r_j^{\theta_r} \right)^{-\sigma} \left(\tau_{ij}^M \varepsilon_j^M \right)^{-\sigma} n_j^M}{\sum_z \left(\frac{\sigma}{\sigma - 1} h_z^{\theta_h} w_z^{\theta_w} r_z^{\theta_r} \tau_{iz}^M \varepsilon_z^M \right)^{1-\sigma} n_z^M}; \lambda_j^M(\cdot) \equiv \sum_z Y_z \frac{\left(\frac{\sigma}{\sigma - 1} h_j^{\theta_h} w_j^{\theta_w} r_j^{\theta_r} \tau_{zj}^M \varepsilon_j^M \right)^{-\sigma} n_j^M}{\sum_{z'} \left(\frac{\sigma}{\sigma - 1} h_{z'}^{\theta_h} w_{z'}^{\theta_w} r_{z'}^{\theta_r} \tau_{zz'}^M \varepsilon_{z'}^M \right)^{1-\sigma} n_{z'}^M};$$

$$\delta_{ij}^I(\cdot) \equiv \beta^{-\frac{1}{\beta - 1}} \rho_j^{-\frac{\alpha}{\beta - 1}} \frac{\left(\tau_{ij}^I \varepsilon_j^I \right)^{\gamma}}{\left[\sum_z \left(h_z \tau_{zj}^I \varepsilon_j^I \right)^{1+\gamma} \right]^{\xi}}; \lambda_i^I(\cdot) \equiv \sum_z n_z^I \beta^{-\frac{1}{\beta - 1}} \rho_z^{-\frac{\alpha}{\beta - 1}} \frac{\left(h_i \tau_{iz}^I \varepsilon_z^I \right)^{\gamma}}{\left[\sum_{z'} \left(h_{z'} \tau_{z'z}^I \varepsilon_z^I \right)^{1+\gamma} \right]^{\xi}};$$

k^M and k^I are constant terms[4], e_{ij}^M and e_{ij}^I are stochastic error terms and $\varphi_j(.)$ and $\varphi_i(.)$ are specified as in (11). It is important to note that $Q_i^{I^d}$ is proxied by $Q_i^{I^d} = (\eta_i)^{-1} Q_i^M$ in (13), using

[4] It is important to note that the assumption of monopolistic competition has no qualitative implications in the empirical model as the mark-up $\sigma/(\sigma - 1)$ is absorbed in the constant term of the regression.

the technological relationship (10). The denominator of $\delta_{ij}^{M}\left(\cdot\right)$ and the term $\lambda_{j}^{M}\left(\cdot\right)$ are akin to Anderson and van Wincoop (2003)'s inward and outward multilateral resistance indexes for trade flows of processed goods going from *j* to *i*. Naturally, an increase in trade costs for goods exported into *i* from countries other than *j* increases the trade flow from *j* into *i*. An increase in trade costs for supplier *j* in markets other than *i* causes a surge in trade flow from *j* into *i*. This substitution effect is captured by $\lambda_{j}^{M}\left(\cdot\right)$. A similar interpretation applies for the primary good's multilateral resistance indexes, the denominator of $\delta_{ij}^{I}\left(\cdot\right)$ and the term $\lambda_{i}^{I}\left(\cdot\right)$.

As in Anderson and van Wincoop (2004), a multiplicative trade barrier function is assumed such that it can be decomposed into an *ad valorem* tariff and distance function. The trade barrier specifications for the primary cattle and the bovine meat sectors are:

$$\tau_{ij}^{I}=t_{ij}^{I}d_{ij}^{\psi^{I}}\ ; \qquad \tau_{ij}^{M}=t_{ij}^{M}d_{ij}^{\psi^{M}} \tag{14}$$

where t_{ij}^{I} and t_{ij}^{M} are the *ad valorem* tariffs on cattle and meat, d_{ij} is the distance between countries *i* and *j* and ψ^{I} and ψ^{M} are the trade barriers distance elasticities for cattle and meat. The *ad valorem* measure of support aggregates the *ad valorem* domestic and export subsidy measures.

Transport cost proxies are important variables in gravity models. Previous studies have found that trade elasticities with respect to transport cost and other transaction cost variables are sensitive to the method used to approximate transport cost (Wei, 1996; Helliwell, 1998; Head and Mayer, 2000, 2002). A conventional measure is the greater circle distance between two economic major cities, initially introduced by Wei (1996). Some authors designed more intricate measures that take into consideration the dispersion of economic activity within a region. Head and Mayer (2000, 2002) proposed the following indicator: $d_{ij} = \sum_{a \in i} \left(\sum_{b \in j} \chi_b dist_{ab} \right) \chi_a$, where $dist_{ab}$ is the distance between the two sub-regions *a* and *b* and χ_a and χ_b represents the economic activity share of sub-regions a and b, respectively. The *Centre d'Études Prospectives et d'Informations Internationales* (CEPII) used the above formula to create their data set. Because the latter reports bilateral distances for EU countries individually, we applied the Head and Mayer equation to construct a set of bilateral indicators between the EU as a whole and non-EU countries. We used the same formula to compute the transport cost proxy within the EU. The indicators involving non-EU countries are the CEPII estimates.

