Technology, Ecology and Agricultural Trade

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Abstract

I introduce a novel general equilibrium framework for agricultural trade policy analysis with heterogeneous producers in which agro-ecological characteristics influence patterns of specialization within the sector and trade costs are product-specific. This induces substantial variation in market share elasticities with respect to trade costs, with the largest magnitude elasticities between countries most likely to compete head-to-head in the same products. The model is thus able to generate more nuanced predictions for how bilateral agricultural trade and production patterns shift in response to changes in policy than existing models. I draw on techniques pioneered in the discrete choice literature to estimate parameters that describe the distribution of productivity and trade costs across products. This approach has the considerable advantage of allowing me to solve a product-level conceptual model with little data beyond what is used in a standard gravity model. This framework promises to allow researchers to make more informed predictions for how global agricultural trade and production patterns shift in response to policy change.

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1. Introduction

A central prediction of economic theory is that opening to trade allows countries to specialize according to comparative advantage. However, simplifying assumptions on the structure of production in existing quantitative models of trade abstract from the forces that drive intra-sectoral comparative advantage. Empirical models that define technology with "heterogeneous productivity" across products provide the tools to define comparative advantage at the individual product level, but employ strong distributional assumptions on productivity and trade costs to preserve tractability. These assumptions impose strong restrictions on the elasticity of market share with respect to a given exporter's trade costs. This results in rather coarse predictions for how intra-sector patterns of production and trade shift in response to policy changes.

My point of departure is the probabilistic Ricardian model of Eaton and Kortum (2002)[1], henceforth EK, with two tradable sectors: agriculture and manufacturing which are differentiated by the forces that shape intra-sector specialization patterns. As in EK, production efficiency is modeled as an independent random variable following a country- and sector-specific Frechet distribution. Unlike EK, non-random, product-specific agro-ecological suitability provides a second source of productivity differences in agriculture. Trade occurs as buyers in each import market purchase each product from the source country with the lowest price inclusive of "iceberg" trade costs. Trade costs vary across agricultural products due to differences in perishability and policy treatment.

In the EK model, market share elasticity with respect to a given exporter's costs is constant across all of its competitors. This means, for example, that the agricultural products market shares of the United States and Costa Rica are equally sensitive to cuts in tariffs on Canadian agricultural products. In contrast, my model generates larger magnitude trade elasticities among countries whose agro-ecological characteristics make them suitable to produce the same agricultural products.

I estimate parameters describing the distribution of agricultural trade costs and productivity using methods pioneered in the literature on differentiated products demand systems, notably by Berry, Levinsohn and Pakes (1995)[2]. This technique allows me to connect the product-level conceptual model to sector-level trade flow data without making strong distributional assumptions on productivity and trade costs. Simulated trade elasticities predict, sensibly, that US agricultural market share is highly sensitive to changes in Canadian bilateral trade costs. In contrast, changes in Costa Rican bilateral trade costs have a negligible effect on the market share of U.S. agricultural products.

With a model that generates more nuanced cross-country elasticities, I perform two experiments. First, I compare trade liberalization of all agricultural products to partial liberalization that maintains trade barriers on cotton and beef. This experiment illustrates how the global distribution of product-specific land productivity influences model outcomes. The largest losses from partial relative to full liberalization are in countries where 1) cotton or beef represent a large share of agricultural imports; and 2) agro-ecological conditions are not well-suited for their production.

Next, I demonstrate the ease with which the model can incorporate a more complex set of changes in product-specific tariffs. I compare responses to an across-the-board 50% cut in average agricultural trade costs to a set of product-specific tariff cuts that represent a mean-preserving spread of the 50% cut. This experiment reveals that uneven cuts in tariffs across products can potentially negate gains from trade liberalization.

The experiments I carry out here are admittedly abstract. While the model is explicitly intended for practical policy analysis, the goal of the present paper is primarily to introduce a new methodology. Future work will focus on applications.

My work follows other extensions of the EK model to multiple tradable sectors, most notably Chor (2010)[3], Caliendo and Parro (2012)[4] and Shikher (2012). All three models allow absolute advantage to vary across sectors. Chor allows for deterministic variation based on the interaction between country and industry characteristics. However, intra-sectoral comparative advantage is randomly determined in all three models. Costinot and Donaldson (2011)[5] use agro-ecological information to estimate agricultural productivity in an EK-style model. However, their model focuses on the U.S. agricultural sector alone and their data restrict them to just 17 crops.

My model retains the basic structure that delivers the log-linear gravity-like relationship in EK, which can also be obtained form other quantitative trade models [6]. Arkolakis, Costinot and Rodriguez-Clare (2012)[7] show that models which feature this relationship also feature the restrictive system of elasticities described above, which they dub a “CES import demand system”. This includes models built on Melitz (2003)[8] or on an Armington assumption.

In my model the gravity-like relationship between trade flows and country characteristics cannot be log-linearized because of the way non-random sources of product-specific comparative advantage enter the model. Simulation techniques are thus required to estimate the parameters of the productivity and trade cost distribution. Chor (2010)[3] also employs simulation methods, however this is necessitated by assumptions on the distribution of *random* sources of product-specific comparative advantage.

Simonovska and Waugh (2012)[9] point out that the underlying micro-structure of heterogeneous productivity models provides a better basis for estimating trade elasticities than models that abstract from heterogeneity. My methodology supports and extends their arguments by demonstrating how these models can allow for a more complex characterization of elasticity when a nuanced understanding of bilateral trade patterns is desirable.

In the following section I present the model. Next, I illustrate how cross-country trade elasticities are generated. In Section 4 I specify the gravity-like model from which I estimate unobservable trade costs and parameters of the productivity distribution. I fully calibrate and solve the general equilibrium model in Section 5. In Section 6 and 7 I conduct counterfactual experiments. Section 8 concludes.

2. 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, services. Tradable sectors are each comprised of a continuum of products indexed by $j \in [0, 1]$. Individual products are distinguished only by their intrinsic characteristics. 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 agricultural production. All production is constant returns to scale and markets are perfectly competitive.

Trade occurs as buyers in market n seek to purchase each product from the source country that offers the lowest price. 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:

$$q_i^k(j) = z_i^k(j)\Big(N_i^{\beta_i^k}\,(a_i(j)L_i)^{1-\beta_i^k}\Big)^{\alpha_i^k}\mathbf{Q}_i^{k\,1-\alpha_i^k} \qquad k = A, M \quad \beta_i^M = 1\ \forall i$$

where $z_i^k(j)$ is a technological productivity-augmenting random variable specific to product j in country i; $a_i(j)$ is country i, product j-specific land productivity; and $\mathbf{Q}_i^k$ is an aggregate of intermediate inputs from all three sectors combined in a Cobb-Douglas fashion as in Caliendo and Parro (2012)[4]:

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

where 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 $\sigma > 0$:

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

The services sector produces a homogeneous good using only labor with productivity z_i^S.

As in EK, technological productivity, $z_i^k(j)$ is independently distributed across products following a Frechet distribution with parameters T_i^k and θ:

$$F_{z_n}^k(z) = exp\{-T_i^k z^{-\theta}\} \qquad k = A, M \tag{2}$$

A high value of T_i^k means country i is more likely to have a high draw of $z_i^k(j)$. A smaller value of $\theta > 1$ implies a larger dispersion of technological productivity differences. The value $a_i(j)$ reflects the suitability of exporter i's natural environment for product j production. I assume $a_i(j)$ follows a parametric density that is a deterministic function of exporter i's agro-ecological characteristics and product j's agro-ecological production requirements. For example, countries with volcanic soil and tropical climate will tend to have higher values of $a_i(j)$ for pineapple, which thrives in volcanic soil and tropical climate.

