Trade and production impacts of rolling back NAFTA's agricultural preferences:
An application of the systematic heterogeneity general equilibrium gravity model

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Abstract

We explore several scenarios under which NAFTA preferences for agriculture are rolled back using a systematic heterogeneity general equilibrium (GE) gravity model. In the systematic heterogeneity model, the distribution of productivity within the agricultural sector is linked to land and climate characteristics. The set of agricultural products in which a country is likely to have comparative advantage is then influenced by these characteristics. A country's production and bilateral trade response to changes in a competitor's trade costs is thus larger (smaller) for competitors that are more (less) likely to have comparative advantage in a similar set of products. We find that rolling back NAFTA's agricultural preferences depresses consumer demand for agricultural products in North America and decreases the competitiveness of agricultural producers, both within and outside North America. As a consequence, NAFTA members' exports decline in North America and globally.

Introduction

The North American Free Trade Agreement (NAFTA) has dramatically expanded trade within North America. However, the increase in trade has also been accompanied by adjustment in the structure of production within and across industries. In the agricultural sector, NAFTA has contributed to increased importance of Canada and Mexico as destinations for U.S. exports. North America's share of U.S. agricultural exports grew from 18 percent during 1989-93 (the 5 years immediately prior to NAFTA's implementation in 1994) to 28 percent during 2012-16 (USDA/FAS 2017).

NAFTA members are renegotiating the pact, in part as a response to the concerns among some in the United States that the agreement had some major shortcomings. If negotiators cannot agree to new terms, one or more parties could conceivably withdraw from the agreement and its trade preferences could be rolled back or even eliminated.

NAFTA is one of several preferential trade pacts in active (re)negotiation, and a number of other trade agreements have been proposed. The United States has expressed interest in pursuing bilateral deals with several countries, the European Union (EU) is expanding its effort to pursue preferential agreements outside Europe while negotiating the United Kingdom's exit. Many other large agricultural trading nations are involved in similar efforts. However, many preferential trade agreements include special provisions exempting individual agricultural products from commitments to open markets – particularly those perceived to be sensitive to import competition (WTO 2011). The complexities implied by the variation in market access across agricultural products and among trading partners generate interest in developing frameworks for *ex ante* analysis of how changes in preferential treatment could potentially affect producers of exports and consumers of all agricultural products.

In this paper, we use the systematic heterogeneity general equilibrium (GE) gravity model to explore the potential implications of a rollback in NAFTA preferences for agricultural products. Fox, Shikher and Tsigas (2015), Shikher (2012) and Caliendo and Parro (2012) have demonstrated the advantages of GE gravity models pioneered by Eaton and Kortum (2002) relative to Armington style computable general equilibrium (CGE) models commonly used for GE analysis of trade reform. As in other GE gravity models, in the systematic heterogeneity model, countries specialize according to comparative advantage, which is determined by the distribution of productivity and trade costs across products. A gravity-like structural relationship is used to estimate the key parameters that define patterns of production and trade for each sector.

In contrast to other GE gravity models, in the systematic heterogeneity model, the set of products *within the agricultural sector* in which a country is likely to have comparative advantage depends on the suitability of its land and climate. Countries that are well-suited for the production of similar products are thus identified as closer competitors. As a result, the model allows the production and trade response of individual countries to a change in a competitor's trade costs to depend in part on the degree to which the two countries are likely to compete head-to-head in the same products. For example, a loss of Mexico's trade preferences in Canada is predicted to disproportionately benefit Costa Rica and Honduras, since these countries' land and climate make them more likely to specialize in a set of products similar to those in which Mexico has comparative advantage.

In addition, the systematic heterogeneity model allows trade costs to vary across products within sectors. This is important in agriculture where there are large and systematic differences in trade costs across products. These differences stem both from intrinsic product characteristics and from policy. Whereas corn can be stored for long periods of time in large grain elevators and transported inexpensively by container, chilled beef requires more costly handling to avoid spoilage. Likewise, dairy products face systematically higher tariffs than the average agricultural product.

The disadvantage of introducing non-random sources of comparative advantage and trade costs is that the gravity-like structural relationship used to parameterize the model cannot be specified in the log-linear form commonly used in gravity modeling. Instead, we specify the equation relating bilateral trade flows to trade costs and country characteristics as a random coefficients logit model (Berry, Levinsohn and Pakes 1995). This allows a country's sensitivity to changes in a competitor's trade cost to vary across competitors without breaking the agricultural sector into several sub-sectors (Heerman 2016; Heerman, Arita and Gopinath 2015).

Our ability to draw strong conclusions about the magnitude of the potential effects of rolling back agricultural preferences within North America is limited by our data. Nevertheless, we are able to demonstrate the advantages offered by the systematic heterogeneity model for trade policy analysis.

Background on NAFTA and agriculture

NAFTA is a comprehensive economic and trade agreement, implemented in 1994, that establishes a free-trade area encompassing Canada, Mexico, and the United States. In May 2017, the U.S. Trade Representative (USTR) notified the U.S. Congress that the United States planned to renegotiate this agreement. From August to November 2017, the three countries engaged in a series of five rounds to hammer out a new agreement. More rounds of negotiations were anticipated at the time that this paper was written.

NAFTA's tariff schedule is basically structured as three separate bilateral agreements, one between Canada and the United States, a second between Mexico and the United States, and a third between

Canada and Mexico. The U.S.-Canada schedule is drawn from the Canada-United States Free Trade Agreement (CUSTA), which took effect on January 1, 1989, and was subsumed by NAFTA. The second and third schedules are found in NAFTA itself, which took effect on January 1, 1994 (Zahniser, et al. 2015).

Tariff elimination for the items addressed by CUSTA concluded on January 1, 1998. CUSTA exempted certain agricultural products from U.S.-Canada trade liberalization: U.S. imports of dairy products, peanuts, peanut butter, cotton, sugar, and sugar-containing products and Canadian imports of dairy products, poultry, eggs, and margarine. Quotas that once governed bilateral trade in these commodities were redefined as tariff-rate quotas (TRQs) to comply with the Uruguay Round Agreement on Agriculture (URAA), which took effect on January 1, 1995. NAFTA also exempted dairy and poultry products from Canada-Mexico trade liberalization. Canada has been extremely reluctant to consider full trade liberalization of its dairy, poultry, and egg product sectors, which are governed by supply management and protected by high over-quota tariffs—a long-standing position by Canada in international trade negotiations. However, in recent trade negotiations, such as the Comprehensive Economic and Trade Agreement (CETA) with the EU and the Trans-Pacific Partnership (TPP), Canada has shown a willingness to increase its TRQs for selected supply-managed products as part of a larger trade agreement.

Tariff elimination for the agricultural products addressed by NAFTA concluded on January 1, 2008. NAFTA did not exclude any agricultural products from U.S.-Mexico trade liberalization. Numerous restrictions on bilateral agricultural trade were eliminated immediately upon NAFTA's implementation, while others were phased out over periods of 4, 9, or 14 years. Trade restrictions on the last handful of agricultural commodities (including U.S. exports to Mexico of corn, dry edible beans, and nonfat dry milk and Mexican exports to the United States of sugar, cucumbers, orange juice, and sprouting broccoli) were removed in 2008. Similar but not identical restrictions on Canada-Mexico trade also were phased out. The official document expressing the U.S. objectives for the NAFTA renegotiations identifies the maintenance of "existing reciprocal duty-free market access for agricultural goods" as one of the objectives in the area of agricultural goods (USTR 2017).

In the area of sanitary and phytosanitary (SPS) measures, NAFTA recognizes the right of each member country "to adopt, maintain or apply any sanitary or phytosanitary measure necessary for the protection of human, animal or plant life or health in its territory," and like the URAA, NAFTA requires that SPS measures be scientifically based, nondiscriminatory, and transparent, and that these measures restrict trade in a minimal fashion. NAFTA also established NAFTA Committee on Sanitary and Phytosanitary Measures to facilitate technical cooperation between NAFTA countries in developing, applying, and enforcing SPS measures. To fulfill these responsibilities, NAFTA governments have worked to fine tune their SPS measures in ways that facilitate trade and to cooperate on regulatory issues involving trade. Such regulatory cooperation often occurs on a bilateral basis, although NAFTA Committee on Sanitary and Phytosanitary Measures still meets in response to a direct request from any NAFTA government. News reports (see, for example, Brasher (2017)) indicate that U.S. negotiators in the NAFTA negotiations proposed text for SPS provisions similar to those found in the final text of the TPP.

Another important element within NAFTA is the establishment of key principles regarding the treatment of foreign investors. These principles include a firm commitment from each NAFTA country to treat foreign investors from the other member countries no less favorably than it treats its own domestic investors. In addition, the accord prohibits the application of certain performance requirements on foreign investors, such as a minimum amount of domestic content in production. These provisions reinforce similar changes that Mexico made to its foreign investment laws prior to NAFTA. NAFTA also created formal mechanisms for the resolution of disputes concerning the agreement's provisions for investment (Chapter 11) and services (Chapter 14), the final antidumping and countervailing duty determinations of the member countries (Chapter 19), and the general interpretation and application of the agreement (Chapter 20). These mechanisms have provided the framework for addressing disputes on a variety of topics, including U.S. countervailing duties (CVDs) on live swine from Canada, Mexican antidumping duties (ADs) on selected U.S. apples, Mexico's former sales tax on beverages made from sweeteners other than cane sugar, NAFTA's provisions for cross-border trucking between Mexico and the United States, and Canada's application of TRQs allowed under the URAA to U.S. products imported under NAFTA.