Trade volumes of cattle $\left(I_{ij}\right)$ and bovine meat $\left(M_{ij}\right)$ were obtained from the database of the Agricultural Trade Policy Simulation Model (ATPSM, Peters and Vanzetti, 2004).[5] The ATPSM bilateral trade volumes are reported as averages of the 1999-2001 annual trade statistics of the United Nations Conference on Trade and Development (UNCTAD) trade deflator dataset. Trade policies are also taken from the ATPSM dataset. We rely on two separate trade policy variables: *i*) applied tariffs found in the Agricultural Market Access Database (AMAD) administered by the Organization for Economic Co-operation and Development (OECD), and *ii*) exports subsidies as reported by WTO member countries in their notifications to the WTO. Using the Trade Analysis and Information System (TRAINS) dataset, adjustments were made to applied tariffs to account for preferential trade agreements. Our domestic support estimates were taken from the ATPSM database which relied on a UNCTAD compilation of various measures of domestic support that corrects for double counting when domestic and border policies are

[5] The cattle notation is equivalent to the ATPSM livestock sector covering cattle, buffaloes, sheep and goat as specified in the FAO coding system. The ATPSM bovine meat sector covers meat of cattle; offals of cattle, edible; meat of cattle, boneless; meat of beef dried, salted, smoked; meat of buffaloes; offals of buffaloes, edible; as specified in the FAO coding system.

combined into one instrument, as in the case of an administered price for example. Domestic support equivalent measures in the ATPSM dataset include either 2000 or 2001 data depending on the country.

Cattle prices and total production were borrowed from the Food and Agriculture Organization (FAO) Agricultural Producer Price series and FAO Statistical Yearbook, respectively. Production volumes of bovine meat were collected from the FAOSTAT database of the FAO. Estimates of Gross Domestic Product (GDP) were taken from the International Monetary Fund's (IMF) World Economic Outlook Database. Wages in the manufacturing sector $\left(w_j\right)$ were collected from the United Nations Industrial Development Organization (UNIDO) database. The price of capital $\left(r_j\right)$ is proxied by the price of investment in the Penn World Tables. We followed the approach of Antweiler and Trefler (2002) in using the GDP generated by livestock per unit of pasture in 1985 to proxy land rents $\left(\rho_j\right)$ in each country. These variables were obtained from Tables 1.4 and 1.6 of FAO (1992). After adjustments for missing and outlier data, the constructed database includes 46 countries which are listed in table 1A of the appendix.

In order to simulate trade liberalization scenarios, we must first estimate the following structural parameters: σ, γ, ψ^I, ψ^M, β, α, θ_h, θ_w and θ_r. Two issues must be confronted in the estimation of the empirical model. First, cattle prices appear in the resistance indexes in (12) and (13), but from the equilibrium conditions in (10), prices and trade flows are determined simultaneously. Second, zeros are found for 64% of the cattle trade flows and for 42% of the meat trade flows. The left hand-side truncation in the data is addressed with a standard type 1 Tobit procedure as in Haveman, Nair-Reichert and Thursby (2003) and Redding and Venables (2004).

The simultaneity issue could be addressed by relying on full information Maximum Likelihood (ML) techniques, but they are generally computationally intensive (Wooldridge, 2002), especially so in the present case because of the pronounced nonlinearity in the parameters appearing in the multilateral resistance terms. Instead, we use the two-step algorithm of Nelson and Olsen (1978). In the first stage, a reduced form approximation for cattle prices in (11) was used to generate predicted cattle prices. In the second stage, the h_z's in (12) and (13) were replaced by the predicted values, and the cattle and beef bilateral trade functions were estimated by ML subject to the censoring rule. The two-step Nelson and Olsen (1978) algorithm yields a consistent estimator when there is a well defined linear projection of the reduced form.[6] A Non-linear Least squares (NLS) estimator could have been used to estimate (12) and (13), but it was not implemented because of the high proportion of zeros in the dataset and the fact that the variance of NLS estimators is known to be variable in the neighbourhood of corner solutions.[7]

The first stage of our econometric estimation involves estimating a linear approximation of the reduced form for the cattle price defined in (11):

$$\begin{aligned}\ln h_j = {} & \vartheta_0 + \vartheta_1 \ln \overline{d}_j + \vartheta_2 \ln t_j^I + \vartheta_3 \ln t_j^M + \vartheta_4 \ln \varepsilon_j^M + \vartheta_5 \ln \overline{t}_j^{\,I} + \vartheta_6 \ln \overline{t}_j^{\,M} + \vartheta_7 \ln \overline{\varepsilon}_j^M \\ & + \vartheta_8 \ln w_j + \vartheta_9 \ln r_j + \vartheta_{10} \ln \rho_j + \vartheta_{11} \ln n_j^I + \vartheta_{12} \ln n_j + \vartheta_{13} \ln Y_j + u_j \end{aligned} \tag{15}$$

where $\overline{d}_j \equiv \sum_{z \neq j} \omega_z^{GDP} d_{jz}$ is a remoteness variable (Helliwell, 1998) based on the GDP weight of country z $\left(\omega_z^{GDP}\right)$ relative to the aggregate GDP of its trading partners, t_j^I and t_j^M are the applied tariffs for cattle and meat respectively, ε_j^M is the support policy of country j,

[6] Blundell and Smith (1989) show that efficiency gains can be achieved using a similar two-step procedure when the reduced form is linear.

[7] Efficiency gains could be achieved from using weighted NLS in the second stage, but the weights would have to be arbitrarily selected. Khan and Lewbel (2007) propose a weighted two-stage LS estimator for censored problems that is robust to various forms of heteroskedasticity. Its applicability to a non-linear truncated model like ours remains to be investigated.

$\overline{t}_j^{M,I} \equiv \sum_z \omega_{zj}^{M,I} t_{zj}^{M,I}$ is an average outward tariff for cattle and meat with $\omega_{zj}^{M,I}$ the export weight of country j to country z relative to total exports, $\overline{\varepsilon}_j^{M,I} \equiv \sum_z \omega_{jz}^{M,I} \varepsilon_z^{M,I}$ is an inward support policy variable, w_j, r_j and ρ_j are respectively the wage rate, the price of capital and land rent as defined before, n_j^I and n_j are measures of the size of cattle and bovine meat sectors respectively, Y_j is proxied by GDP and u_j is assumed to be a well-behaved stochastic error term.