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 $\tau_{ni}^k(j) \geq \tau_{nj}^k(j)\tau_{ji}^k(j)$. As in EK, I assume trade costs are constant for all manufactured products, i.e., $\tau_{ni}^M(j) = \tau_{ni}^M \;\; \forall j$. Agricultural trade costs follow a parametric density that is a deterministic function of product-specific policies and marketing requirements. I assume $\tau_{ni}^A(j)$ is independent of both $a_i(j)$ and $z_i^A(j)$.

With perfect competition the prices offered for product j, by exporter i in market n are therefore:

$$p_{ni}^A(j) = \frac{\tilde{a}_i(j) c_i^A \tau_{ni}^A(j)}{z_i^A(j)} \;\; \mathit{and} \;\; p_{ni}^M(j) = \frac{c_i^M \tau_{ni}^M}{z_i^M(j)} \tag{3}$$

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

$$c_i^k = \kappa_i^k w_i^{\alpha_i^k \beta_i^k + (1-\alpha_i^k)\xi_S^k} r_i^{\alpha_i^k(1-\beta_i^k)} p_i^{A^{(1-\alpha_i^k)\xi_A^k}} p_i^{M^{(1-\alpha_i^k)\xi_M^k}} \tag{4}$$

where κ_i^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.[1]

Buyers in market n purchase each product from the exporter with the lowest price offer. The price actually paid for product j in market n is therefore $p_n^k(j) = min_i\{p_{ni}^k(j)\}$. 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 EK, 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 on the other hand, are non-randomly influ-

[1] $\kappa_i^k =$
$\alpha_i^k \beta_i^{k^{-\alpha_i^k \beta_i^k}} \left(\alpha_i^k(1-\beta_i^k)\right)^{-\alpha_i^k(1-\beta_i^k)} \left(z_i^S \xi_S^k (1-\alpha_i^k)\right)^{-(1-\alpha_i^k)\xi_S^k} \left(\xi_A^k(1-\alpha_i^k)\right)^{-(1-\alpha_i^k)\xi_A^k} \left(\xi_M^k(1-\alpha_i^k)\right)^{-(1-\alpha_i^k)\xi_M^A}$

enced by the distribution of $a_i(j)$ and $\tau_{ni}(j)$. For example, the Canadian R&D process may deliver a high value of z for cultivating coffee beans, but without the appropriate climate and terrain, Canada is unlikely to be a competitive coffee exporter.

More generally, the model predicts that countries that are "tropical-climate-abundant" will tend to specialize in agricultural products that are "tropical-climate-intensive". However, this does not produce complete specialization in a bilateral relationship at the sector-level or even in like products within a sector. Differences in realizations of $z_i^A(j)$ and values of $a_i(j)$ create comparative advantage and thus incentives for agricultural trade even in tropical-intensive-products among tropical countries.

Given the aggregation technology buyers use to assemble individual goods from each sector, a unit price index for sector $k = A, M$ is:[2]

$$p_n^k = \left(\int_0^1 p_n^k(j)^{-(\sigma-1)} dj \right)^{1/(1-\sigma)} = \left(\int_0^1 p^{(1-\sigma)} dG_n^k(p) dp \right)^{1/(1-\sigma)} \tag{5}$$

Caliendo and Parro (2012)[4] and Shikher (2012)[10] show that the assumptions I make on trade costs and technology for the manufacturing sector imply that Equation 5 is equal to:

$$p_n^M = \gamma \Omega_n^{M\, \frac{-1}{\theta}} \tag{6}$$

where $\Omega_n^M = \sum_{l=1}^{I} T_l^M (c_l^M \tau_{nl}^M)^{-\theta}$.

Using the price distributions for agricultural products, $G_n^A(p)$,[3] Equation 5 becomes:

$$p_n^A = \gamma \left(\int \Omega_n^A(j)^{\frac{(\sigma-1)}{\theta}} dF_{a_n}(\tilde{\mathbf{a}}) dF_{\tau_n}^A(\boldsymbol{\tau}) \right)^{\frac{1}{1-\sigma}} \tag{7}$$

where $\Omega_n^A(j) = \sum_{l=1}^{I} T_l^A \left(\tilde{a}_l(j) c_l^A \tau_{nl}^A(j) \right)^{-\theta}$; $\gamma = \Gamma \left[\frac{\theta+1-\sigma}{\theta} \right]^{\frac{1}{(1-\sigma)}}$, and $\Gamma(\cdot)$ is the gamma function, so the parameters satisfy $\theta > 1-\sigma$; and $dF_{a_n}(\tilde{\mathbf{a}}) dF_{\tau_n}^A(\boldsymbol{\tau})$ is the joint density of $\tilde{\mathbf{a}} = [\tilde{\mathbf{a}}_1, \ldots, \tilde{\mathbf{a}}_I]$ and $\boldsymbol{\tau}_n^A = \left[\boldsymbol{\tau}_{n1}^A, \ldots, \boldsymbol{\tau}_{nI}^A \right]$[4] over all agricultural

[2]See Appendix A for details.
[3]I derive this distribution in Appendix A.
[4]$\tilde{\mathbf{a}}_1 = [\tilde{a}_1(0), \tilde{a}_1(1)]$, $\boldsymbol{\tau}_{n1}^A = [\tau_{n1}^A(0), \tau_{n1}^A(1)]$

products consumed in import market n.

Invoking the law of large numbers, EK show that the share of expenditure on manufactured goods spent on imports from country i is equal to the probability it offers the lowest price. Given the assumptions on the distribution of $z_i^M(j)$ this is:

$$Pr\left(p_{ni}^M(j) = p_n^M(j)\right) \equiv \pi_{ni}^M = \frac{T_i^M(c_i^M \tau_{ni}^M)^{-\theta}}{\sum_{l=1}^{I} T_l^M(c_l^M \tau_{nl}^M)^{-\theta}} \tag{8}$$

I show in Appendix A that an exporter's share of market n agricultural products expenditure is likewise equivalent to the probability it offers the lowest price for an agricultural product. To arrive at an agricultural sector expression that corresponds to Equation 8, first note that the probability exporter i offers the lowest price for product j in market n is:

$$Pr(p_{ni}^A(j) \leq p_{nl}^A(j)\ \forall l) = \pi_{ni}^A(j) = \frac{T_i^A\left(\tilde{a}_i(j) c_i^A \tau_{ni}^A(j)\right)^{-\theta}}{\sum_{l=1}^{I} T_l^k(\tilde{a}_l(j) c_l^A \tau_{nl}^A(j))^{-\theta}} \tag{9}$$

This product-specific probability is a function of the global distribution of land productivity and trade costs for product j. Exporter i's total share of market n agricultural expenditure is the unconditional probability it offers the lowest price for an agricultural product. Since land productivity and trade costs are independently distributed, this is:

$$\pi_{ni}^A = \int \frac{T_i^k(\tilde{a}_i c_i^A \tau_{ni}^A)^{-\theta}}{\sum_{l=1}^{I} T_l^k(\tilde{a}_l c_l^A \tau_{nl}^A)^{-\theta}} dF_{\tilde{a}_n}(\tilde{\mathbf{a}}) dF_{\tau_n}(\boldsymbol{\tau}) \tag{10}$$

2.1. Equilibrium

Equilibrium consists of factor prices w_i and r_i; price indices for tradable goods p_i^A and p_i^M; 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. Equations 8 and 10 define equilibrium trade shares and Equations 6 and 7 define equilibrium price indices.