As part of the NAFTA renegotiations, the United States is reported to have proposed major changes to the agreement's existing dispute resolution provisions. For Chapter 11, member countries would be allowed to decide whether to "opt in" on a case-by-case basis; for chapter 19, the dispute resoultion mechanism would be eliminated altogether; and for chapter 20, the existing provisions would be substituted with non-binding advisory councils (Wingrove and Martin 2017).

The systematic heterogeneity model

The systematic heterogeneity model builds on the probabilistic Ricardian model of Eaton and Kortum (2002), which captures how the distribution of comparative advantage across products around the world drives production and trade patterns. In the model, the set of products in which a country has comparative advantage is determined by the distribution of productivity within sectors. As in Eaton and Kortum, comparative advantage is product-specific and is generated by differences in productivity. Unlike Eaton and Kortum and other analyses based on their pioneering work, the specific set of products in which a country has comparative advantage within the agricultural sector is systematically influenced by land and climate characteristics rather than entirely by chance. We further allow trade costs to vary across products within the agricultural sector. This allows the influence of comparative advantage on trade to be weaker (stronger) for products for which intrinsic characteristics or policy barriers make them systematically more expensive (inexpensive) to trade.

The Model

The world is comprised of I countries engaged in bilateral trade. Importers are indexed by n and exporters by i. There are two tradable sectors, agriculture and manufacturing, and one non-tradable sector. Tradable sectors are each comprised of a continuum of products indexed by $j \in [0, 1]$. From the buyer's perspective, individual products are distinguished only by their intrinsic characteristics, not by the source country. Countries are endowed with consumers who inelastically supply labor N_i and land L_i. Labor is allocated freely across all three sectors. Land is specific to agriculture. All production is constant returns to scale, and markets are perfectly competitive.

Productivity

Heterogeneous productivity within a sector is generated in part by differences in production technology. As in Eaton and Kortum and the many extensions of their model, we model technological productivity,

$z_i^k\ (j)$, as independently distributed across products following a Frechet distribution with parameters T_i^k and θ:

Equation 1

$$F_{z_n}^k(z) = \exp\{-T_i^k z^{-\theta}\} \qquad k = A, M$$

A high value of T_i^k means that country i is more likely to have a high draw of $z_i^k\ (j)$, implying greater average productivity. A smaller value of $\theta > 1$ implies a larger dispersion of technological productivity. The value of $z_i^k(j)$ is an outcome of an R&D process that, by our independence assumption, can realize higher than average values on any product, regardless of product or country characteristics. The process is equally likely to deliver a high value of $z_{Canada}^A(wheat)$ as it is $z_{Canada}^A(tomatoes)$, regardless of the natural advantage Canada's great plains offer for wheat production versus the disadvantage its cold winters and short summers imply for tomato production. In fact, despite this disadvantage, Canadian producers' use of greenhouse technology has contributed to its ability to be a competitive exporter of some varieties of tomato to the United States.

In the agricultural sector, the distribution of productivity across products has a second component, which is systematically influenced by the characteristics of its land and climate. Product-specific land productivity is represented by the random variable $a_i(j)$, which reflects the suitability of exporter i's natural environment for producing product j. We assume that $a_i(j)$ follows a continuous, parametric density that is a deterministic function of exporter i's agro-ecological characteristics and product j's agro-ecological production requirements. For example, Mexico is likely to have higher values of $a_{Mexico}(tomatoes)$ and would thus be more likely to have comparative advantage in growing tomatoes, all else equal. As such, Mexico is more likely to compete head-to-head with other countries whose climates also make them systematically more likely to have comparative advantage in growing tomato varieties.

Production and Trade

The technology to produce quantity $q_i^k\ (j)$ of tradable product j combines labor, land, and intermediate inputs according to the nested Cobb-Douglas function:

Equation 2

$$q_{k_i}(j) = z_i^k(j)\left(N_i^{\beta^k}(a_i(j)L_i)^{1-\beta^k}\right)^{\alpha^k} \boldsymbol{Q}_i^{k\,1-\alpha^k} \qquad k = A; M \quad \beta^M = 1$$

where $\boldsymbol{Q}_i^k$ is an aggregate of intermediate inputs from all three sectors combined in a Cobb-Douglas fashion as in Caliendo and Parro (2012):

Equation 3

$$\boldsymbol{Q}_i^k = Q_i^{A^{\xi_A^k}} Q_i^{M^{\xi_M^k}} Q_i^{S^{\xi_S^k}} \qquad \sum_{l=A,M,S} \xi_l^k = 1$$

Q_i^A and Q_i^M are individual products from the agricultural and manufacturing sectors combined according to a Dixit-Stiglitz technology with elasticity of substitution $\sigma > 0$ (Equation 4). Equation 3 links the three sectors. A high value of, e.g. ξ_S^A, implies inputs from the services sector are important in the production of agricultural products.

Equation 4

$$Q_i^k = \left(\int_0^1 q_i^k(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}} \qquad k = A, M$$

The services sector produces a homogeneous good using only labor with productivity z_i^S. Producers in exporter i face additional costs $\tau_{ni}^k(j) \geq 1$ to sell a product in import market n. These trade costs are assumed to take the iceberg form, with $\tau_{nn}^k(j) = 1$ and $\tau_{ni}^k(j) \geq \tau_{nj}^k(j)\tau_{ji}^k(j)$.

Differences in trade costs across products influence the extent to which comparative advantage creates trade. As in Eaton and Kortum, we assume trade costs are constant for all manufactured products, i.e., $\tau_{ni}^M(j) = \tau_{ni}^M \; \forall j$. Trade costs are product-specific for agricultural products. We assume agricultural trade costs follow a continuous, parametric density that is a deterministic function of product-specific policies and marketing requirements. We assume $\tau_{ni}^A(j)$ is independent of both $a_i(j)$ and $z_i^A(j)$.

Trade occurs as buyers in market n seek to purchase each product from the source country that offers the lowest price. With perfect competition the prices offered for product j, by exporter i in market n are:

Equation 5

$$p_{ni}^A(j) = \frac{\tilde{a}_i(j) c_i^A \tau_{ni}^A(j)}{z_i^A(j)} \quad and \quad p_{ni}^M(j) = \frac{c_i^M \tau_{ni}^M}{z_i^M(j)}$$

where $\tilde{a}_i(j) = a_i(j)^{-\alpha^A(1-\beta^A)}$ and c_i^k is the cost of a sector k input bundle. For cost-minimizing producers:

Equation 6

$$c_i^k = \kappa^k w_i^{\alpha^k \beta^k} r_i^{\alpha^k(1-\beta^k)} p^{i^A (1-\alpha^k)\xi_A^k} p^{i^M (1-\alpha^k)\xi_M^k}$$

where κ^k is a constant, w_i^k is the wage, r_i^k is the land rental rate, and p_i^k is a price index for intermediate goods produced by sector k.

The set of products in which a country has comparative advantage are those for which it is most likely to have the lowest price offer. As in Eaton and Kortum, the set of manufacturing products in which a country has comparative advantage is determined solely by random realizations of $z_i^M(j)$. Specialization patterns in the agricultural sector are also non-randomly influenced by the distribution of $a_i(j)$ and $\tau_{ni}^A(j)$. A model that does not account for product-specific land productivity based on systemic factors would neither account for Mexico's systematic advantage due to the suitability of its land and climate for tomato production, nor would it account for the systematically larger trade cost advantage of Mexico and Canada in tomatoes compared to, e.g., rice, which is less perishable and therefore easier to store and transport.

Equilibrium

Equilibrium consists of factor prices w_i and r_i, price indices for tradable goods p_i^A and p_i^M, bilateral trade shares π_{ni}^A and π_{ni}^M, and labor allocation rules such that producers and consumers are optimizing, factor and product markets clear, and trade is balanced.

Given the aggregation technology buyers use to assemble individual goods from each sector, Caliendo and Parro (2012) and Shikher (2012) show that our assumptions on the trade costs and technology of the manufacturing sector imply that a unit price index for the manufacturing sector is:

Equation 7

$$p_n^M = \gamma {\Omega_n^M}^{-\frac{1}{\theta}}$$

where $\Omega_n^M = \sum_{l=1}^{I} T_l^M \left(c_l^M \tau_{nl}^M\right)^{-\theta}$, $\gamma = \Gamma\left[\frac{\theta+1-\sigma}{\theta}\right]^{\frac{1}{1-\sigma}}$, and $\Gamma(\cdot)$is the gamma function. Heerman (2016) shows that an agricultural price index is:

Equation 8

$$p_n^A = \gamma\left(\int \Omega_n^A(j)^{\frac{\sigma-1}{\theta}}\, dF_{a_n}(\tilde{\boldsymbol{a}}) dF_{\tau_n}^A(\boldsymbol{\tau}^{\boldsymbol{A}})\right)^{\frac{1}{1-\sigma}}$$

where $\Omega_n^A(j) = \sum_{l=1}^{I} T_l^A \left(\tilde{a}_l(j) c_l^A \tau_{nl}^A(j)\right)^{-\theta}$ and $dF_{a_n}(\tilde{\boldsymbol{a}}) dF_{\tau_n}^A(\boldsymbol{\tau})$ is the joint density of $\tilde{\boldsymbol{a}} = [\tilde{\boldsymbol{a}}_{\boldsymbol{1}}, \dots, \tilde{\boldsymbol{a}}_{\boldsymbol{I}}]$ and $\boldsymbol{\tau}^{\boldsymbol{A}} = [\boldsymbol{\tau}_{\boldsymbol{n1}}^{\boldsymbol{A}}, \dots, \boldsymbol{\tau}_{\boldsymbol{I(I-1)}}^{\boldsymbol{A}}]$ over agricultural products consumed in import market n.