The OLS results of the cattle price equation in (15) are reported in table 1. Column (i) presents the most general specification for cattle prices while column (ii) presents a more parsimonious specification.[8] The latter was obtained by excluding individual variables that were not significant at the 10 percent level, starting with the variables that had the highest *p*-value.[9] The OLS estimates in column (ii) were used to predict cattle prices which were subsequently inserted into the bilateral trade functions that were estimated with a Tobit model.[10]

Table 2 reports the ML Tobit estimation of the system composed of equations (12) and (13) when cattle prices are instrumented according to (15). Column (i) reports the results of the basic specification. The elasticity of substitution (σ) is highly significant at the 1% level and has a value of 3.2, implying moderate substitutability in consumption between bovine meats of

[8] Given the relatively low degree of significance of the independent variables in explaining cattle prices, we also implemented a robust *M*-estimator which consists of selecting different weights for each observation in order to control for the absolute size of the errors in the regression (Kennedy, 2003). When weights are equal to one, the estimator minimizes the sum of the absolute errors. The procedure is based on iterated weighted least squares. With the robust *M*-estimator, more policy variables have a significant impact on cattle prices, but the effects of several policy variables on the price of cattle were implausibly large. Therefore, we used the ordinary least square procedure to generate the instruments.

[9] Obviously, the distribution of the *t*-statistics in column (ii) of table 1 is subject to the well-known pre-estimation bias (Kennedy, 2003), but standard errors appear small relative to their coefficients.

[10] Because the logarithmic transformation of the trade volume is undefined when trade is null, we added one unit to all observed trade flows.

different origins. The estimate of the elasticity of transformation (γ) is relatively low at 1.9 although its standard error is more than three times smaller. The low estimate of γ is consistent with countries using non-tariff barriers. In the present case, the lack of harmonization in sanitary, phytosanitary and other technical regulations across importing countries implies that diversification is costly. The implied coefficient on distance is -2.4 for the primary cattle sector $(-\gamma \times \psi^{I})$ and -1.9 for bovine meat $(-\sigma \times \psi^{M})$. The estimates of the other parameters have the expected signs and are highly significant. The coefficient on the per-unit cost of cattle production (α) is positive. The estimates of the cost parameters on cattle product and labour in the production of bovine meat, θ_h and θ_w, are positive and significant while the coefficient for capital rent (θ_r) has the wrong sign, but is not significantly different from zero. The value of β is larger than one and is consistent with the second order conditions of profit maximization.

Column (ii) in Table 2 presents estimation results for a slightly different specification of the empirical model. These results explicitly account for the EU import embargo on hormone-treated cattle/beef. It should be noted that part of the impact of the EU embargo is captured by the elasticity of transformation parameter, which measures frictions in substituting destinations in *cattle* trade, and through the cattle price in the EU. The import embargo may be seen as an exporting-country targeted policy that requires special attention. Although the embargo does not discriminate across countries per se (as it applies to all hormone-treated cattle/beef regardless of origin), it affects countries in which the use of growth hormones is widespread such as the US, Canada, Australia and New Zealand. Hence, a dummy variable for all inward bilateral trade flows going to the EU and originating from these four countries was added to the specifications in (12) and (13). The dummy variable is significant at the ten percent level, but its inclusion did not affect very much the estimates of the structural parameters considering how similar they are to the estimates in column (i).

4. Trade liberalization scenarios

The objective of this section is to determine the effects of various policy liberalization scenarios on trade flows using the estimated structural parameters reported in column (i) of Table 2. We simulate the following scenarios: 1) full liberalization which entails the elimination of tariffs and domestic and export subsidies; 2) the elimination of tariffs; 3) removal of export and domestic subsidies; and 4) a (hypothetical) Doha partial liberalization outcome. It is unknown at this stage what concessions are likely to emerge at the end of the Doha round, considering the disparity in the positions of member countries. Nevertheless, a few details have transpired through the official negotiating positions of some WTO members. Our Doha scenario thus includes the total removal of export subsidies as agreed to in the 2004 July framework (WTO, 2004) and a 50% cut in domestic support. The latter policy is based on the proposal by some countries to discipline product-specific domestic support and a 50% cut in trade-distorting domestic support emerges a reasonable and plausible compromise. Tariffs are also lowered depending on whether protection is in the form of a Tariff-Rate Quota (TRQ) or a tariff.[11] The WTO 2004 July framework recognized the notion of sensitive products by stating that a "distinct treatment for tariff cuts" could be applied, as long as it does not prevent "substantial improvement" in market access (WTO, 2004). Hence, the Doha scenario includes tariff cuts of 20% when there are TRQs and 50% in all other instances. It should be emphasized that non-tariff barriers remain in effect in all four scenarios.

[11] TRQs are two-tier tariffs that were introduced at the outset of the UR because the UR tariffication process resulted in prohibitively high tariffs that threatened historic market access for several so-called sensitive products. In many cases, TRQs act *de facto* as import quotas as they set a binding level of imports because in-quota imports are taxed at a very low rate while over-quota imports would be taxed at a very high rate.

There is a considerable amount of intra-industry trade in the cattle/beef industry and thus the results of the liberalization scenarios are sorted out according to their impact on imports and exports. The results are presented in terms of changes (in %) relative to the status quo. Tables 3 and 4 report the impacts of liberalization on exports and imports of cattle for selected countries, respectively. Tables 5 and 6 report the impacts of liberalization on exports and imports of bovine meat for selected countries, respectively. The results presented in Tables 3-6 pertain to a subset of important trading countries. For each of the four liberalization scenarios and each country, the shaded line describes the effect of liberalization in the cattle and meat sectors while the two lines below pertain to liberalization in cattle only and liberalization in meat only. The first line of each country-specific bloc of results in Tables 3-6 reports border effects. The latter are computed for both inward and outward trade flows of cattle and meat and are measured based on Anderson and van Wincoop (2003) concept that contrasts fitted values of trade flows under tariff-only liberalization to the fitted values of trade under the current policy regime. We make a contribution to that particular strand of the literature because our framework allows for contrasting border effects for the tariff-only, subsidy-only and full liberalization scenarios. The latter serves as the baseline to which other trade liberalization scenarios and the status quo are compared.