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

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

subject to the budget constraint: $w_i N_i + r_i L_i$. Here Q_i^k is the sector k aggregate defined by Equation 1. This utility function implies that consumers spend a constant share λ_i^k of their total income on products from sector k.

To solve the model I begin with the tradable products market clearing and trade balance conditions as in Dekle, Eaton and Kortum (2008)[11]:

$$Y_i^k = \sum_{n=1}^{I} \pi_{ni}^k X_n^k = X_i^k - D_i^k \qquad k = A, M \tag{11}$$

where Y_i^k is country i's gross sector k production and X_i^k is country i's gross absorption of sector k goods. Under the trade balance condition country i may be a net importer of sector k goods in the amount D_i^k, however economy-level trade balance requires $D_i^A + D_i^M = 0$. Sectoral trade deficits are exogenous and $\sum_{i=1}^{I} D_i^k = 0$.

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

$$X_i^k = \lambda_i^k X_i + (1 - \alpha_i^k)(\xi_k^M Y_i^M + \xi_k^A Y_i^A) \tag{12}$$

where X_i is total final absorption and $(1 - \alpha_i^k)(\xi_k^M Y_i^M + \xi_k^A Y_i^A)$ is demand for sector k intermediate inputs.

Substituting Equation 12 in Equation 11 yields:

$$Y_i^M = \frac{\lambda_i^M X_i + (1 - \alpha_i^A)\xi_M^A Y_i^A - D_i^M}{1 - (1 - \alpha_i^M)\xi_M^M} \qquad \textit{and} \qquad Y_i^A = \frac{\lambda_i^A X_i + (1 - \alpha_i^M)\xi_A^M Y_i^M - D_i^A}{1 - (1 - \alpha_i^A)\xi_A^A} \tag{13}$$

With perfect competition, value-added equals factor payments in each sector:

$$V_i^k = w_i N_i^k + r_i L_i^k \quad [5] \tag{14}$$

[5] $L_i^M = L_i^S = 0$

Substituting Equation 13 for the manufacturing sector and the trade balance condition $X_i = Y_i$, Equation 13 yields an expression for agricultural output in terms of the total value of labor, the exogenous agricultural sector deficit D_i^A and model parameters:

$$Y_i^A = \kappa_{1i}^A w_i N_i + \kappa_{2i}^A D_i^A \tag{15}$$

where the κ terms are functions of parameters.[6] Similarly, for the manufacturing sector.[7]

$$Y_i^M = \kappa_{1i}^M w_i N_i + \kappa_{2i}^M Y_i^A + \kappa_{3i}^M D_i^A \tag{16}$$

Substituting this into the market clearing condition yields an equation for manufacturing sector expenditure:

$$X_i^M = \kappa_{1i}^M w_i N_i + \kappa_{2i}^M Y_i^A + \kappa_{4i}^M D_i^A \tag{17}$$

3. Ag Sector Substitution Patterns in the Model

In the remainder of the paper I will compare the quantitative implications of the model I introduced in the previous section to an alternative model in which, like manufacturing, $z_i^A(j)$ is the sole source of differences in agricultural productivity and $\tau_{ni}^A(j) = \tau_{ni}^A \ \forall j$. I denote agricultural market share as $\pi_{ni}^{A'}$ and likewise with other variables in the alternative model. In this section I contrast the implications of these two approaches for the response of bilateral trade patterns to changes in trade costs.

3.1. The Alternative Model

Under the alternative model, agricultural market share takes the same form as Equation 8. Equation 18 displays the elasticity of this market share with

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[6] $\kappa_{1i}^A = \frac{\lambda_i^A(1-(1-\alpha_i^M)\xi_M^M)+\lambda_i^M(1-\alpha_i^M)\xi_A^M}{(1-(1-\alpha_i^M)\xi_M^M-(1-\alpha_i^A)\xi_A^A)-(\lambda_i^A(1-(1-\alpha_i^M)\xi_M^M)+\lambda_i^M(1-\alpha_i^M)\xi_A^M)\alpha_i^A(1-\beta_i^A)}$,
$\kappa_{2i}^A = \frac{(1-\alpha_i^M)\xi_A^M-(1-(1-\alpha_i^M)\xi_M^M)}{(1-(1-\alpha_i^M)\xi_M^M-(1-\alpha_i^A)\xi_A^A)-(\lambda_i^A(1-(1-\alpha_i^M)\xi_M^M)+\lambda_i^M(1-\alpha_i^M)\xi_A^M)\alpha_i^A(1-\beta_i^A)}$,
$\kappa_{3i}^A = \frac{\lambda_i^A(1-(1-\alpha_i^M)\xi_M^M)+\lambda_i^M(1-\alpha_i^M)\xi_A^M)\alpha_i^A(1-\beta_i^A)+((1-\alpha_i^M)\xi_A^M-(1-\alpha_i^A)\xi_A^A}{(1-(1-\alpha_i^M)\xi_M^M-(1-\alpha_i^A)\xi_A^A)-\alpha_i^A(1-\beta_i^A)(\lambda_i^A(1-(1-\alpha_i^M)\xi_M^M)+\lambda_i^M(1-\alpha_i^M)\xi_A^M)}$

[7] $\kappa_{1i}^M = \frac{\lambda_i^M}{1-(1-\alpha_i^M)\xi_M^M}$, $\kappa_{2i}^M = \frac{\lambda_i^M\alpha_i^A(1-\beta_i^A)+(1-\alpha_i^A)\xi_M^A}{1-(1-\alpha_i^M)\xi_M^M}$, $\kappa_{3i}^M = \frac{1}{1-(1-\alpha_i^M)\xi_M^M}$, $\kappa_{4i}^M = \frac{1-\alpha_i^M}{1-(1-\alpha_i^M)}$

respect to a change in bilateral trade costs between competitor country l and the importing country n, holding all prices constant:

$$\frac{\partial \pi_{ni}^{A'}}{\partial \tau_{nl}^{A}} \frac{\tau_{nl}^{A}}{\pi_{ni}^{A'}} = \begin{cases} -\theta(1-\pi_{nl}^{A'}) & if\ l = i \\ \theta \pi_{nl}^{A'} & otherwise \end{cases} \tag{18}$$

The system of elastiticies in equation 18 is a defining characteristic of a "CES import demand system".[8] The CES import demand system imposes strong restrictions on both own-country and cross-country market share elasticity.

First, since $(1-\pi_{ni}^{A'}) \approx 1$ for almost every pair of countries, Equation 18 implies that own-country elasticities are virtually equal to θ. To the extent it varies at all, elasticity is strictly decreasing in $\pi_{ni}^{A'}$. To see why this is an inappropriate assumption for the agricultural sector, consider an example: Côte d'Ivoire is one of a few countries that produce and export a significant amount of cocoa. It is the dominant source of UK cocoa imports. Yet, since its total share of the UK agricultural products market is very small, the alternative model predicts Côte d'Ivoire's market share is more elastic than e.g., Germany. However, Germany's agricultural exports to the UK primarily consist of grains and meats that can be produced competitively in many countries, including domestically. The EK model's predictions thus run counter to basic microeconomic theory, which would suggest that German market share should be more elastic than that of Côte d'Ivoire.