Invoking the law of large numbers, Eaton and Kortum show that the share of expenditure spent on imports from country i is equal to the probability it offers the lowest price:

Equation 9

$$\Pr\left(p_{ni}^M(j) = p_n^M(j)\right) \equiv \pi_{ni}^M = \frac{T_i^M \left(c_i^M \tau_{ni}^M\right)^{-\theta}}{\sum_{l=1}^{I} T_l^M \left(c_l^M \tau_{nl}^M\right)^{-\theta}}$$

An exporter's share of market n's expenditure on a specific agricultural products is likewise equivalent to the probability that it offers the lowest price for that product. Since land productivity and trade costs are distributed independently of each other, this can be expressed as follows:

Equation 10

$$\Pr\left(p_{ni}^A(j) = p_n^A(j)\right) \equiv \pi_{ni}^A = \int \frac{T_i^A \left(\tilde{a}_i c_i^A \tau_{ni}^A\right)^{-\theta}}{\sum_{l=1}^{I} T_l^A \left(\tilde{a}_l c_l^A \tau_{nl}^A\right)^{-\theta}} dF_{a_n}(\tilde{\boldsymbol{a}}) dF_{\tau_n}^A(\boldsymbol{\tau}^{\boldsymbol{A}})$$

This expression is derived in Heerman (2016). Notice that the numerator in Equation 9 and Equation 10 is country i's contribution to the sectoral price index. Thus, if π_{ni}^k is large, production and trade costs in exporter i have a large influence on sector k prices in country n.

The consumer's problem is to choose quantities of individual products $q_i^k(j)$ from all three sectors to maximize utility:

Equation 11

$$u_i(Q) \; = \; Q_i^{A^{\lambda^A}} Q_i^{M^{\lambda^M}} Q_i^{S^{\lambda^S}}$$

subject to the budget constraint: $X_i = \; w_i N_i + r_i L_i$. Here Q_i^k is the sector k's aggregate defined by Equation 4. This utility function implies that consumers spend a constant share λ^k of their total income on products from sector k.

Individual products are purchased by consumers for final consumption and by producers as intermediate inputs. Total demand for sector k's goods is thus:

Equation 12

$$X_i^k = \lambda^k X_i + (1 - \alpha^k)(\xi_k^M Y_k^M + \xi_k^A Y_k^A)$$

where Y_i^k is country i's gross sector k production and $(1 - \alpha^k)(\xi_k^M Y_k^M + \xi_k^A Y_k^A)$ is demand for sector k intermediate inputs.

To solve the model for equilibrium, we follow Levchenko and Zhang (2014). Trade balance and market clearing conditions imply:

Equation 13

$$Y_i^k = \lambda_i^k X_i + \; (1 - \alpha^k)\left(\xi_k^M \sum_{n=1}^{I} \pi_{ni}^M X_n^M + \xi_k^A \sum_{n=1}^{I} \pi_{ni}^A X_n^A\right) \quad k \; = \; A; M$$

First order conditions of the producer's problem deliver optimal labor force allocations:

Equation 14

$$Y_i^k = \frac{w_i N_i^k}{\alpha^A \beta^A}$$

and labor market clearing implies: $N_i = \sum_{k=A,M,S} N_i^k$. Finally, land rent is obtained from the agricultural producer's problem:

Equation 15

$$\frac{r_i L_i}{\alpha^A (1 - \beta^A)} = \frac{w_i N_i^A}{\alpha^A \beta^A}$$

and the non-tradeable sector price index is $p_i^S = w_i$.

Specification and Data

We estimate parameters of the productivity and trade cost distributions for agriculture as in Heerman et al. (2015) by specifying Equation 10 as a random coefficients logit model. For the manufacturing sector, we follow Eaton and Kortum and others and specify a log-linear model from Equation 9. We begin as in

Eaton and Kortum by defining $S_i^k = \ln\left(T_i^k\right) - \theta \ln\left(c_i^k\right)$. This is exporter i's average sector k technological productivity adjusted for unit production costs.

Land Productivity Distribution

We specify $a_i(j)$ as a parametric function of exporter agroecological characteristics and product agro-ecological requirements:

Equation 16

$$ln(a_i(j)) = \boldsymbol{X}_i\boldsymbol{\delta}(j) = \boldsymbol{X}_i\boldsymbol{\delta} + \boldsymbol{X}_i\,(\boldsymbol{E}(j)\boldsymbol{\Lambda})' + \boldsymbol{X}_i(\nu_E(j)\boldsymbol{\Sigma}_E)'$$

where $\boldsymbol{X}_i$ is a $1 \times k$ vector of variables describing country i's agro-ecological characteristics; $\boldsymbol{\delta}$ is a $k \times 1$ vector of coefficients; $\boldsymbol{E}(j)$ is a $1 \times m$ vector of product j-specific agroecological production requirements that can be observed and quantified; $\boldsymbol{\Lambda}$ is an $m \times k$ matrix of coefficients that describes how the relationship between elements of $\boldsymbol{X}_i$ and land productivity varies across products with $\boldsymbol{E}(j)$; and $\boldsymbol{\nu}_E(j)$ is a $1 \times k$ vector that captures the effect of unobservable product j-specific requirements with matrix $\boldsymbol{\Sigma_E}$.

We specify three types of exporter characteristics—agricultural land, elevation, and climate:

$$\boldsymbol{X}_i = [al_i \quad elv_i \quad trp_i \quad tmp_i \quad bor_i]$$

where al_i is the log of arable land per capita, elv_i is the share of rural land between 800 and 3000 meters above sea level, and the remaining elements are the shares of total land area in tropical, temperate, and boreal climate zones. The vector $j = [\boldsymbol{E}(j) \quad \boldsymbol{\nu_E}(j)]$ defines products in terms of their suitability for production under the conditions defined by $\boldsymbol{X}_i$. We define:

$$\boldsymbol{E}(j) = [alw(j) \quad elv(j) \quad trp(j) \quad tmp(j) \quad bor(j)]$$

where $alw(j)$ describes product- j land requirements, $elv(j)$ captures its elevation requirements, and $trp(j)$, $tmp(j)$, and $bor(j)$ describe climate requirements. These variables relate exporter i's agro-ecological characteristics to absolute advantage in agriculture through $\boldsymbol{X}_i\boldsymbol{\delta}$ and describe how they systematically influence the set of products within the agricultural sector in which it has comparative advantage through $\boldsymbol{X}_i\,(\boldsymbol{E}(j)\boldsymbol{\Lambda})'$.

Trade Cost Distribution

We specify product- j trade costs as:

Equation 17

$$ln(\tau_{ni}^k(j)) = \boldsymbol{t}_{ni}\boldsymbol{\beta}^{\boldsymbol{k}}(j) = \boldsymbol{t}_{ni}\boldsymbol{\beta}^{\boldsymbol{k}} + ex_i^k + \boldsymbol{t}_{ni}\,(\boldsymbol{\nu}_{t_n}^k(j)\boldsymbol{\Sigma}_t^k)' + \xi_{ni}^k$$ [1]

[1] Given our assumption that manufacturing trade costs are constant across products, Equation 17 becomes: $ln(\tau_{ni}^M) = \boldsymbol{t}_{ni}\boldsymbol{\beta}^{\boldsymbol{M}} + ex_i^M + \xi_{ni}^M$.

where $\boldsymbol{t}_{ni}$ is a $1 \times m$ vector describing the relationship between exporter i and import market n, $\boldsymbol{\beta}^{\boldsymbol{k}}$ is an $m \times 1$ vector of parameters; ex_i^k is an exporter-specific trade cost captured by a fixed effect; $\boldsymbol{\nu}_{t_n}^k(j)$ is a $1 \times m$ vector that captures the effect of unobservable product j-specific trade costs with scaling matrix $\boldsymbol{\Sigma}_{\boldsymbol{t}}^{\boldsymbol{k}}$, and ξ_{ni}^k captures unobservable or unquantifiable bilateral trade costs that are common across products and orthogonal to the regressors. We define:

$$\boldsymbol{t}_{ni} = [b_{ni} \quad l_{ni} \quad rta_{ni} \quad \boldsymbol{d}_{ni}]$$

where b_{ni}, l_{ni} and rta_{ni} equal one if the two countries share a common border or language or are members of a common regional free trade agreement. The 1×6 vector $\boldsymbol{d}_{ni}$ assigns each country pair to one of six distance categories as defined in Eaton and Kortum (see Table 1).