Formally, let $\hat{M}_{i,\cdot}^{FT}$ and $\hat{M}_{i\cdot}^{SQ}$ measure respectively the fitted value of country *i*'s total beef imports under full liberalization (free trade) and the fitted value of country *i*'s beef imports under the status quo. The inward border effect reported in the full (liberalization) column is measured as $BEM_{i,\cdot}^{FT} \equiv \hat{M}_{i,\cdot}^{FT} \big/ \hat{M}_{i,\cdot}^{SQ}$. In fact, it measures the border effect under the status quo. A border effect in excess of one is indicative of a restricted market access under the status quo. Defining $\hat{M}_{i,\cdot}^{\tau}$ and $\hat{M}_{i,\cdot}^{s}$ as the fitted values of beef imports under tariff-only and subsidy-only liberalization scenarios, we can define inward border effects for beef as: $BEM_{i,\cdot}^{\tau} \equiv \hat{M}_{i,\cdot}^{FT} \Big/ \hat{M}_{i,\cdot}^{\tau}$ and $BEM_{i,\cdot}^{s} \equiv \hat{M}_{i,\cdot}^{FT} \Big/ \hat{M}_{i,\cdot}^{s}$. These measure border effects that remain following the tariff-only and subsidy-only liberalization processes. By the same token, the inward border effect in the Doha liberalization scenario is defined as: $BEM_{i,\cdot}^{Doha} \equiv \hat{M}_{i,\cdot}^{FT} \Big/ \hat{M}_{i,\cdot}^{Doha}$. The last three border effect variables indicate what would happen if the liberalization process was to follow its full course once partial liberalization has been achieved. Similar border effects can be derived for trade in cattle. Let $\hat{I}_{i,\cdot}^{FT}$ be the fitted value of country *i*'s cattle imports under scenario *x*. The cattle inward border effects are thus: $BEI_{i,\cdot}^{FT} \equiv \hat{I}_{i,\cdot}^{FT} \Big/ \hat{I}_{i,\cdot}^{SQ}$, $BEI_{i,\cdot}^{\tau} \equiv \hat{I}_{i,\cdot}^{FT} \Big/ \hat{I}_{i,\cdot}^{\tau}$, $BEI_{i,\cdot}^{s} \equiv \hat{I}_{i,\cdot}^{FT} \Big/ \hat{I}_{i,\cdot}^{s}$ and $BEI_{i,\cdot}^{Doha} \equiv \hat{I}_{i,\cdot}^{FT} \Big/ \hat{I}_{i,\cdot}^{Doha}$. Finally, we can define outward border effects by computing fitted exports of country *i* under scenario *x* $\left(\hat{M}_{\cdot,i}^{x}, \hat{I}_{\cdot,i}^{x}\right)$ to obtain: $BEM_{\cdot,i}^{x} \equiv \hat{M}_{\cdot,i}^{FT} \Big/ \hat{M}_{\cdot,i}^{x}$ and $BEI_{\cdot,i}^{x} \equiv \hat{I}_{\cdot,i}^{FT} \Big/ \hat{I}_{\cdot,i}^{x}$.

As mentioned in the introduction, one advantage of the current methodology over CGE models is that it allows the computation of statistically-consistent confidence intervals around predicted impacts of trade liberalization scenarios. While the parameters of the model may be asymptotically normally distributed, it is difficult to derive the asymptotic distribution of predicted trade flows obtained from a Tobit model. We rely on the simulation techniques of Krinsky and Robb (1986, 1991) to approximate the distribution of the predicted trade patterns.[12] To get the gist of how the procedure can be implemented, consider the general type I Tobit model (Amemiya, 1985):

$$y_i^* = \mathbf{x}_i\boldsymbol{\beta} + v_i; \quad y_i = \max\left\{0, y_i^*\right\}; \quad v_i \big| \mathbf{x}_i \sim N\left(0, \sigma^2\right) \tag{16}$$

[12] Standard bootstrapping methods are not appealing in this instance because the model is highly non-linear.

where the dependent variable y_i measures actual bilateral trade flows and the vector $\mathbf{x}_i$ represents the policy variables and other exogenous covariates. The simulation exercise requires drawing from the joint asymptotic distribution of the parameters' ML estimates $\hat{\boldsymbol{\beta}}$. Let $\boldsymbol{\beta}^b$ denote a draw of a set of parameters. The liberalization scenarios involves fixing the independent variables to $\tilde{\mathbf{x}}_i$ and computing $E\left[y_i\middle|\tilde{\mathbf{x}}_i\right]$ when $\boldsymbol{\beta}=\boldsymbol{\beta}^b$, which yields (Wooldridge, 2002):

$$E\left[y_i\middle|\tilde{\mathbf{x}}_i\right]=\Pr\left[y_i>0\middle|\tilde{\mathbf{x}}_i\right]\cdot E\left[y_i\middle|\tilde{\mathbf{x}}_i,y_i>0\right]=\Phi\left(\tilde{\mathbf{x}}_i\boldsymbol{\beta}^b/\sigma\right)\left[\tilde{\mathbf{x}}_i\boldsymbol{\beta}^b+\sigma\left(\frac{\phi\left(\tilde{\mathbf{x}}_i\boldsymbol{\beta}^b/\sigma\right)}{\Phi\left(\tilde{\mathbf{x}}_i\boldsymbol{\beta}^b/\sigma\right)}\right)\right] \tag{17}$$

with $\phi(\cdot)$ and $\Phi(\cdot)$ denoting the probability distribution and cumulative distribution functions respectively of the normal distribution. This exercise is repeated 1000 times. The simulated series for $E\left[y_i\middle|\tilde{\mathbf{x}}_i\right]$ is sorted in ascending order and the 2.5 and 97.5 percentile values are used as confidence interval bounds. The confidence intervals are reported for the Doha predicted trade flows in Tables 3-7 between brackets.