More problematic is that cross-country elasticities are constant across competitors. Any change in exporter l's bilateral trade costs has the same effect on $\pi_{ni}^{A'}$ for all $i \neq l$, including domestic producers. To see why this is illogical, suppose the United States raises tariffs on all Costa Rican agricultural products. Equation 18 implies that US buyers will substitute toward each of its other trading partners in proportion to their market share. This implies that any two countries with the same share of the U.S. agricultural products mar-

[8]Arkolakis, Costinot and Rodriguez-Clare note that a CES import demand system is a feature of models built on the EK framework as well as many of those built on Melitz (2003)[8] and on the Armington assumption.

ket, for example Ecuador and The Netherlands, will see identical increases in exports. However, given their similarity in terms of climate and location, one would expect agricultural trade flows from Ecuador to increase more than The Netherlands in response to higher Costa Rican tariffs.

3.2. The Benchmark Model

The simplicity of Equation 8 is one of the most appealing features of the EK model. However, its usefulness for applied policy analysis is limited if the CES import demand structure does not hold in the data at the available level of aggregation. In contrast to Equation 18, elasticity with respect to a given exporter's trade costs varies across countries and competitors.

$$\frac{\partial \pi_{ni}^A}{\partial \tau_{nl}^A}\frac{\tau_{nl}^A}{\pi_{ni}^A} = \begin{cases} \frac{-\theta}{\pi_{ni}^A}\int \pi_{ni}^A(j)(1-\pi_{ni}^A(j))dF_{\tilde{a}}(\tilde{\mathbf{a}})dF_{\tau_n}(\boldsymbol{\tau}) & if\ l=i \\ \frac{\theta}{\pi_{ni}^A}\int \pi_{ni}^A(j)\pi_{nl}^A(j)dF_{\tilde{a}}(\tilde{\mathbf{a}})dF_{\tau_n}(\boldsymbol{\tau}) & otherwise \end{cases} \tag{19}$$

Sector-level elasticity in the benchmark model is a weighted average of product-specific sensitivities, where the weights are based on each product's share of market n agricultural expenditure. An individual product's sensitivity to changes in trade costs depends on the intensity of cross-country competition in the import market, which in turn depends on cross-country variation in $p_{ni}^A(j)$.

Own-country trade elasticity can be written:

$$\frac{\partial \pi_{ni}^A}{\partial \tau_{ni}^A}\frac{\tau_{ni}^A}{\pi_{ni}^A} = -\theta((1-\pi_{ni}^A) - \frac{1}{\pi_{ni}^A}var(\pi_{ni}^A(j))) \tag{20}$$

In the alternative model, any exporter is equally likely to offer the lowest price in any agricultural product, so $var(\pi_{ni}^A(j)) = 0$. In the benchmark model $var(\pi_{ni}^A(j))$ depends on variation in $a_i(j)$ and $\tau_{ni}^A(j)$. If $\pi_{ni}^A(j)$ varies widely it suggests that high-productivity or low trade costs are only available to producers in a few countries. This is characterized by extreme values of $a_i(j)$ or $\tau_{ni}^A(j)$. Exporters with extreme values will tend to have a larger $var(\pi_{ni}^A(j))$. The direct effect of lowering bilateral agricultural tariffs will therefore be smaller for exporters that specialize in products for which competition outside of its borders is not intense, or for which trade costs remain high. This is consistent with basic micro-economic theory.

Similarly, country i's cross-country elasticity with respect to exporter l in market n can be written:

$$\frac{\partial \pi_{ni}^A}{\partial \tau_{nl}^A}\frac{\tau_{nl}^A}{\pi_{ni}^A} = \frac{\theta}{\pi_{ni}^A}(cov(\pi_{ni}^A(j), \pi_{nl}^A(j)) + \pi_{ni}^A \times \pi_{nl}^A) \qquad l \neq i \tag{21}$$

In the benchmark model, cross-country elasticity is increasing in $cov(\pi_{ni}^A(j), \pi_{nl}^A(j))$, whereas $cov(\pi_{ni}^A(j), \pi_{nl}^A(j)) = 0$ in the alternative model. Covariance in $\pi_{ni}^A(j)$ in the benchmark model comes entirely from covariance $a_i(j)$ and $\tau_{ni}^A(j)$. Thus the benchmark model delivers relatively strong covariance between Costa Rica and Ecuador's probability of having the lowest price offer. An African country may be equally similar to Costa Rica as Ecuador in terms of agro-ecology, but its market share will nevertheless be less sensitive to the extent it faces different trade costs.

4. Estimating Productivity and Trade Costs

I estimate the parameters of each sector's productivity and trade cost distributions from the structural equations that define π_{ni}^k, $k = A, M$. In the benchmark model the relevant equations are 8 and 10. In the alternative model I estimate parameters for both sectors from Equation 8.

4.1. Manufacturing and Alternative Agriculture Sector Specification

To specify Equation 8 I define:

$$S_i^k \equiv \ln T_i^k - \theta \ln c_i^k \quad k = A', M \tag{22}$$

as in EK. Trade costs are proxied following EK, Waugh (2010)[12] and others:

$$ln(\tau_{ni}^k) = b_{ni}^k + l_{ni}^k + \sum_{r=1}^{6} d_{r_{ni}}^k + ex_i^k + EU_{ni}^k + NAFTA_{ni}^k + \xi_{ni}^k$$

where b_{ni}^k and l_{ni}^k are coefficients on dummy variables indicating that exporter i and market n share a border or common language, respectively; $d_{r_{ni}}^k$ is the coefficient on a dummy variable equal to one if the two countries are in distance category $r \in [1, 6]$; ex_i^k is a country fixed effect that captures exporter-specific sector k trade costs;[9] EU^k_{ni} and $NAFTA^k_{ni}$ are coefficients on dummy variables indicating intra-EU and intra-NAFTA trade respectively, and ξ^k_{ni} is a mean-zero error term that is assumed orthogonal to the other regressors. Substituting these into Equation 8, normalizing by π^k_{nn}, and taking logs yields a gravity-like model of agricultural trade flows:

$$ln\left(\frac{\pi^k_{ni}}{\pi^k_{nn}}\right) = S^k_i - S^k_n - \theta\left(b^k_{ni} + l^k_{ni} + \sum_r d^k_{r_{ni}} + ex^k_i + EU^k_{ni} + NAFTA^k_{ni} + \xi^k_{ni}\right) \tag{23}$$

I estimate this expression using linear methods with country fixed effects to capture S^k_i and ex^k_i.

4.2. Agricultural Sector Benchmark Specification

In this section I specify Equation 10 as a random coefficients logit model. In contrast to the alternative model, here I estimate parameters that describe the *distribution* of production and trade costs across agricultural products. Since the focus of this paper is on introducing the methodology, I keep the specification of the econometric model that follows as simple as possible. Future applications of this framework will demand a more methodical approach.

To begin, I define $S^A_i \equiv ln(T^A_i) - \theta ln(c^A_i)$ as in the alternative model. I specify $\tilde{a}_i(j)$ as a parametric function of exporter agro-ecological characteristics and product agro-ecological requirements:

$$ln(\tilde{a}_i(j)) = \mathbf{X}_i\boldsymbol{\delta}(j) \equiv \mathbf{X}_i\boldsymbol{\delta} + \mathbf{X}_i(\mathbf{E}(j)\boldsymbol{\Lambda})^{'} + \mathbf{X}_i(\boldsymbol{\nu}_{\mathbf{E}}(j)\boldsymbol{\Sigma}_E)' \tag{24}$$

where $\mathbf{X}_i$ 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; $\mathbf{E}(j)$ is a $1 \times m$ vector of product j-specific agro-ecological production requirements that can be observed and quantified; $\boldsymbol{\Lambda}$ is an $m \times k$ matrix of coefficients that describe how the relationship between elements of $\mathbf{X}_i$ and land productivity varies across products; $\boldsymbol{\nu}_{\mathbf{E}}(j)$ is

[9] EK includes importer fixed effect in trade costs, whereas Waugh (2010) demonstrates that an exporter fixed effect is more appropriate.

a $1 \times k$ vector that captures unobservable product j-specific requirements; and $\mathbf{\Sigma}_E$ is a scaling matrix .