Table 1: Definition of distance variables

Variable	Distance, miles
Distance 1	[0,375)
Distance 2	[375,750)
Distance 3	[750,1,500)
Distance 4	[1,500,3,000)
Distance 5	[3,000,6,000)
Distance 6	[6,000, maximum]

Estimating Productivity and Trade Cost Distribution Parameters

Using our definitions of $a_i(j)$ and $\tau_{ni}^A(j)$ in Equation 10, we obtain a random coefficients logit model of agricultural market share:

Equation 18

$$\pi_{ni} = \int \frac{\exp\{S_i + \theta\alpha_i(1-\beta_i)\boldsymbol{X}_i\boldsymbol{\delta}(j) - \theta\boldsymbol{t}_{ni}\boldsymbol{\beta}(j)\}}{\sum_{l=1}^{I}\{S_i + \theta\alpha_l(1-\beta_l)\boldsymbol{X}_l\boldsymbol{\delta}(j) - \theta\boldsymbol{t}_{nl}\boldsymbol{\beta}(j)\}} d\hat{F}_{E_n}(\boldsymbol{E}) d\hat{F}\boldsymbol{\nu}_n(\boldsymbol{\nu})$$

where $d\hat{F}_{E_n}(\boldsymbol{E}) d\hat{F}\boldsymbol{\nu}_n(\boldsymbol{\nu})$ is the empirical density of products imported by market n defined jointly by their land and climate characteristics, unobserved agro-ecological requirements and trade costs. We estimate Equation 19 using a simulated method of moments approach similar to that in Berry, Levinsohn, and Pakes (1995), which is detailed in Nevo (2000) and Train (2009). To evaluate the integral, we use the "smooth simulator" suggested by Nevo:

Equation 19

$$\hat{\pi}_{ni} = \frac{1}{ns}\sum_{j=1}^{ns} \frac{\exp\{\tilde{S}_i + \theta\alpha_i(1-\beta_i)\boldsymbol{X}_i\boldsymbol{\delta}(j) - \theta\boldsymbol{t}_{ni}\boldsymbol{\beta}(j)\}}{\sum_{l=1}^{I}\{\tilde{S}_i + \theta\alpha_l(1-\beta_l)\boldsymbol{X}_l\boldsymbol{\delta}(j) - \theta\boldsymbol{t}_{nl}\boldsymbol{\beta}(j)\}}$$

where $\tilde{S}_i = S_i + \theta\alpha_i(1-\beta_i)\boldsymbol{X_i}\boldsymbol{\delta}$ is a country fixed effect. We use the minimum distance procedure suggested by Nevo (2000) to obtain $\hat{S}_i$ and $\boldsymbol{\delta}$ from $\hat{\tilde{S}}_i$. To estimate productivity and trade cost parameters in the manufacturing sector, we follow Eaton and Kortum (2002), Waugh (2010) and others, using S_i^M and the definition of manufacturing trade costs in Equation 9, and then use linear methods to estimate:

Equation 20

$$\ln\left(\frac{\hat{\pi}_{ni}^{M}}{\hat{\pi}_{nn}^{M}}\right) = S_i^M - S_n^M - \theta \boldsymbol{t}_{ni}\boldsymbol{\beta}^{\boldsymbol{M}}$$

Data

Parameters of the distributions of productivity and trade costs are estimated using production and trade data from 2006, the most recent year for which we have a complete data set for both sectors. The age of the data used to parameterize the model is a disadvantage to the extent that the data do not capture structural changes in supply and demand stemming from income and productivity growth, as well as changes in trade and other policies that affect bilateral market access. However, sources of natural resource-based comparative advantage can be assumed to be unchanged, and differences in relative average technological productivity can be assumed to be small. In future work, we will update the model to more recent years by simulating changes in policy and average productivity.

Sector-level bilateral market shares are calculated by dividing bilateral import value by sector-level expenditure, calculated as $X_i^k = Y_i^k + EX_i^k - IM_i^k$. Domestic market share is calculated as $\pi_{nn}^k = 1 - \sum_{i \neq n} \pi_{ni}^k$. For the agricultural sector, our data consist of the 134 agricultural items for which data on both bilateral trade and the gross value of production in U.S. dollars are available (FAO 2013). These are mostly primary agricultural products. Data on bilateral market shares for the manufacturing sector are calculated using 2006 production and trade data from CEPII.[2] Elements of $\boldsymbol{t}_{ni}$ are obtained from the CEPII gravity data set (Head, Mayer and Ries 2009).

Table 2 lists the ten largest agricultural exporters to each North American country and their agricultural sector market shares. Domestic producers have the largest market share in each country by far. The United States has the largest foreign market share in the Canadian and Mexican markets. Among non-NAFTA countries, Indonesia, Chile, Costa Rica, and Brazil have the largest shares of individual exporters to North America.

Tables 13-15 list the top agricultural imports in our data set for Canada, Mexico and United States. Fresh fruit and vegetables and tropical products like coffee represent the bulk of U.S. and Canadian imports in our data set. Mexico's largest imports are bulk field crops – corn, soybeans, wheat, and cotton – and meats.

We do not observe land and climate requirements for each product, but we do observe conditions of their production around the world. We use observable characteristics of exporting countries to construct a matrix of "observable" product requirements, $\boldsymbol{E}(j)$, for each of the $J = 134$ items for which the FAO publishes both production and trade data. This approach is valid under two assumptions. First, $\boldsymbol{E}(j)$ is distributed across products following the empirical distribution of requirements for agricultural products defined at the "item" level by the FAO. Second, exporting is positively correlated with high natural resource productivity. We measure $elv(j)$ and $alw(j)$ as in Heerman et al. (2015) as the export-weighted average of exporters' share of land at high elevation (elv_i) and arable land per agricultural worker (alw_i), using data on arable land per capita and land per agricultural worker from World Bank (2012) and elevation data from CIESIN (2010), respectively.

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[2] Manufacturing production value is interpolated from previous years for some countries.

Notice that we define the land intensity of product j using data on land per agricultural worker, whereas we use agricultural land per capita in $\boldsymbol{X}_i$. The motivation for this distinction is that elements of $\boldsymbol{X}_i$ represent the factors that influence exporter i's potential comparative advantage, whereas elements of $\boldsymbol{E}(j)$ represent the ideal conditions under which product j is produced. Products are represented by their observed production conditions, but countries are represented by their potential production conditions.

Defining product requirements as export-weighted averages of country characteristics has the potential of being imprecise. Many important agricultural exporters have varied terrain and climate within their borders. For example, Canada supplied about 20 percent of global wheat exports in 2006. However, while a large share of Canada's total land area is in the boreal climate zone, the country's wheat production is concentrated in temperate regions. A trade-weighted average of climate distributions would thus misrepresent wheat's climate requirements.

We improve on the measurement of product-specific climate requirements used in Heerman et al. (2015), taking advantage of information on product-specific production across climate zones within countries provided by the GTAP land use database (Lee, et al. 2005). As part of an effort to model the impact of climate change on the agricultural sector, the database provides estimates of land rent for ten product categories in 18 agro-ecological zones (AEZs) within in each of several countries.

An AEZ is a defined zone based on soil, landform and climactic characteristics. A country's estimated land rent in AEZ x for crop y is calculated by by apportioning the crop's total land rent across AEZ's in proportion to its share in the value of crop y production. To calculate product climate requirements, we assign each of the crops in our data set to one of the ten GTAP aggregates. We then calculate the share of land rent in each zone and aggregate these shares into a distribution of land rent across tropical, temperate and boreal climate zones for each product, country pair. Finally, we define product j climate requirements as the export-weighted average of these land rent distributions. The GTAP land use database does not calculate a distribution of land rent across climate zones for animal products. We use export-weighted averages of country climate distributions, as we did for land and elevation intensity, to calculate $[trp(j) \quad tmp(j) \quad bor(j)]$ for these products.

The $ns = 900$ products used to evaluate Equation 20 for each importer and its trading partners are drawn from $d\hat{F}_{E_n}(\boldsymbol{E})d\hat{F}\boldsymbol{v}_n(\boldsymbol{v})$. We construct this density as in Heerman et al. (2015), first using FAO item level import data to estimate $d\hat{F}_{E_n}(\boldsymbol{E})$, the empirical distribution of $\boldsymbol{E}(j)$ across products imported by each market by compiling a list of 1,000 imported items defined by the vector $\boldsymbol{E}(j)$ for each market n. Unique values of $\boldsymbol{E}(j)$ are represented in $d\hat{F}_{E_n}(\boldsymbol{E})$ in proportion to the associated FAO item's share in total imports. That is, if 15 percent of importer n's total agricultural imports consist of the FAO item "wheat," then $E(wheat)$ makes up 150 entries on $d\hat{F}_{E_n}(\boldsymbol{E})$. Next we make uniform draws of $\boldsymbol{E}(j)$ from each country's distribution. The distribution is completed by associating each item on the list with $v_n(j) = [\boldsymbol{v}_{\boldsymbol{E}}(j) \quad \boldsymbol{v}_{\boldsymbol{t}_n}(j)]$ drawn from a standard multivariate normal distribution, effectively generating a "data set" of 900 unique products imported by each market.