The most noticeable feature of the border effect estimates displayed in Tables 3-6 is that most of them are small relative to the border effects usually reported in the literature (*e.g.*, Anderson and van Wincoop, 2003, 2004). In fact, many border estimates are below one, thus indicating that imports and exports under a distorted environment are larger than under full liberalization. The structure of protection and intervention in agri-food industries explains this phenomenon as the interaction of tariff protection and support policies can easily produce border effects below unity. Furthermore, the relatively large border effects reported in other studies may be partially explained by the trade-related impacts of sanitary and phytosanitary regulations and other technical barriers to trade that are accounted for in the current study by the elasticity of transformation parameter.

In Table 3, the EU outward border effect in the cattle sector is above one under full liberalization scenario. This indicates that EU cattle exports would increase if tariffs and subsidies were entirely eliminated. More specifically, full liberalization in both the cattle and beef sectors would induce a 5% increase in cattle exports. If full liberalization was restricted to the cattle sector, EU cattle exports would drop by 17%, but full liberalization restricted to bovine meat trade would boost cattle exports by 18%. As expected, the EU border effect drops below unity for the subsidy-only scenario while the border effect of other exporting countries increases above unity. This shows that one's domestic and export subsidies can seriously impact on the world market for meat and livestock products, as argued by Larue and Ker (1993). Moving to full liberalization from the status quo would increase cattle exports of Canada and Mexico. This contrasts with the decreases for the US and Australia under full liberalization. The confidence intervals regarding the changes in exports under the Doha scenario are quite wide. They span over considerable positive and negative values for the EU, the US and Australia.

Table 4 indicates that the inward border effect in the EU for the cattle sector is 0.7 under full liberalization. This means that EU cattle imports would fall by 30% once border protection and subsidies on cattle *and* beef were eliminated. Relative to the status quo, US cattle imports would increase under all scenarios except under the tariff-only scenario which would cause a small reduction of 1.6%. The inward border effects for Japan are well below one which means that its cattle imports would continue falling as all countries move from partial to full liberalization. The border effects for Brazil, Canada and Mexico indicate that these countries would experience import growth as they liberalize whether it is from the status quo or from a partial liberalization starting point. The confidence intervals about Doha outcomes for these three countries reveal that their imports could grow by as little as 7% or by as much as 34%. In contrast, EU cattle imports would fall by a percentage between 15.6% and 31.7%.

The outward and inward border effects for beef trade for selected countries are reported in Tables 5 and 6, respectively. The EU outward border effect is 1.25 for the full liberalization scenario which suggests that total liberalization would lead to a 25 percent increase in EU meat exports compared to the current situation. The full liberalization scenario when restricted to cattle has very little impact on EU exports and imports of beef. This is largely due to the fact that non-tariff barriers remain effective under the liberalization scenarios. In contrast, EU beef exports would fall by 82% under the subsidy-only liberalization scenario (covering cattle and beef) compared to their current level. However, this negative impact on the processed product would be partially offset by the 19% increase in the primary product reported in Table 3. EU exports increase most under the tariff-only scenario. EU bovine meat exports drop sharply under the Doha scenario (60%). These results are consistent with the widely-held perception that subsidies in the EU have important distortions in export and import decisions. They also illustrate the "retaliatory" nature of import tariffs imposed by EU trading partners. The increase in the EU imports is remarkable, scoring a high of 1391% under the full liberalization scenario and 950% under the Doha scenario in Table 6. The EU confidence intervals in Tables 5 and 6 illustrate the large extent by which a partial liberalization Doha scenario could drastically reduce exports and increase imports of beef. Such large changes would be difficult to cope with and this is why the EU has not been supportive of ambitious liberalization proposals in agriculture. The Doha liberalization scenario positively affects outward trade for the US (22%), Argentina (21%) and Australia (14%). Canada would see its current beef exports fall by 8-21% and its beef imports increase by 5-16%. Still, full liberalization would have an even stronger impact on the Canadian beef industry.

Table 7 reports the overall world border effect for the cattle and beef sectors. The border effect for cattle and beef under full liberalization is 1.13 and 1.18, respectively. This means that cattle and beef trade would increase by 13% and 18%, respectively. Glancing at the numbers for cattle-only and meat-only liberalization scenarios, it is obvious that reducing subsidies and tariff on beef only would have much more potent effects than doing the same for cattle only. Fully liberalizing beef would induce an 18% and a 12% increase in beef and cattle trade, respectively, while fully liberalizing the cattle sector would actually reduce beef exports by less than 0.1% and increase cattle trade by only 2.4%. The Doha scenario would increase cattle and beef trade by only 2.1% and 4.1%, respectively, but it would bring about significant changes in market shares among exporting countries.

5. Conclusion

The current round of multilateral talks at the WTO is at an important crossroad. While some progress has been made with respect to disciplining general forms of export subsidies, there are significant disparities between WTO members' negotiating position on market access improvements and reductions in trade distorting domestic support. Most of the lessons that were learned from liberalizing trade in industrial products continue to hold in the current context, but the agri-food markets have important particularities that add a whole host of new issues requiring careful analysis. Trade-distorting support policies and the vertical linkages between upstream and downstream industries must be accounted for when evaluating the impacts of liberalizing agri-food trade.

We develop a gravity-based framework to explain bilateral trade flows of processed agri-food commodities *and* primary agricultural products. The theoretical framework yields empirically tractable bilateral trade flow equations that are estimated to analyze the impacts of trade liberalization scenarios in the cattle/beef markets. The empirical model is a two-stage type I Tobit model which accounts for the significant number of zeros in trade flows between many country pairs and the simultaneity issue between the cattle bilateral export supply functions and meat import demand schedules.