I define $\mathbf{X}_i = \begin{bmatrix} AL_i & trop_i & temp_i & bor_i \end{bmatrix}$, where AL_i is log arable land area, and the remaining elements are the shares of total land area in tropical, temperate, and boreal climate zones. I define $\mathbf{E}(j) = \begin{bmatrix} trop(j) & temp(j) & bor(j) \end{bmatrix}$, where elements of $\mathbf{E}(j)$ are the intensity of product j's cultivation in each climate zone. I assume $\mathbf{E}(j)$ is distributed across products following the empirical distribution of product requirements for products defined at the "item" level by the FAO. I assume unobservable agro-ecological requirements $\boldsymbol{\nu}_E(j)$, follow a standard multivariate normal distribution.

I specify product-specific trade costs as:

$$ln(\tau_{ni}^A(j)) = \mathbf{t}_{ni}\boldsymbol{\beta}(j) \equiv \mathbf{t}_{ni}\boldsymbol{\beta} + ex_i^A + \mathbf{t}_{ni}(\boldsymbol{\nu}_{t_n}(j)\mathbf{\Sigma}_t)' + \xi_{ni}^A \qquad (25)$$

where $\mathbf{t}_{ni}$ is the 1×10 vector of proxy variables for trade costs used in the alternative model,[10] $\boldsymbol{\beta}$ is a vector of coefficients; ex_i^A is an exporter-specific trade cost; $\boldsymbol{\nu}_{t_n}(j)$ is a 1×10 vector of standard normal random variables representing unobserved product-specific trade costs; $\mathbf{\Sigma}_t$ is a scaling matrix; and ξ_{ni}^A captures unobservable or unquantifiable bilateral trade costs that are orthogonal to the regressors.

Note that product-specific trade policy variables could be included here and interacted with elements of $\mathbf{t}_{ni}$ in the same way that $\mathbf{E}(j)$ interacts with $\mathbf{X}_i$. Such variables could include tariffs or other measures of protection. The model can also accommodate product-specific policy variables, such as price supports, that affect unit *production* costs.

Using Equations 24 and 25 in Equation 10 I get the benchmark model of

[10] These are dummy variables indicating that the countries share a border or language, their distance, and whether they are members of the EU or NAFTA FTAs.

agricultural trade flows, which corresponds to Equation 23:

$$\pi_{ni}^A = \int \frac{exp\{\tilde{S}_i^A + \mathbf{X}_i(\mathbf{E}(j)\mathbf{\Lambda})' + \mathbf{X}_i(\boldsymbol{\nu}_E(j)\mathbf{\Sigma}_E)' - \theta \mathbf{t}_{ni}\boldsymbol{\beta}(j) - \theta ex_i\}}{\sum_{l=1}^{I} exp\{\tilde{S}_l^A + \mathbf{X}_l(\mathbf{E}(j)\mathbf{\Lambda})' + \mathbf{X}_l(\boldsymbol{\nu}_E(j)\mathbf{\Sigma}_E)' - \theta \mathbf{t}_{nl}\boldsymbol{\beta}(j) - \theta ex_l\}} d\hat{F}_{E_n}(\mathbf{E}) d\hat{F}_{\nu_n}(\boldsymbol{\nu}) \tag{26}$$

where $\tilde{S}_i^A \equiv S_i^A + \mathbf{X}_i\boldsymbol{\delta}$ and $d\hat{F}_{E_n}(\mathbf{E})d\hat{F}_{\nu_n}(\boldsymbol{\nu})$ is the estimated density of products imported into market n defined jointly by their climate and unobserved agro-ecological requirements and trade costs.

I estimate Equation 26 using a simulated method of moments approach similar to that in Berry, Levinsohn and Pakes (1995)[2], which is detailed in Nevo (2000)[13] and Train (2009)[14]. To numerically evaluate the integral, I use the "smooth simulator" suggested by Nevo (2000):

$$\pi_{ni}^A = \frac{1}{ns}\sum_{j=1}^{ns} \frac{exp\{\tilde{S}_i^A + \mathbf{X}_i(\mathbf{E}(j)\mathbf{\Lambda})' + \mathbf{X}_i(\boldsymbol{\nu}_E(j)\mathbf{\Sigma}_E)' - \theta \mathbf{t}_{ni}\boldsymbol{\beta}(j) - \theta ex_i\}}{\sum_{l=1}^{I} exp\{\tilde{S}_l^A + \mathbf{X}_l(\mathbf{E}(j)\mathbf{\Lambda})' + \mathbf{X}_l(\boldsymbol{\nu}_E(j)\mathbf{\Sigma}_E)' - \theta \mathbf{t}_{nl}\boldsymbol{\beta}(j) - \theta ex_l\}} \tag{27}$$

where ns is a large number. Finally, I use the minimum distance procedure suggested by Nevo (2000)[13] to obtain $\hat{\boldsymbol{\delta}}$ from $\hat{\tilde{S}}_i^A$.

Before I discuss the results, I briefly demonstrate how this specification generates sensible trade elasticity estimates. Recall from Equation 21 that cross-country trade elasticity is increasing in $cov(\pi_{ni}^A(j), \pi_{nl}^A(j))$. Given the above specification:

$$\begin{aligned} cov(\pi_{ni}^A(j), \pi_{nl}^A(j)) &= \sum_{k,q}\sum_{m,p} \lambda_{km}\lambda_q p \mathbf{X}_{i,k}\mathbf{X}_{l,q} cov(\mathbf{E}_m(j), \mathbf{E}_p(j)) \quad (28) \\ &+ \sum_k \sigma_k^2 \mathbf{X}_{i,k}\mathbf{X}_{l,k} + \sum_d \sigma_{t,d}^2 \mathbf{t}_{ni,d}\mathbf{t}_{nl,d} \end{aligned}$$

The first two sums describe covariance arising from the degree to which the exporters are well-suited for similar agricultural products. The last captures covariance due to "gravity" with respect to market n. The parameters $\mathbf{\Lambda}$, $\mathbf{\Sigma}_E$ and $\mathbf{\Sigma}_t$ define the influence of each term on covariance.

4.3. Data

The data cover trade among 42 countries in the year 2000. I began by assembling data from the countries with the 50 highest GDP per capita and the 50 highest shares of agricultural raw materials in agricultural value added[15]. I constructed agricultural expenditure shares using data from the UN Food and Agriculture Organization (FAO)[16] at the "item" level of aggregation. I used bilateral trade flows and production aggregated over 177 agricultural items for which data on both bilateral trade and the gross value of production in US dollars are available to calculate bilateral expenditure shares X_{ni}^A/X_n^A, where X_{ni}^A is the total value of the agricultural trade flow from country i to country n. I calculate X_n^A as the sum of total production plus total agricultural imports less total exports. Domestic shares are calculated as $X_{nn}^A/X_n^A = 1 - \sum_{i \neq n}^{I} X_{ni}^A/X_n^A$. For the manufacturing sector I use production and bilateral trade data from the CEPII TradeProd database, described in de Sousa et al (2012)[17].

Countries for which complete trade and production data was not available for both sectors were dropped from the sample. I also dropped eleven countries for which trade and production data were available, but bilateral agricultural trade flows were zero for more than half of the import markets. I replace the remaining zero bilateral trade flows with $1 flows. The impact of zero dependent variables on parameter estimates is an important issue for research that relies on the log-linear gravity equation. I do not pursue analysis of the robustness to the treatment of zero trade observations here since my focus is on introducing an alternative framework that does not rely on the log-linear gravity model to estimate trade costs.