Table 2: Share of NAFTA agricultural expenditure, selected countries (percent)

USA		**Canada**		**Mexico**		**North America Total**

Exporter	Share		Exporter	Share		Exporter	Share		Exporter	Share
Canada	1.76		Canada	63.49		Canada	1.88		Canada	7.55
USA	87.94		USA	19.95		USA	14.20		USA	77.76
Mexico	2.51		Mexico	2.73		Mexico	81.86		Mexico	6.64
Indonesia	1.06		Chile	1.49		Chile	0.57		Indonesia	1.03
Chile	0.92		Indonesia	1.29		Indonesia	0.17		Chile	0.96
Costa Rica	0.59		Colombia	1.23		Costa Rica	0.15		Costa Rica	0.60
Brazil	0.56		Costa Rica	0.93		Honduras	0.12		Brazil	0.56
Colombia	0.50		Brazil	0.83		Brazil	0.12		Colombia	0.55
Italy	0.40		Italy	0.79		Spain	0.11		Italy	0.42
Thailand	0.29		China	0.78		Australia	0.11		Thailand	0.30
Peru	0.29		N. Zealand	0.52		Sri Lanka	0.10		Peru	0.29
Ecuador	0.29		Thailand	0.51		Argentina	0.10		Ecuador	0.28
Australia	0.26		Cote d'Ivoire	0.47		China	0.09		China	0.27

In addition to the estimated parameters that define the productivity distribution, computing world equilibrium requires data on labor and land endowments, values for utility and production function parameters, and the elasticity of substitution, σ. Data on arable land in hectares and total labor force are obtained from the World Bank World Development Indicators (World Bank 2012). Table 3 summarizes all structural parameters.

Table 3: Summary of parameter values

Parameter	Value	Source
$\boldsymbol{\delta}, \boldsymbol{\Lambda}, \boldsymbol{\Sigma_E}$	Table 4	Estimated from Equation 19
$\boldsymbol{\beta^A}, \boldsymbol{\Sigma_t}, \boldsymbol{ex^A}$	Table 5 and Table 16	
$\boldsymbol{\beta^M}, \boldsymbol{ex^M}$	Table 5 and Table 16	Estimated from Equation 21 Manufacturing estimating equationEquation 21
$\boldsymbol{T}^A, \boldsymbol{T}^M$	*Not reported*	Estimates of $\tilde{\boldsymbol{S}}^A$ and $\boldsymbol{S^M}$
$\lambda^k, \alpha^k, \xi_l^k$	Table 11 and Table 12	Input-Output Tables (OECD 2013)
β	0.66	Gollin (2002)
θ	4.12	Simonovska and Waugh (2014)
σ	2.00	Ruhl (2008)

Estimated productivity distribution and base model solution

Land Productivity Distribution

Table 4 contains estimates for the land productivity distribution parameters $\boldsymbol{\delta}$, $\boldsymbol{\Lambda}$, and $\boldsymbol{\Sigma_E}$. The total effect of each exporter characteristic in $\boldsymbol{X}_i$ on the probability of comparative advantage in a given product, $\pi_{ni}(j)$ is the sum of the mean effect in the first column and the product-specific effects in the columns that follow.

Table 4: Land Productivity Distribution Parameter Estimates

Exporter Characteristics (X_i)	**Mean Effects (δ)**	**Unobserved Reqs (Σ_E)**	**Agro-Ecological Requirements (Λ)**				
			$elv(j)$	$alw(j)$	$trp(j)$	$tmp(j)$	$bor(j)$
ln Arable Land per Ag Worker	0.17***	-0.01	-4.51***	0.42***	1.81***	0.33***	-2.14
High Elevation	1.14***	-0.21	47.96***	0.44***	1.31***	-12.32***	11.01
Tropical Climate Share	0.7***	-0.16**	-3.96***	0.73***	6.86***	0.19	-7.04
Temp. Climate Share	0.19***	-0.03	1.46***	-0.53***	-2.8***	0.7***	2.1
Boreal Climate Share	-0.88***	0.19**	2.5***	-0.2***	-4.06***	-0.89***	4.94

***significant at the 1% level, ** significant at the 5% level, *significant at the 10% level.
Note: Values in this table are inclusive of the term $\theta\alpha_i(1-\beta_i)$

Coefficients on all climate variables are normalized to sum to zero. As such, coefficients on exporter climate characteristics are interpreted with respect to the average climate, and the effects of product-specific climate requirements are interpreted with respect to the average production requirement. The positive mean effect on tropical land share ($\delta_{trp} = 0.7$) implies that having more than the average share of land in a tropical climate increases agricultural market share on average. The positive and larger coefficient on $trp(j)$ ($\lambda_{trp,trp} = 6.86$) implies this effect is increasing for products that are more intensively tropical than average. Negative coefficients imply the advantage of tropical land is decreasing for more intensively boreal products ($\lambda_{trp,bor} = -7.4$) and elevation-intensive products ($\lambda_{trp,elv} = -3.96$).

The mean effect of a higher than average amount of land at high elevation acreage is positive ($\delta_{elev} = 1.14$). This implies that having more land at high elevation increases agricultural market share on average. However, this benefit is substantially diminished for products more intensively produced in temperate climates than the average product ($\lambda_{elev,tmp} = -12.32$). In contrast, the benefit is greatly magnified for products that are more intensely boreal than the average product ($\lambda_{elev,bor} = 11.01$). Boreal climates are associated with high elevation, therefore we expect to see countries with higher than average acreage at high elevations are more likely to specialize in boreal crops. The statistically and economically insignificant value of the estimated coefficient on unobservable product characteristics ($\sigma_{elev} = -0.21$), implies that variation in the effect of high elevation across products is sufficiently explained by the product requirements in $\boldsymbol{E}(j)$.

Estimates for $\hat{\hat{S}}_i^A$ and $\hat{S}_i^M$ are listed in Table 16. These values are normalized to sum to zero and are thus interpreted as average sector-level productivity relative to the average country, and in the case of agriculture, in the average product. Recall that $\hat{\hat{S}}_i^A$ and $\hat{S}_i^M$ are increasing in average technological (and land productivity in the agricultural sector), but decreasing in costs of production c_i^k. Therefore, a country with high average productivity may nevertheless have a small $\hat{S}_i^k$ if it has, e.g., very high wages or land rental rates. Values of $\hat{T}_i^k$ are obtained from $\hat{S}_i^k$ as in Waugh (2010).

Trade Costs

Table 6 contains estimates for the agricultural trade cost distribution parameters $\boldsymbol{\beta^A}$ and $\boldsymbol{\Sigma_t^A}$ and the manufacturing trade cost parameters $\boldsymbol{\beta^M}$. Positive coefficient values in $\boldsymbol{\beta^A}$ and $\boldsymbol{\beta^M}$ imply higher trade costs, but lower expected market share. Elements of $\boldsymbol{\Sigma_t^A}$ capture heterogeneity in the effect of each element of $\boldsymbol{t}_{ni}^{A}$ across agricultural products and can thus be interpreted like a standard error around the mean effect.

In the agricultural sector, positive mean effects imply that sharing a common language and participating in an RTA increases market share on average, while negative coefficients imply increasing distance tends to decrease it. The negative mean effect of sharing a border ($\beta_b^A = -1.76$) may seem counterintuitive. However, the relatively larger magnitude of the estimated standard error ($\sigma_b = 3.13$) implies sharing a border increases market share for some products and decreases it for others. Sharing a border may reduce trade in individual products for a number of reasons. For example, agricultural policies often systematically advantage domestic producers relative to their close competitors.

Coefficient estimates on the components of trade costs in the manufacturing sector are generally similar to the agricultural sector. Smaller magnitude coefficients on the distance variables suggest in manufactured products are less costly to transport than agricultural products on average. This is sensible since agricultural products are often perishable or otherwise require special handling. The positive and significant effect implies sharing a border unambiguously increases manufactured products market share on average ($\beta_b^M = 0.82$).

Values of $\widehat{ex}_i^k$ are reported in Table 16. The values are normalized to sum to zero, so positive (negative) values imply that exporter i is a lower (higher)-than-average-cost exporter. Our results suggest that Belgium, Canada and the United States are the lowest-cost exporters of agricultural products. The United States and the Netherlands are the lowest-cost exporters of manufactured products.

Table 5: Trade Cost Distribution Parameters

	Agriculture			Manufacturing
Country Pair Characteristics	**Mean Effect ($\boldsymbol{\beta^A}$)**	**Unobserved Heterogeneity ($\boldsymbol{\Sigma_t}$)**		**Mean Effect ($\boldsymbol{\beta^M}$)**
Common Border	-1.76***	3.13***		0.82***
Common Language	1.24***	0.95***		1.10***
Common RTA	0.19**	-0.11		0.11
Distance 1	-5.28***	2.36***		-4.54***
Distance 2	-7.67***	2.33***		-4.96***
Distance 3	-7.43***	-0.16		-5.42***
Distance 4	-9.95***	1.37***		-5.71***
Distance 5	-11.56***	-0.04		-7.09***
Distance 6	-12.94***	0.64***		-7.67***

*** significant at 1%, ** significant at 5%, *significant at 10%.
Note: Values in this table are inclusive of the term θ.

General Equilibrium Solution

We use a two-step process similar to that outlined in Levchenko and Zhang (2014) to solve the model. In step one, given a vector of unobserved trade costs ($\bar{\boldsymbol{\xi}}$), the data, the parameters described in Table 3, and an initial guess for a vector of wages, ($\bar{\boldsymbol{w}}$), land rent, ($\bar{\boldsymbol{r}}$), we solve for equilibrium, beginning by solving for $\boldsymbol{p^A}$ and $\boldsymbol{p^M}$ consistent with the guessed values (Equation 7 and Equation 8), and simulating the integral in Equation 8 as:

Equation 21

$$p_n^A = \frac{\gamma}{ns}\left(\sum_{j=1}^{ns} \Omega_n^A(\bar{\boldsymbol{w}}; j)^{\frac{\sigma-1}{\theta}}\right)^{\frac{1}{1-\sigma}}$$

using the same ns products used to estimate Equation 20.