A number of trade liberalization scenarios are evaluated and the results of these critically hinge on two important structural parameters which are the elasticity of substitution for meat and the cattle elasticity of transformation. The substitution elasticity estimate implies that there is a significant product differentiation at the consumers' level with respect to the source of the product. The low estimate of the elasticity of transformation suggests that there are significant impediments to substituting cattle exports across destinations from an exporting country's perspective. One of the advantages of our econometric model over Computable General Equilibrium (CGE) models is that confidence intervals with respect to predicted impacts of trade liberalization can be obtained using conventional bootstrap methods.

The first three selected trade liberalization scenarios feature the elimination of tariffs and domestic and export subsidies, the elimination of tariffs only and the elimination of subsidies. We also simulate a fourth scenario which calls for the elimination of export subsidies, the cutting in half of trade-distorting domestic subsidies and the implementation of tariff cuts that recognize the sensitive nature of the cattle/beef industry in some countries. Despite the uncertainty surrounding the future of the Doha round of multilateral talks, the latter scenario is interpreted as a potential Doha compromise. The US and Australia emerge as the exporting countries that stand to benefit the most from cuts in tariffs and subsidies under the Doha and full liberalization scenarios, as beef imports in the European Union and Japan would significantly increase. Cattle US exports and imports respectively decrease and increase. Canada's cattle imports would increase at a higher rate than its exports under the Doha and full liberalization scenarios. Also, Canada would experience deterioration in its beef trade position as its exports would decrease and its imports would increase under both scenarios. Finally, Argentina's beef trade position would improve due to an increase in exports and a decrease in imports.

Interesting comparisons can be made also across scenarios to detect which countries are likely to push or oppose aggressive cuts in tariffs and/or subsidies. For example, EU beef imports increase much more dramatically under the tariffs-only liberalization scenario than under the subsidies-only liberalization scenario, while for the US, reduction in beef imports are more pronounced when only subsidies are eliminated. Finally, overall trade in cattle and beef would not increase very much if both the cattle and beef sectors were fully liberalized, but the shares of exporting countries would change substantially.

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Table 1. OLS estimates of the reduced form cattle price equation

Variables	(i)	(ii)
Land Rent	-0.06	-
	(0.15)	
Wage	0.22	-0.133
	(0.16)	(0.070)
Price of Capital	-0.22	-
	(0.26)	
Remoteness	-1.02	-0.982
	(0.66)	(0.381)
Intra-national Distance	0.05	0.224
	(0.20)	(0.121)
Cattle output	0.20	-0.188
	(0.25)	(0.069)
Meat output	-0.44	-
	(0.26)	
GDP	0.11	-
	(0.113)	
Applied tariffs (cattle)	-0.13	-
	(1.37)	
Applied tariffs (meat)	-1.26	-
	(0.70)	
Export subsidies (meat)	1.12	-
	(1.64)	
Domestic subsidy (meat)	0.25	-
	(0.65)	
Outward tariff (cattle)	-0.57	-
	(1.35)	
Outward tariff (meat)	-1.59	-
	(1.37)	
Inward export subsidy	6.02	-
(meat)	(3.48)	
Inward export subsidy	-1.39	-
(meat)	(1.43)	

Notes: Standard errors are between parentheses.

Table 2. Maximum likelihood estimates of the structural parameters of the import demand and export supply schedules

Parameters	Basic specification (i)	EU embargo (ii)
σ	3.249	3.278
	(0.286)	(0.292)
γ	1.882	1.957
	(0.533)	(0.564)
ψ^M	0.570	0.564
	(0.066)	(0.066)
ψ^I	1.286	1.232
	(0.392)	(0.381)
α	0.312	0.295
	(0.104)	(0.099)
β	2.028	1.994
	(0.307)	(0.300)
θ_h	0.508	0.514
	(0.058)	(0.058)
θ_w	0.629	0.621
	(0.049)	(0.049)
θ_r	-0.137	-0.135
	(0.071)	(0.070)
υ^M	4.424	4.419
	(0.096)	(0.096)
υ^I	4.768	4.756
	(0.123)	(0.122)
κ^M	-3.392	-3.469
	(1.058)	(1.107)
κ^I	12.038	12.034
	(1.156)	(1.178)
Log-likelihood	-2.733	-2.731

Notes: Standard errors are between parentheses. A total of 1,722 observations are available for each specification. Column (i) report the results of the maximum likelihood estimates of the basic model defined in (12) and (13) with the sum of the parameters for the meat cost function restricted to one in accordance with the constant returns to scale assumption. Column (ii) reports the results when a dummy accounting for the EU embargo on imports of hormone-treated cattle/beef is included. The maximum likelihood function is maximized using the BFGS algorithm (Davidson and McKinnon, 2004).

Table 3. Impacts of various liberalization scenarios on exports of cattle for selected countries

Country	Liberalized Sectors	Full	Subsidy	Tariff	Doha
		Liberalization scenarios			
European Union	Border Effect	1.05	0.88	1.08	1.05
	% Δ (both sectors)	4.71	18.91	-3.07	-0.51 [-7.90;18.70]
	% Δ (cattle)	-17.17	0.00	-17.17	
	% Δ (bovine meat)	17.91	18.91	17.25	
United States	Border Effect	0.95	1.04	0.89	0.97
	% Δ (both sectors)	-5.30	-8.97	6.65	-2.39 [-13.53;5.09]
	% Δ (cattle)	12.79	0.00	12.79	
	% Δ (bovine meat)	-10.17	-8.97	-4.66	
Australia	Border Effect	0.96	1.06	0.97	1.09
	% Δ (both sectors)	-4.20	-9.21	-1.12	0.99 [-8.28;7.22]
	% Δ (cattle)	6.72	0.00	6.72	
	% Δ (bovine meat)	-6.97	-9.21	-4.30	
Canada	Border Effect	1.08	1.01	1.04	1.01
	% Δ (both sectors)	7.84	6.31	3.73	6.26 [-2.73;13.57]
	% Δ (cattle)	11.99	0.00	11.99	
	% Δ (bovine meat)	0.09	6.31	-7.01	
Mexico	Border Effect	1.11	1.03	1.07	1.03
	% Δ (both sectors)	10.77	7.08	3.13	7.91 [-0.35;15.16]
	% Δ (cattle)	9.49	0.00	9.49	
	% Δ (bovine meat)	3.13	7.08	-5.64	