I assemble the trade cost proxy variables using the CEPII gravity dataset of Head, Mayer and Ries (2010)[18] available for download from www.cepii.fr. The language variable equals one if at least 9% of the population in both countries speaks a common language. As in EK and Waugh (2010)[12], I classify distance into six categories (see Table 1) using the population-weighted average distance between the largest cities of the two countries.

Table 1: Definition of Distance Variables

Variable	Distance, miles
Distance 1	[0,375)
Distance 2	[375,750)
Distance 3	[750,1500)
Distance 4	[1500,3000)
Distance 5	[3000,6000)
Distance 6	[6000,maximum]

The vector of observable production requirements $\mathbf{E}(j) = \begin{bmatrix} trop(j) & temp(j) & boreal(j) \end{bmatrix}$ is estimated as a production-weighted distribution of climate across all 42 countries. For example the tropical cultivation intensity for item j is estimated as:

$$trop(j) = \sum_{i=1}^{I} \omega_i(j) \times trop_i$$

where $\omega_i(j)$ is country i's share of global item j production value.

To estimate $\hat{F}_{E_n}(\mathbf{E})$, the empirical distribution of $\mathbf{E}(j)$ across products imported by each market, I first compile a list of 100 products in proportion to their share of the item they represent in total imports. That is, if 15% of importer n's total agricultural imports are of the FAO item "wheat", then $\mathbf{E}(wheat)$ makes up 15 entries on the list. The distribution $\hat{F}_{E_n}(\mathbf{E})\hat{F}_{\nu_n}(\boldsymbol{\nu})$ is completed by associating each product with the corresponding value of $\boldsymbol{\nu}_n(j) = [\boldsymbol{\nu}_E(j) \;\; \boldsymbol{\nu}_{t_n}(j)]$ drawn from a standard multivariate normal distribution. I draw $ns = 100$ values of $(\mathbf{E}(j), \boldsymbol{\nu}_n(j))$ at random, effectively generating a "data set" of 100 products imported by each market. Data on the distribution of each country's total land area across climate zones comes from the GTAP Land Use Database [19] and data on total arable land (AL_i) comes from the World Bank World Development Indicators [15].

4.4. Parameter Estimates

Technological Productivity. I set $\theta = 4.12$, the baseline value estimated in Simonovska and Waugh (2011)[9]. I obtain estimates of T_i^A from $\tilde{S}_i^A$ in the benchmark model and $T_i^{A'}$ from S_i^A in the alternative model as in Waugh (2010)[12].

I report estimates for $\tilde{S}_i^A$, $S_i^{A'}$, T_i^A and $T_i^{A'}$ relative to the USA in Table 4. Coefficients on producer fixed effects are normalized to sum to zero[20]. In the alternative model, values of $\hat{S}_i^A > 0$ imply that exporter i is more competitive in agriculture than the average country. The relevant comparison in the benchmark model is to the *average* country's competitiveness in the *average* product. The average country's climate distribution in my sample is 23% tropical, 64% temperate and 13% boreal. The average distribution of cultivation for products in my sample is 10% tropical, 80% temperate and 10% boreal.

Land Productivity. Estimates of $\hat{\boldsymbol{\delta}}$, $\hat{\boldsymbol{\Lambda}}$, and $\hat{\boldsymbol{\Sigma}}_E$. are listed in Table 2. Coefficients on all climate variables are normalized to sum to zero. As such, the effects of 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.

Table 2: Land Productivity Distribution Parameter Estimates

Exporter Characteristics	Mean Effect (δ)	Climate Requirements (Λ)		Unobserved
		Tropical	Temperate	Requirements (Σ_E)
ln Arable Land	-0.07***	-1.14***	-1.23***	0.04***
(AL_i)	(0.01)	(0.05)	(0.04)	(0.004)
Tropical Climate Share	-2.64***	4.12***	7.93***	-0.03
($trop_i$)	(0.12)	(0.35)	(0.29)	(0.1)
Temperate Climate Share	1.61***	-0.03	-4.02***	0.19**
($temp_i$)	(0.12)	(0.33)	(0.28)	(0.10)
Boreal Climate Share	1.03***	-4.09***	-3.92***	-0.16
(bor_i)	(0.19)	(0.46)	(0.41)	(0.17)

As an example of how to interpret the estimates in Table 2, consider the effect of an exporter's share of land in a tropical climate zone ($trop_i$). The negative mean effect estimate indicates that market share in the average product is decreasing in the extent to which an exporter has a larger-than-average share of tropical land. However, the large and positive estimates of $\lambda_{trop,trop} = 4.12$ and $\lambda_{trop,temp} = 7.93$ imply that this disadvantage is reversed for products that are more intensively tropical or temperate than the average product. The left panel of Figure 1 displays the distribution of the total effect of tropical climate share: $\delta_{trop} + \mathbf{E}(j)\boldsymbol{\lambda}_{trop} + \boldsymbol{\nu}(j)\boldsymbol{\sigma}_{trop}$ across the 130 traded items. The figure illustrates that the total effect is positive for a large number of products even though the mean effect is negative.

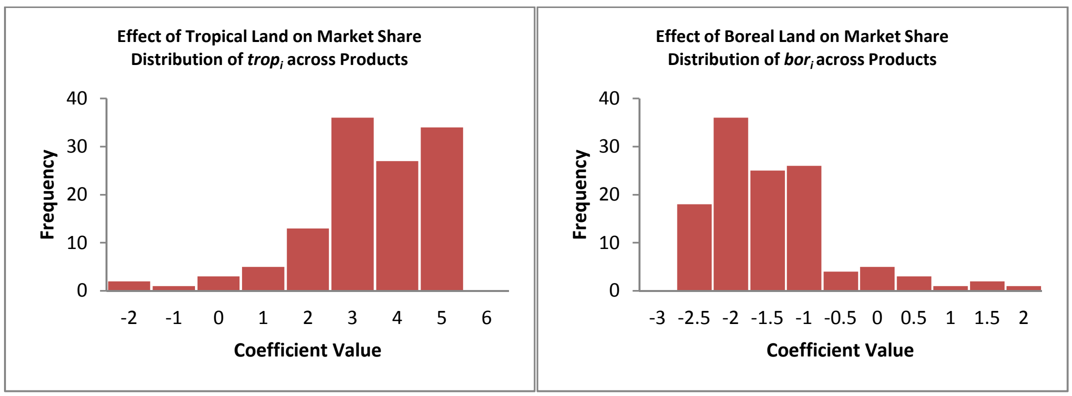

Figure 1: Distribution of Climate Effects Across Products

The only climate share characteristic for which the effect of unobserved product-specific requirements is statistically significant is $temp_i$. This suggests that the distribution of production requirements across three climate zones is inadequate to explain how the value of temperate land share varies across products. This is unsurprising given that the average country is characterized by a large share of temperate land and the average product is intensively cultivated in temperate climate zones. A more precise measure of the relationship between exporter agro-ecological characteristics and trade patterns will thus require either additional refinements to the temperate land characteristic or additional variables representing non-climate production requirements that influence the differential value of temperate land across products.