We then calculate the cost of an input bundle in each tradeable sector (Equation 6), consumer final demand, $X_i^k = \lambda^k(w_i N_i + r_i L_i)$, bilateral market shares (Equation 9 and Equation 10, simulating the integral as above), total demand for each sector (Equation 12), labor allocations (Equation 14) and land rental rates (Equation 15). We adjust the vector of guessed wages until labor market clearing conditions hold. In the next step, $\bar{\boldsymbol{\xi}}$ is adjusted until observed and predicted trade shares are sufficiently close.

Rolling back NAFTA

To explore the effects of rolling back NAFTA preferences for agricultural products we run several scenarios in which we increase trade costs on a product or set of products and then re-solve the model for a new equilibrium.[3] Scenario 1a represents a full dissolution of NAFTA. This is implemented in the model by increasing trade costs individually on the 49 products that represent the bulk of trade within North America by the amount of the relevant applied MFN tariff (Table 17).[4] We use the changes in trade and consumer welfare implied by this scenario as a baseline against which we compare other scenarios.

Table 6: Summary of NAFTA scenarios

Scenario1a: Full dissolution of NAFTA	Tariffs on all agricultural products in **Error! Reference source not found.** are increased to MFN levels (Table 17).
Scenario 1b: U.S. withdrawal	Tariffs on all agricultural products in **Error! Reference source not found.** are increased to MFN except for trade between Canada and Mexico (Table 17).
Scenario 2a: U.S. imposes duty on seasonal imports from Mexico	25% duty on U.S. fresh fruits and vegetable imports from Mexico.
Scenario 2b: Mexico retaliates with duty on seasonal imports from the United States	25% duty on fresh fruits and vegetables traded between the United States and Mexico.
Scenario 3: NAFTA is dissolved and Mexico lifts its MFN tariff on corn to bound levels	Scenario 1a changes plus the MFN tariff on corn is increased to the 191.51% bound level.

In Scenario 1b the U.S. unilaterally withdraws from NAFTA agricultural preferences while bilateral trade between Mexico and Canada remains duty-free. In Scenarios 2a and 2b, a 25 percent anti-dumping duty

[3] We implicitly assume current tariffs in North America are zero in conducting these scenarios.
[4] We use the most recent reported applied MFN tariff in the UNCTAD TRAINS database. For products without applied MFN tariffs in the database we interpolate the tariff value from other information.

is applied on seasonal products. In Scenario 2a the United States imposes a duty on fresh fruit and vegetable imports from Mexico. In scenario 2b Mexico retaliates with its own import duty on these products from the United States. These scenarios are implemented in the model by raising trade costs on each of the fresh fruits and vegetables listed in Table 17 by 25 percent.

In Scenario 3, in addition to the dissolution of NAFTA, Mexico raises its MFN tariff on corn imports from the 13 percent weighted average applied level to the 191.51 percent weighted average bound in its WTO schedule.[5] Without NAFTA agricultural preferences, imports of U.S. corn are subject to MFN tariffs. Thus, in accordance with WTO rules, unlike other scenarios where changes in trade costs are confined to North America, corn tariffs increase for all countries except for the 33 countries in our data set with which Mexico has a preferential trade agreement.[6]

Consumer welfare effects

We measure the impact of each rollback scenario on consumer welfare in terms of total per capita income divided by the price level, as in Levchenko and Zhang (2014). That is:

Equation 22

$$W_i = \frac{w_i + r_i l_i}{P_i}$$

where $l_i = \frac{L_i}{N_i}$ and $P_i = \prod_{k=A,M,S} \left(p_i^k / \lambda^k\right)^{\lambda^k}$.

In scenario 1a and 1b, price increases and consumer welfare losses in percentage terms are smallest in the United States and highest in Mexico (Table 7). In part this can be explained by policy differences. The United States and Canada apply much lower MFN tariffs than Mexico (Table 17). The increase in prices of North American imports due to higher is correspondingly smaller. The relatively small impact of rolling back NAFTA agricultural preferences on p_{USA}^A is also due to the large share of expenditure that goes to domestic producers (see Equation 8).[7] When the U.S. unilaterally withdraws from NAFTA preferences on agricultural products (Scenario 1b), U.S. and Mexican consumer welfare loss is only very slightly larger than the baseline scenario. Canadian consumer welfare loss is significantly smaller.

Table 7: Agricultural price and consumer welfare responses to NAFTA scenarios

Scenario	**Importer**	**% Change in p^A**	**%Change in W**	**Ratio of %Change in W to %Change in W, Scenario 1a**
Scenario 1a: Baseline NAFTA dissolution	Canada	0.16%	-0.75%	--
	USA	0.15%	-0.36%	--

[5] Bound and applied weighted averages for corn are calculated by the authors.
[6] Mexico has PTAs with Chile, the European Union, the European Free Trade Association, Uruguay, Japan, Colombia, Israel, Peru, Central America and Panama.
[7] The U.S. domestic share of expenditure is 87.94%. For Canada it is 63.49% and for Mexico it is 87.86%.

	Mexico	2.18%	-3.38%	--
Scenario 1b: U.S. withdraws from NAFTA	Canada	0.17%	-0.53%	0.71
	USA	0.14%	-0.35%	0.97
	Mexico	1.90%	-3.27%	0.97
Scenario 2a: U.S. applies 25% duty as remedy on Mexico seasonal products	Canada	0.08%	0.52%	-0.69
	USA	0.44%	-0.67%	1.86
	Mexico	-0.88%	-5.22%	1.54
Scenario 2b: Scenario 2a plus Mexico applies 25% duty as remedy on U.S. seasonal products	Canada	0.08%	0.52%	-0.69
	USA	0.44%	-0.68%	1.89
	Mexico	-0.50%	-5.88%	1.74
Scenario 3: NAFTA ends and Mexico lifts corn tariff to bound level	Canada	0.23%	-0.79%	1.05
	USA	0.21%	-0.47%	1.31
	Mexico	12.82%	-28.55%	8.45

In scenarios 2a and 2b, U.S. consumer welfare falls almost twice as much (1.86 times) as the baseline and Mexican consumers lose 1.5 times more. The effect is larger in Scenario 2b when Mexico retaliates with a duty on imports from the United States, but the difference primarily falls on its own consumers' welfare. Canadian consumer welfare increases.

When NAFTA dissolution is accompanied by dramatically increased MFN tariffs on Mexican corn imports (scenario 3), the loss to Mexican consumers is more than eight times larger than the baseline NAFTA dissolution. Consumer welfare in the United States and Canada also deteriorate more than the baseline, but the difference is small.

The value of agricultural exports within North America declines substantially under the baseline scenario, as does the value of each country's global agricultural exports (Table 8). The percent decline in global export value is smallest for the U.S. and largest for Mexico. However, since U.S. global exports of the products in our data set are 3.6 times larger than Canada's and almost six times Mexico's an equivalent percent change represents a larger loss in value. In contrast, the percent decline in agricultural exports within NAFTA is largest for the United States and smallest for Mexico. Notice that Mexico's global export value falls just slightly more than its North American export value, reflecting the dominance of the United States as a destination for Mexican exports: The United States is the destination for 73.4 percent of Mexican agricultural exports in our data set.

Table 8: Changes in export value, NAFTA Scenarios

	Canada		**USA**		**Mexico**	
	Percent change in agricultural export value					
	Global	NAFTA	Global	NAFTA	Global	NAFTA
Scenario 1a	-1.61%	-5.33%	-0.94%	-5.99%	-4.29%	-4.75%
Scenario 1b	-0.95%	-2.97%	-0.95%	-6.10%	-3.80%	-4.25%
Scenario 2a	1.76%	6.23%	-0.46%	-0.69%	-14.68%	-18.97%
Scenario 2b	1.77%	6.29%	-0.52%	-1.15%	-14.92%	-19.18%

Scenario 3	-1.47%	-4.83%	-1.00%	-6.35%	-7.44%	-7.63%

The largest penalty on the value of Mexico's exports occurs in scenario 2a and 2b. Fresh fruits and vegetables make up just over two-thirds of Mexico's exports to the United States. U.S. exports decline more in scenario 2b, when its products face a higher duty in Mexico, than in scenario 2a. However, unlike for Mexico the loss is smaller than the baseline scenario. U.S. export value still falls in scenario 2a even though none of its exports are subject to higher tariffs. The decline can largely be attributed to lower demand from Mexico, where consumers have lost about five percent of their income (Table 7). The import duty also has an impact on U.S. competitiveness, as it increases the cost of production through p_{USA}^{A} (Equation 6) increases more in this scenario than the baseline (see Table 7).

In scenario 3, Mexico raises tariffs on corn, a highly valuable U.S. export. U.S. export value consequently falls more than it does in the baseline. Interestingly, although tariffs faced by its producers are identical to the baseline, Mexican export value falls more under scenario 3 than under the baseline. This can be attributed in part to depressed demand from lower incomes in Canada and the United States, but here the higher costs of production for agricultural products that use corn as an input are likely a more important factor. While Canadian and U.S. incomes decline slightly more than the baseline scenario, p_{Mex}^{A} increases by 12.82 percent compared to 2.18 percent in the baseline (Table 7). The importance of agricultural products as inputs is captured by the parameter $\xi_{A}^{A} = 0.37$ (see Equation 3). Since this is held constant across products, it does not capture the fact that corn is a particularly important intermediate input in the production of the animal products in our data set. As such, the effect may be understated.