Note: The numbers between brackets under the Doha scenario represent the 95 percent confidence interval for the trade liberalization impacts. The border effect for full liberalization is defined as: $BEM_{i,\cdot}^{FT} \equiv \hat{M}_{i,\cdot}^{FT} / \hat{M}_{i,\cdot}^{SQ}$, where *FT* stands for free trade and *SQ* for status quo. For the other scenarios, the border effect captures the change in exports from moving from partial liberalization scenario *x* to free trade: $BEM_{i,\cdot}^{x} \equiv \hat{M}_{i,\cdot}^{FT} / \hat{M}_{i,\cdot}^{x}$. Conversely, the percentage figures for each liberalization scenario are computed with respect to the status quo situation.

Table 4. Impacts of various liberalization scenarios on imports of cattle for selected countries

Country	Liberalized Sectors	Liberalization scenarios: Full	Subsidy	Tariff	Doha
European Union	Border Effect	0.70	1.46	0.30	0.87
	% Δ (both sectors)	-29.85	-51.93	130.79	-19.79 [-31.67;-15.62]
	% Δ (cattle)	161.07	0.00	161.07	
	% Δ (bovine meat)	-73.13	-51.93	-11.60	
United States	Border Effect	1.18	0.99	1.20	1.04
	% Δ (both sectors)	17.98	18.69	-1.56	13.50 [6.30;23.94]
	% Δ (cattle)	6.40	0.00	6.40	
	% Δ (bovine meat)	10.88	18.69	-7.47	
Japan	Border Effect	0.26	0.65	0.35	0.42
	% Δ (both sectors)	-74.29	-60.66	-27.21	-38.14 [-45.56;-27.85]
	% Δ (cattle)	-0.27	0.00	-0.27	
	% Δ (bovine meat)	-74.22	-60.66	27.01	
Brazil	Border Effect	1.34	1.18	1.17	1.14
	% Δ (both sectors)	33.66	13.19	14.29	17.61 [9.96;28.35]
	% Δ (cattle)	4.28	0.00	4.28	
	% Δ (bovine meat)	28.18	13.19	9.60	
Canada	Border Effect	1.28	1.07	1.21	1.07
	% Δ (both sectors)	27.94	19.56	6.13	19.57 [11.74;34.09]
	% Δ (cattle)	-0.63	0.00	-0.63	
	% Δ (bovine meat)	28.75	19.56	6.80	
Mexico	Border Effect	1.25	1.08	1.18	1.07
	% Δ (both sectors)	25.18	15.39	6.52	17.32 [7.14;26.33]
	% Δ (cattle)	8.56	0.00	8.56	
	% Δ (bovine meat)	15.32	15.39	-1.88	

Note: The numbers between brackets under the Doha scenario represent the 95 percent confidence interval for the trade liberalization impacts. The border effect for full liberalization is defined as: $BEI_{i,.}^{FT} \equiv \hat{I}_{i,.}^{FT} / \hat{I}_{i,.}^{SQ}$, where *FT* stands for free trade and *SQ* for status quo. For the other scenarios, the border effect captures the change in exports from moving from partial liberalization scenario *x* to free trade: $BEI_{i,.}^{x} \equiv \hat{I}_{i,.}^{FT} / \hat{I}_{i,.}^{x}$. Conversely, the percentage figures for each liberalization scenario are computed with respect to the status quo situation.

Table 5. Impacts of various liberalization scenarios on exports of bovine meat for selected countries

Country	Liberalized Sectors	Full	Subsidy	Tariff	Doha
		Liberalization scenarios			
European Union	Border Effect	1.25	7.07	0.66	3.12
	% Δ (both sectors)	24.87	-82.33	87.98	-59.94 [-68.49;-44.66]
	% Δ (cattle)	1.40	0.00	1.40	
	% Δ (bovine meat)	23.15	-82.33	85.39	
United States	Border Effect	1.73	1.86	0.92	1.42
	% Δ (both sectors)	72.85	-7.81	86.65	21.87 [14.06;26.16]
	% Δ (cattle)	-1.48	0.00	-1.48	
	% Δ (bovine meat)	75.43	-7.81	89.44	
Argentina	Border Effect	1.44	1.39	1.02	1.20
	% Δ (both sectors)	44.17	3.91	41.97	20.51 [12.54;27.12]
	% Δ (cattle)	0.60	0.00	0.60	
	% Δ (bovine meat)	43.31	3.91	41.12	
Australia	Border Effect	1.33	1.24	1.03	1.16
	% Δ (both sectors)	32.51	7.00	28.61	13.88 [3.74;20.85]
	% Δ (cattle)	-0.01	0.00	-0.01	
	% Δ (bovine meat)	32.53	7.00	28.62	
Brazil	Border Effect	1.02	1.03	0.95	1.01
	% Δ (both sectors)	1.78	-1.14	7.38	1.31 [-4.81;5.06]
	% Δ (cattle)	-0.10	0.00	-0.10	
	% Δ (bovine meat)	1.88	-1.14	7.48	
Canada	Border Effect	0.84	0.99	0.84	0.96
	% Δ (both sectors)	-15.84	-15.36	-0.38	-12.43 [-20.46;-7.96]
	% Δ (cattle)	-0.46	0.00	-0.46	
	% Δ (bovine meat)	-15.45	-15.36	0.08	

Note: The numbers between brackets under the Doha scenario represent the 95 percent confidence interval for the trade liberalization impacts. The border effect for full liberalization is defined as: $BEM_{i,.}^{FT} \equiv \hat{M}_{i,.}^{FT} / \hat{M}_{i,.}^{SQ}$, where FT stands for free trade and SQ for status quo. For the other scenarios, the border effect captures the change in exports from moving from partial liberalization scenario x to free trade: $BEM_{i,.}^{x} \equiv \hat{M}_{i,.}^{FT} / \hat{M}_{i,.}^{x}$. Conversely, the percentage figures for each liberalization scenario are computed with respect to the status quo situation.