Figure 2 demonstrates that the modified model predicts exporters will specialize in products for which their agro-ecological characteristics are well-suited. This is in contrast to the EK model, where specialization is randomly determined by realizations of $z_i^A(j)$. Estimates of $\tilde{S}_i^A$ suggest that the United States and Turkey both have an absolute advantage over Costa Rica in the average agricultural product.[11] Figure 2 illustrates the model's prediction that Costa Rica is more "naturally" competitive than the United States in all coffee, tea and spice products, and more naturally competitive than Turkey in most of them. It is a relative frequency distribution of $\tilde{S}_i^A + \mathbf{X}_i(\mathbf{\Lambda E}(j))$ for $j=$ coffee, tea and spice products and i=Costa Rica, The United States, and Turkey.

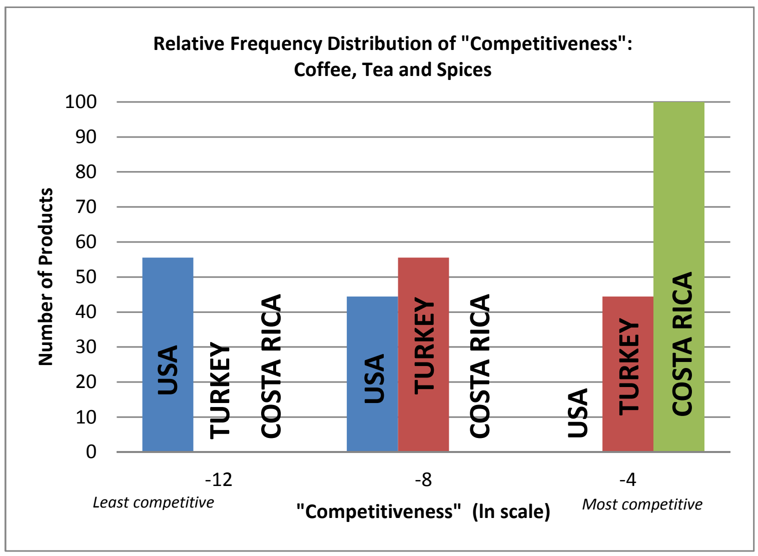

Figure 2: "Competitiveness" in Coffee, Tea and Spices

Trade Costs. Table 3 contains parameter estimates for the trade costs distribution. Coefficients in the first column capture the average effect of each trade cost component on market share in the benchmark model. Positive coefficients imply the effect decreases trade costs, but increases market share. The second column contains coefficient estimates on the product-specific heterogeneity around each trade cost component, $\hat{\Sigma}_t$. These values can be interpreted like a

[11] $\hat{\tilde{S}}_{TUR}^A = 4.30$, $\hat{\tilde{S}}_{USA}^A = 2.38$, $\hat{\tilde{S}}_{CRI}^A = -6.27$

standard deviation. The third column contains estimates from the alternative model. Notice that these are broadly similar to the mean effect estimates from the benchmark.

Table 3: Trade Cost Distribution Parameters

	Agriculture			
	Benchmark Model		Alternative Model	Manufacturing
Exporter Characteristic	Mean (β)	Unobserved Heterogeneity (σ_t)	Coefficient	Coefficient
Common Border	0.54*	0.93***	0.75*	0.58***
	(-0.35)	(-0.33)	(-0.56)	(0.19)
Common Language	1.30**	-0.48**	1.49***	0.91***
	(-0.29)	(-0.21)	(-0.35)	(0.12)
Distance 1	-8.82***	-3.26***	-5.89***	-3.53***
	(-0.21)	(-0.29)	(-0.70)	(0.24)
Distance 2	-7.75***	-0.78***	-8.47***	-4.47***
	(-0.34)	(-0.26)	(-0.44)	(0.15)
Distance 3	-9.57***	0.60***	-10.27***	-5.16***
	(-0.31)	(-0.24)	(-0.32)	(0.11)
Distance 4	-11.33***	0.63***	-11.87***	-5.33***
	(-0.32)	(-0.20)	(-0.32)	(0.11)
Distance 5	-14.09***	-1.14***	-13.91***	-6.78***
	(-0.32)	(-0.33)	(-0.18)	(0.06)
Distance 6	-14.38***	0.10	-15.00***	-7.34***
	(-0.23)	(-0.34)	(-0.17)	(0.06)
Intra-EU	-5.68***	-2.76***	-2.62***	-0.61***
	(-0.19)	(-0.20)	(-0.47)	(0.16)
Intra-NAFTA	-14.92***	-8.21***	-1.64***	0.12
	(-0.28)	(-0.58)	(-1.63)	(0.56)

It is perhaps surprising that the signs on $NAFTA$ and EU are negative in both models, implying that membership in these FTAs increases agricultural trade costs on average. This result can be rationalized by the product-specific interpretation of trade cost effects in the modified model. Indeed, there are many agricultural products for which no member country of the EU or NAFTA will be well-suited: The lowest price offer for green coffee beans in France certainly has a very low probability of coming from producers in another EU member state!

I report estimates of the exporter-specific trade cost ex_i^A, in Table 4. Like the producer fixed effects, these values are interpreted with respect to the average country: In both models, values of $\hat{ex}_i^A > 0$ imply country i faces higher than average agricultural trade costs and vice versa. Coefficient estimates from the benchmark model are highly correlated with and of broadly similar magnitude to alternative model estimates.

Table 4: Country-Specific Estimates: Agriculture Sector

	Producer Effects $\tilde{S}_i^A$, S_i^A		T_i^A/T_{USA}^A		Exporter Effects ex_i^A	
Country	Benchmark	Alternative	Benchmark	Alternative	Benchmark	Alternative
Argentina	3.96***	2.32***	0.01	0.01	3.67***	2.06***
	(0.48)	(0.57)			(0.72)	(0.83)
Australia	1.97***	-0.10	0.02	0.05	4.05***	4.45***
	(0.4)	(0.58)			(0.56)	(0.85)
Austria	0.79*	-1.53***	0.38	0.51	-1.01	0.46
	(0.54)	(0.57)			(0.77)	(0.83)
Brazil	-1.83***	0.98**	0.00	0.00	2.68***	3.69***
	(0.52)	(0.56)			(0.74)	(0.81)
Canada	-1.11***	-1.81***	0.02	0.02	8.93***	6.28***
	(0.35)	(0.58)			(0.40)	(0.85)
Chile	1.00**	-0.22	0.01	0.01	2.72***	3.09***
	(0.54)	(0.57)			(0.77)	(0.83)
Colombia	-4.69***	1.35***	0.00	0.00	-2.04***	-0.99
	(0.51)	(0.56)			(0.73)	(0.81)
Costa Rica	-6.27***	2.56***	0.00	0.00	-3.22***	-1.92***
	(0.51)	(0.56)			(0.70)	(0.82)
Denmark	0.44	-1.81***	0.13	0.24	2.85***	3.73***
	(0.49)	(0.57)			(0.71)	(0.84)
Ecuador	-3.52***	2.70***	0.00	0.00	-2.80***	-3.13***
	(0.54)	(0.57)			(0.74)	(0.82)
Estonia	1.22**	1.59***	0.00	0.00	-7.67***	-8.47***
	(0.55)	(0.57)			(0.79)	(0.83)
Finland	-0.98**	-2.96***	1.10	1.83	-4.38***	-3.41***
	(0.52)	(0.57)			(0.66)	(0.83)

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Table 4 – continued from previous page