Table 9 illustrates shifts in North American trading patterns resulting from a rollback of NAFTA agricultural preferences through each country's bilateral *import*s. The first three columns list the percent change in the value of each North American country's agricultural imports from selected countries under the baseline scenario. The next three columns list the corresponding value of that change. The remaining columns compare changes in import value under each scenario to the baseline.

In the baseline scenario, expenditure increases more on domestic products than products from any individual importer. U.S. producers increase the value of domestic sales by $1.9 billion. However, for the United States and Canada, the loss of exports in North America exceeds the increase in expenditure on domestic products. U.S. exports to Canada and Mexico fall by $2.3 billion. The relatively large percent changes in Mexico's imports from outside of North America represents significant diversification, primarily away from the United States. The corresponding changes in import value nevertheless remain small, emphasizing the tremendous advantage U.S. producers have in the Mexican market. With unilateral U.S. withdrawal from NAFTA agricultural preferences (Scenario 1b) the decline in U.S. imports from Canada is slightly larger (1.06 times) than in the baseline NAFTA dissolution scenario and the decline in imports from Mexico is slightly smaller (0.94 times).

Costa Rica, Colombia, Chile, Indonesia, Australia and Brazil are the primary beneficiaries of the dissolution of NAFTA. In the baseline scenario, Costa Rica's exports to North America increase by a total of $72 million, Colombia's increase by $59 million. This suggests these countries compete head-to-head with the United States, Canada and Mexico in several products in North American markets. These countries are among the ten largest exporters to North America outside of NAFTA (Table 2), with the exception of Australia, which is the eleventh largest exporter.[8] However, increase in export value are relatively small for China, Ecuador, Italy and Thailand (Table 2). This suggests these countries are less likely to compete head-to-head with NAFTA members in agricultural products in North America. When Mexican trade costs in Canada fall relative to the baseline in scenario 1b, Canada's imports from Honduras and Costa Rica fall relative to the baseline even though imports from all other countries increase. The model thus captures that when Mexico maintains its preferences in the Canadian market, Canadian buyers are less likely to substitute toward Mexico's closest competitors.

This demonstrates an important feature of the systematic heterogeneity model relative to other GE gravity models. It is the assumption that heterogeneity in productivity is assumed to be independently distributed across products that allows the structural relationship between trade flows and trade costs to be log-linearized and take the form of a standard gravity equation. However, the assumption also imposes a close link between the response to changes in competitors' trade costs and a country's initial market share, abstracting from the degree to which the country is likely to compete head to head in the same products as its competitor. This is discussed in detail in Heerman (2016) and Heerman et al (2015).

[8] Australia is in the top ten exporters to the United States and Mexico.

Table 9: Changes in import flows for selected countries

Scenario 1	% change in import flows			Change in import value ($million)			Ratio: Change in import value relative to Scenario 1a											
							Scenario 1b			Scenario 2a			Scenario 2b			Scenario 3		
Exporter	Canada	USA	Mexico	Can.	USA	Mex.	Can.	USA	Mex.	Can.	USA	Mex.	Can.	USA	Mex.	Can.	USA	Mex.
Canada	0.48	-3.60	-32.04	425	-801	-462	0.78	1.06	-0.31	-0.35	-1.92	0.13	-0.34	-1.93	0.12	1.28	0.82	1.05
USA	-1.38	0.17	-17.70	-380	1,944	-1,924	0.97	0.98	1.03	0.06	2.12	0.13	0.05	2.15	0.22	0.92	1.48	1.09
Mexico	-3.53	-4.90	3.56	-133	-1,556	2,233	0.37	0.94	0.76	-1.35	4.44	0.09	-1.25	4.48	0.16	2.06	1.56	-0.81
Argentina	0.18	0.27	7.71	1	7	6	1.46	0.97	0.82	1.62	3.63	-0.56	1.71	3.63	-0.49	2.10	1.38	0.70
Australia	2.79	0.19	6.92	16	6	6	1.03	0.97	0.77	0.13	3.08	-0.63	0.14	3.07	-0.58	1.06	1.73	1.11
Brazil	0.36	0.25	6.29	4	18	6	1.24	0.97	0.76	0.97	2.79	-0.70	1.01	2.79	-0.64	1.60	1.41	0.91
Chile	0.08	0.19	5.81	2	22	25	1.90	0.95	0.82	1.15	5.13	-0.75	1.39	5.11	-0.58	-15.08	-6.31	66.55
China	0.13	0.23	4.68	1	7	3	1.45	0.95	0.79	1.37	3.73	-0.94	1.54	3.73	-0.76	4.08	1.69	0.99
Colombia	0.10	0.84	14.70	2	54	4	1.68	0.97	0.67	0.07	2.84	-0.26	0.25	2.85	-0.22	1.46	1.15	39.31
Costa Rica	0.34	0.80	6.57	4	60	8	0.58	0.98	0.82	-2.16	3.03	-0.73	-2.03	3.04	-0.63	-1.50	-0.46	78.47
Ecuador	0.16	0.24	14.74	1	9	6	1.43	0.97	0.67	0.77	3.96	-0.25	0.88	3.96	-0.21	2.39	1.37	0.32
Honduras	0.39	0.80	5.92	1	17	5	0.65	0.98	0.82	-1.63	3.40	-0.79	-1.50	3.41	-0.70	-6.04	-2.89	97.19
Indonesia	0.26	0.22	6.17	5	29	8	1.24	0.96	0.78	0.91	3.49	-0.72	0.98	3.48	-0.65	2.07	1.54	0.84
Italy	0.11	0.20	4.78	1	10	2	1.67	0.94	0.79	2.04	4.13	-0.92	2.23	4.13	-0.78	3.79	1.46	87.96
N. Zealand	0.09	0.20	4.59	1	4	3	1.80	0.93	0.79	2.04	5.16	-0.96	2.23	5.17	-0.81	4.15	1.89	1.13
S. Africa	0.09	0.33	4.26	0	3	0	1.72	0.95	0.80	1.06	4.17	-1.05	1.34	4.17	-0.83	5.59	1.60	0.67
Spain	0.16	0.32	6.25	1	9	5	1.35	0.96	0.83	0.92	3.90	-0.69	1.08	3.90	-0.53	2.60	1.16	87.33
Thailand	0.44	0.23	6.26	3	9	1	1.17	0.96	0.78	0.72	2.98	-0.71	0.75	2.97	-0.64	1.54	1.50	0.92
Turkey	0.16	0.26	5.10	0	4	0	1.36	0.96	0.79	0.78	3.42	-0.87	0.94	3.41	-0.72	3.69	1.51	0.64

Conclusion

The results reported in this paper suggest that a rollback of the agricultural trade preferences available under NAFTA would be costly for all three North American trading partners. Without NAFTA, U.S. producers would face MFN tariffs in the Mexican and Canadian markets they currently access duty-free. As the region's largest exporter and its most valuable market, both exporters and consumers would face substantial losses. Our estimates suggest a full dissolution of NAFTA preferences for agriculture would reduce the value of U.S. exports to North America by about six percent. Canada's North American agricultural exports would fall by 5.33 percent and Mexico's by 4.75 percent. In part, the reduction in U.S. exports would stem from significantly depressed demand due to income losses in export markets: Our estimates find a reduction of 3.27 percent in Mexican per-capita income from the end of NAFTA agricultural preferences. It is also a consequence of a loss of U.S. competitiveness in those export markets. Competing exporters from outside North America, particularly Chile, Indonesia, Costa Rica and Brazil increase their North American exports at the expense of the formerly close trading partners.

In scenarios that focus increases in trade costs on select products, we find even larger potential losses for Mexican consumers and producers. When the United States imposes a 25% antidumping duty on the fresh fruit and vegetable products that make up the bulk of its agricultural imports from Mexico, Mexican per capita income drops by over 5 percent, and Mexican export value falls by almost 20 percent.

The largest losses occur when the end of NAFTA agricultural preferences is accompanied by an increase in Mexico's tariff on its largest agricultural import from the United States: corn. When Mexico raises its MFN tariff on corn to its bound limit, Mexican per capita income declines by almost 30 percent and export value falls by more than seven percent under the dissolution of NAFTA without the accompanying hike in corn tariffs.

While we find that producers and consumers lose from the end of NAFTA agricultural preferences on average, the distribution of those losses across producers of different crops is not addressed here. Moreover, we do not address the likelihood that producers of some individual products may gain from an end to NAFTA preferences. The systematic heterogeneity model allows changes in policy to affect trade patterns in a complex way. Future work will examine the distributional effects within sectors more closely.

There are many limits to the analysis presented here. First, our base model is calibrated with data from 2006, before NAFTA was fully implemented and global trade patterns differed in some important ways, particularly in terms of the nature and degree of competition from Brazil and other rising exporters and the nature and degree of demand from China and other rising importers. Moreover, in our scenario analysis we abstract from the impact of higher manufacturing tariffs. Future work will address these and other issues.