Table 6. Impacts of various liberalization scenarios on imports of bovine meat for selected countries

		Liberalization scenarios			
Country	**Liberalized Sectors**	**Full**	**Subsidy**	**Tariff**	**Doha**
European Union	Border Effect	14.91	5.68	1.42	3.76
	% Δ (both sectors)	1390.88	162.48	950.12	296.65 [165.73;444.50]
	% Δ (cattle)	4.54	0.00	4.54	
	% Δ (bovine meat)	1340.86	162.48	919.22	
United States	Border Effect	0.88	0.99	0.86	0.95
	% Δ (both sectors)	-11.71	-11.52	-0.34	-7.39 [-12.20;-5.50]
	% Δ (cattle)	-0.04	0.00	-0.04	
	% Δ (bovine meat)	-11.71	-11.52	-0.31	
Japan	Border Effect	1.84	1.44	1.03	1.34
	% Δ (both sectors)	84.31	28.07	79.41	37.69 [19.45;59.22]
	% Δ (cattle)	0.05	0.00	0.05	
	% Δ (bovine meat)	84.31	28.07	79.42	
Argentina	Border Effect	0.89	1.03	0.84	0.96
	% Δ (both sectors)	-11.06	-13.66	6.47	-7.47 [-18.44;-1.73]
	% Δ (cattle)	-0.04	0.00	-0.04	
	% Δ (bovine meat)	-11.02	-13.66	6.52	
Brazil	Border Effect	1.05	1.29	0.80	1.07
	% Δ (both sectors)	5.43	-18.44	32.04	-1.76 [-14.50;4.70]
	% Δ (cattle)	0.25	0.00	0.25	
	% Δ (bovine meat)	5.15	-18.44	31.88	
Canada	Border Effect	1.19	1.27	0.92	1.07
	% Δ (both sectors)	19.35	-6.19	29.76	11.33 [5.04;15.76]
	% Δ (cattle)	-0.89	0.00	-0.89	
	% Δ (bovine meat)	20.54	-6.19	31.09	
Mexico	Border Effect	1.13	1.43	0.79	1.12
	% Δ (both sectors)	13.29	-20.77	43.70	0.91 [-8.82;6.00]
	% Δ (cattle)	-0.73	0.00	-0.73	
	% Δ (bovine meat)	14.21	-20.77	44.94	
South Korea	Border Effect	1.22	1.46	0.86	1.17
	% Δ (both sectors)	22.06	16.64	42.45	4.04 [-8.32;10.40]
	% Δ (cattle)	0.07	0.00	0.07	
	% Δ (bovine meat)	22.04	16.64	42.43	

Note: The numbers between brackets under the Doha scenario represent the 95 percent confidence interval for the trade liberalization impacts. The border effect for full liberalization is defined as: $BEI_{i,.}^{FT} \equiv \hat{I}_{i,.}^{FT} / \hat{I}_{i,.}^{SQ}$, where *FT* stands for free trade and *SQ* for status quo. For the other scenarios, the border effect captures the change in exports from moving from partial liberalization scenario *x* to free trade: $BEI_{i,.}^{x} \equiv \hat{I}_{i,.}^{FT} / \hat{I}_{i,.}^{x}$. Conversely, the percentage figures for each liberalization scenario are computed with respect to the status quo situation.

Table 7. Impacts of trade liberalization on world trade

Sector	Liberalized Sectors	Liberalization scenarios: Full	Subsidy	Tariff	Doha
Cattle	Border Effect	1.13	1.09	1.06	1.04
	% Δ (both sectors)	12.93	3.24	6.25	4.07 [-1.97;10.91]
	% Δ (cattle)	2.42	0.00	2.42	
	% Δ (bovine meat)	11.62	3.24	4.48	
Bovine meat	Border Effect	1.18	1.27	0.95	1.02
	% Δ (both sectors)	18.41	-6.41	24.84	2.06 [-4.40;4.52]
	% Δ (cattle)	-0.03	0.00	-0.03	
	% Δ (bovine meat)	17.92	-6.41	24.61	

Note: The numbers between brackets under the Doha scenario represent the 95 percent confidence interval for the trade liberalization impacts. The border effect for full liberalization is defined as: $BEM^{FT} \equiv \hat{M}^{FT} / \hat{M}^{SQ}$, where *FT* stands for free trade and *SQ* for status quo. For the other scenarios, the border effect captures the change in exports from moving from partial liberalization scenario *x* to free trade: $BEM^{x} \equiv \hat{M}^{FT} / \hat{M}^{x}$. Conversely, the percentage figures for each liberalization scenario are computed with respect to the status quo situation.

Appendix

Table 1A-List of Countries

European Union	Colombia	Indonesia	Philippines
United States	Costa Rica	Israel	South Africa
Japan	Dominican Rep.	Korea Rep.	Sri Lanka
Argentina	Ecuador	Malaysia	Syria
Australia	Egypt	Mexico	Thailand
Bangladesh	Ethiopia	New Zealand	Turkey
Bolivia	El Salvador	Nigeria	Uruguay
Brazil	Ghana	Norway	Venezuela
Cameroon	Guatemala	Pakistan	Zimbabwe
Canada	Honduras	Panama	
Chile	India	Peru	