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Appendix Tables

Table 10: Value Added and Consumption Shares

α^A	α^M	α^S	λ^A	λ^M	λ^S
0.49	0.32	0.56	0.05	0.30	0.65

Table 11: Intermediate input shares

ξ_A^A	ξ_M^A	ξ_S^A	ξ_A^M	ξ_M^M	ξ_S^M	ξ_A^S	ξ_M^S	ξ_S^S
0.33	0.37	0.30	0.08	0.62	0.30	0.01	0.31	0.68

Table 12: Import shares by product - Canada

Product	**Import share**
Lettuce and chicory	6.63%
Grapes	6.62%
Coffee, green	5.29%
Maize	5.08%
Tomatoes	4.69%
Strawberries	4.09%
Meat, chicken	3.85%
Bananas	3.70%
Apples	3.05%
Chillies and peppers, green	3.03%
Oranges	2.83%
Oil, olive, virgin	2.53%
Cabbages and other brassicas	2.41%
Tangerines, mandarins, clementines, sats	2.41%
Cocoa, beans	2.17%
Vegetables, fresh nes	1.94%
Carrots and turnips	1.94%
Pineapples	1.81%
Potatoes	1.73%
Cherries	1.69%
Pears	1.57%
Peaches and nectarines	1.47%
Soybeans	1.46%
Watermelons	1.44%
Maize, green	1.29%
Onions, dry	1.29%

Table 13: Import shares by product - Mexico

Product	**Import Share**
Maize	17.97%
Soybeans	14.62%
Wheat	10.92%
Cotton lint	7.72%
Meat, pig	5.51%
Rapeseed	5.45%
Sorghum	5.35%
Meat, chicken	5.14%
Meat, turkey	3.77%
Apples	3.26%
Rice, paddy	2.84%
Grapes	1.69%
Beans, dry	1.28%
Pears	1.27%
Cottonseed	1.06%
Walnuts, with shell	1.01%
Oil, palm	0.95%
Oil, olive, virgin	0.85%
Tobacco, unmanufactured	0.83%
Onions, dry	0.60%
Cinnamon (canella)	0.59%
Meat, sheep	0.54%
Eggs, hen, in shell	0.49%
Potatoes	0.47%
Peaches and nectarines	0.41%
Lettuce and chicory	0.41%

Table 14: Import market share by product, United States

Product	Import Share
Coffee, green	13.59%
Tomatoes	7.77%
Grapes	6.61%
Bananas	6.06%
Oil, olive, virgin	5.11%
Chillies and peppers, green	4.85%
Cocoa, beans	4.31%
Tobacco, unmanufactured	3.89%
Pineapples	2.89%
Cucumbers and gherkins	2.68%
Asparagus	2.01%
Wheat	1.98%
Oil, palm	1.81%
Meat, sheep	1.81%
Oats	1.71%
Avocados	1.58%
Pumpkins, squash and gourds	1.40%
Tangerines, mandarins, clementines, sats	1.27%
Maize	1.25%
Mangoes, mangosteens, guavas	1.19%
Rapeseed	1.18%
Nuts, nes	1.18%
Tea	1.09%
Honey, natural	1.08%
Lemons and limes	1.06%
Meat, pig	1.02%

Table 15: Average Productivity and Exporter Cost Estimates

Country	$\widehat{S}_i^A$	$\widehat{ex}_i^A/\theta$		$\widehat{S}_i^M$	$\widehat{ex}_i^M/\theta$
Argentina	0.86***	1.17***		0.11	0.24***
Australia	0.85***	0.3***		-0.1	0.35***
Austria	-1.06***	-0.03		-0.24	0.32***
Belgium	-8.3***	2.96***		-1.83***	0.88***
Bolivia	0.34	-1.54***		0.29*	-1.28***
Brazil	0.7***	0.69***		0.85***	0.4***
Bulgaria	0.08***	-0.11***		-0.27**	-0.26***
Canada	-5.75***	2.79***		-0.35***	0.48
Chile	1.66***	1.21***		0.58***	0.01***
China	2.61***	1.16		1.15**	0.8***
Colombia	1.42***	0***		0.44***	-0.43***
Costa Rica	1.15***	-0.81***		-0.56***	-0.36***
Cote d'Ivoire	0.56	-0.75***		1.08	-1.27**
Czech Republic	0**	-0.48		-0.16***	0.16***
Denmark	0.44***	0.04***		-1.53***	0.53***
Ecuador	1.21***	-0.32***		0.58***	-0.63**
Estonia	2.77	-2.56***		-1.05***	-0.15***
Ethiopia	-0.37***	-0.96***		-0.96	-1.41***
Finland	1.72***	-1.58***		0.1	0.3***
France	-2.96***	1.76***		0.18	0.62***
Germany	-4.87	2.41***		0.21**	0.81***
Ghana	-0.35***	-1.06		-0.4	-0.94***
Greece	1	0.1***		0.13***	-0.24***
Honduras	-0.24***	-1.35***		-1.44**	-0.82
Hungary	2.1	-0.67***		0.45***	-0.07***
Iceland	-0.14***	-2.2***		-0.72***	-0.58***
India	1.13**	0.57***		0.8	0.31***
Indonesia	0.55***	0.78***		0.13***	0.43***
Ireland	2.14***	-1.3		-2	0.63*
Israel	1.58***	0.06***		0.11**	-0.11***
Italy	-3.31***	2***		0.4***	0.57***
Japan	-1.68***	0.75***		1.37***	0.63***
Kazakhstan	0.78**	-1.76***		-0.5	-0.68***
Kenya	-0.51***	-0.7***		0.05	-0.9***
Lithuania	2.64***	-2.13***		-0.07*	-0.35***
Malaysia	-2.76**	1.51***		-0.3***	0.59***
Mexico	0.65***	0.5***		-0.9	0.46***
Morocco	1.41***	-0.88***		-0.06***	-0.38***
Netherlands	-3.12***	2.16***		-0.66***	0.71**

Country	$\hat{S}_i^A$	$\widehat{ex}_i^A/\theta$		$\hat{S}_i^M$	$\widehat{ex}_i^M/\theta$
New Zealand	2.8***	0.35***		-0.5	0.16
Norway	2.41***	-2.41***		0.14***	0***
Paraguay	1.48***	-0.67		-0.71***	-0.83***
Peru	1	0.12		0.49*	-0.32*
Poland	-0.2***	0.03**		0.27***	0.11***
Portugal	-1.55***	0.17***		-1.96***	0.43***
Russia	-2.49***	0.16***		0.62	0.25**
Slovakia	3.07***	-2.15***		0.12*	-0.16***
Slovenia	1.63	-2.05***		0.31	-0.4***
South Africa	-0.07***	0.41**		-0.26***	0.32***
South Korea	1.85***	-0.21***		1.01	0.52***
Spain	-3.82***	2.12		0.23***	0.4***
Sri Lanka	1.36***	0.11***		2.2	-0.93***
Sweden	-0.64***	-0.25***		-0.08	0.46***
Switzerland	-2.46	0.31***		0.23*	0.3***
Thailand	-0.27***	0.28***		-0.27***	0.58***
Tunisia	3.04***	-1.13***		1.14*	-0.83***
Turkey	1.32***	0.56***		0.26**	0.17**
Ukraine	1.31***	-0.5***		0.4	-0.13***
UK	-4.05***	2.13		0.05	0.57***
Uruguay	2.68**	-0.12***		0.03***	-0.41***
Venezuela	0.62*	-2.36***		1.11	-0.62*
Vietnam	0.4***	0.35***		-0.03	0.1
USA	-4.36***	3.04***		0.3***	0.9***

***significant at the 1% level, ** significant at the 5% level, *significant at the 10% level.

Table 16: MFN Tariffs used in Scenario Analysis

	Weighted Average Applied MFN Tariff		
Product	Canada	Mexico	USA
Wheat	76.5	10	2.8*
Barley	57.75	45	0*
Maize	0	5	0*
Oats	0	0	0
Sorghum	0	7.5	0*
Potatoes	0*	125	0*
Lentils	0	10	0*
Walnuts, with shell	0	20	0*
Pistachios	0	20	0*
Soybeans	0	7.5	0
Rapeseed	0	0	0*
Cabbages and other brassicas	0	10	20
Asparagus	0	10	13.5
Lettuce and chicory	0	10	0*
Spinach	0	10	20
Tomatoes	0	10	0*
Cauliflowers and broccoli	0	10	8.83
Pumpkins, squash and gourds	0	10	15.65
Cucumbers and gherkins	0	10*	0*
Eggplants (aubergines)	0	10	0*
Leeks, other alliaceous vegetables	0	10	20
Beans, green	0	10	0
Peas, green	0	10	0*
Carrots and turnips	0	10	7.45
Mushrooms and truffles	8.5*	10	0*
Vegetables, fresh nes	0	10	14.37
Bananas	0	20	0
Oranges	0	20	0*
Lemons and limes	0	20	0.8
Grapefruit (inc. pomelos)	0	20	0*
Apples	4.25	20	0
Pears	0	20	0
Cherries	3	20	0
Peaches and nectarines	2.83	20	0
Plums and sloes	2.83	20	0
Strawberries	0	20	0*
Blueberries	0*	20*	1.1*

	Weighted Average Applied MFN Tariff		
Cranberries	0	20	0
Grapes	2	20	0
Watermelons	0	20	13
Melons, other (inc.cantaloupes)	0	20	13.98
Mangoes, mangosteens, guavas	0	20	0*
Avocados	0	20	0*
Papayas	0	20*	5.4
Fruit, fresh nes	0	20	1.1
Cotton lint	0	0	0
Meat, pig	0	20	0
Meat, chicken	4.31	115.78	10
Meat, turkey	4.31	115.78	10

*Interpolated from other tariff information

**Calculated by the authors