	Producer Effects $\tilde{S}_i^A$, S_i^A		T_i^A/T_{USA}^A		Exporter Effects ex_i^A	
Country	Benchmark	Alternative	Benchmark	Alternative	Benchmark	Alternative
France	2.21***	-1.04**	0.48	0.72	4.82***	5.21***
	(0.54)	(0.57)			(0.78)	(0.83)
Germany	-0.33	-2.34***	0.07	0.15	5.88***	5.21***
	(0.54)	(0.57)			(0.78)	(0.83)
Hungary	2.73***	1.22**	0.01	0.02	-2.57***	-2.83***
	(0.52)	(0.57)			(0.74)	(0.84)
India	-0.06	3.38***	0.00	0.00	2.18***	-0.2
	(0.52)	(0.57)			(0.72)	(0.82)
Indonesia	-3.68***	0.49	0.00	0.00	2.48***	3.76***
	(0.48)	(0.57)			(0.64)	(0.82)
Iran	2.99***	3.42***	0.00	0.00	-1.44**	-4.36***
	(0.55)	(0.58)			(0.81)	(0.85)
Ireland	1.25***	0.08	0.64	1.24	-3.37***	-2.8***
	(0.53)	(0.57)			(0.76)	(0.83)
Israel	-1.33***	0.14	0.03	0.07	-2.31***	-0.85
	(0.55)	(0.57)			(0.8)	(0.84)
Italy	1.49***	-1.88***	1.21	2.43	4.45***	5.55***
	(0.54)	(0.57)			(0.78)	(0.83)
Japan	-3.57***	-4.76***	0.39	1.53	1.91***	1.09*
	(0.53)	(0.57)			(0.78)	(0.82)
Kenya	-4.15***	2.53***	0.00	0.00	-3.66***	-3.51***
	(0.48)	(0.57)			(0.70)	(0.82)
Malaysia	-4.03***	0.38	0.03	0.08	-3.80***	-0.33
	(0.36)	(0.56)			(0.50)	(0.81)
Mexico	-0.17	0.45	0.00	0.00	1.62**	0.63
	(0.54)	(0.57)			(0.78)	(0.83)
Netherlands	-1.48***	-2.84***	0.03	0.04	4.66***	5.5***
	(0.55)	(0.57)			(0.79)	(0.84)
New Zealand	1.37***	0.49	0.11	0.15	1.27*	1.22*
	(0.56)	(0.58)			(0.82)	(0.85)
Czech Republic	2.16***	-0.03	0.01	0.02	-5.32***	-4.54***
	(0.54)	(0.57)			(0.78)	(0.84)
Poland	2.37***	-1.33***	0.01	0.01	-5.33***	-4.24***
	(0.55)	(0.57)			(0.80)	(0.84)
Portugal	-0.23	-2.26***	0.00	0.01	1.55**	2.63***
	(0.51)	(0.57)			(0.74)	(0.83)
Romania	3.33***	2.79***	0.00	0.00	-3.95***	-5.81***

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Table 4 – continued from previous page

Country	Producer Effects $\tilde{S}_i^A$, S_i^A		T_i^A/T_{USA}^A		Exporter Effects ex_i^A	
	Benchmark	Alternative	Benchmark	Alternative	Benchmark	Alternative
	(0.55)	(0.57)			(0.79)	(0.83)
Russia	2.83***	-1.97***	0.00	0.00	-3.68***	-2.58***
	(0.5)	(0.57)			(0.73)	(0.83)
Slovenia	-0.03	1.07**	0.03	0.03	-9.85***	-9.83***
	(0.55)	(0.57)			(0.79)	(0.84)
Slovakia	1.94***	2.01***	0.01	0.00	-9.69***	-10.57***
	(0.55)	(0.57)			(0.79)	(0.83)
South Africa	2.40***	0.62	0.00	0.01	1.71***	1.39**
	(0.29)	(0.57)			(0.28)	(0.83)
Spain	2.05***	-1.14**	0.08	0.32	4.59***	5.21***
	(0.54)	(0.57)			(0.79)	(0.83)
Sweden	-3.01***	-3.62***	0.01	0.02	0.84	0.22
	(0.54)	(0.57)			(0.73)	(0.83)
Thailand	-5.13***	1.11**	0.00	0.00	2.33***	1.68**
	(0.35)	(0.56)			(0.38)	(0.82)
Turkey	4.30***	1.80***	0.02	0.03	0.56	-0.03
	(0.49)	(0.57)			(0.7)	(0.83)
UK	-1.01**	-2.75***	0.01	0.03	4.97***	4.61***
	(0.54)	(0.57)			(0.79)	(0.83)
USA	2.39***	-1.08**	1.00	1.00	8.13***	7.03***
	(0.59)	(0.58)			(0.9)	(0.87)
Uruguay	1.43***	1.98***	0.00	0.00	-2.75***	-4.29***
	(0.56)	(0.57)			(0.81)	(0.83)

5. Solution

In addition to the estimated parameters discussed above, 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 [15]. Value-added α_i^k, intermediate inputs shares ξ_l^k, and consumption shares λ_i^k are obtained from input-output tables for the early 2000's from the OECD-STAN database[21]. Input-output tables are available for 30 countries. I assign the average value for each parameter to the remaining countries (See Appendix

C). I set $\beta_i^A = 0.66$, the mean estimate of labor's share in production in Gollin (2002)[22] and $\sigma = 2.0$ as in Ruhl (2008)[23]. Finally, I set $z_i^S = 1$ and $D_i^A = 0$.

To solve for equilibrium given the structural parameter values, I first guess a vector of wages $\bar{\mathbf{w}} = [\bar{w}_1, \ldots, \bar{w}_I]$. Let $Y_i^A(\bar{\mathbf{w}})$ be the solution to Equation 15, consistent with the guessed wage vector and country i's total labor endowment. I use the following equilibrium condition with each country's total arable land endowment to solve for land rent:

$$r_i(\bar{\mathbf{w}})L_i = \alpha_i^A(1-\beta_i^A)Y_i^A(\bar{\mathbf{w}}) \tag{29}$$

Given $\bar{\mathbf{w}}$, sectoral price indices are $2 \times I$ equations in $2 \times I$ unknowns. I solve for the agriculture and manufacturing sector price indices in each country, simulating the integral in Equation 7 as:

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

using the same ns products I used to estimate Equation 27. I use $p_i^A(\bar{\mathbf{w}})$, $p_i^M(\bar{\mathbf{w}})$, $r_i(\bar{\mathbf{w}})$, and $\bar{\mathbf{w}}$ to calculate $c_i^A(\bar{\mathbf{w}})$ and $c_i^M(\bar{\mathbf{w}})$ then use these values with $\hat{\tau}_{ni}^A(j)$, and $\hat{\bar{a}}_i(j)$, to solve for $\pi_{ni}^A(\bar{\mathbf{w}})$ from Equation 10 for the benchmark model, simulating the integral as above. Correspondingly, I use estimates of $\tau_{ni}^{A'}$ and $\hat{\tau}_{ni}^M$ to solve for $\pi_{ni}^{A'}$ and π_{ni}^M using Equation 8.

Substituting Equations 15 and 16 into the country i manufacturing sector market clearing condition yields a system of I equations that relate the value of labor in each country to its value in all other countries.

$$\kappa_{1i}^M w_i N_i + \kappa_{2i}^M Y_i^A(w_i) + \kappa_{3i}^M D_i^A = \sum_{n=1}^{I}\left(\kappa_{1n}^M w_n N_n + \kappa_{2n}^M Y_n^A(w_n) + \kappa_{4n}^M D_n^A\right) \tag{30}$$

The vector of guessed wages is adjusted until Equation 30 holds. To complete the equilibrium solution, I calculate labor shares for each sector according to Equation 14.

Base solutions for each model are nearly the same, with the exception of the agricultural price index. (See Appendix D.) Predicted bilateral market shares fit observed shares well, but predictions for other aggregate measures are weakly correlated with the data. The high correlation between the two base solutions suggests that model fit could be improved by adjusting the calibration of structural parameters other than trade costs. There are several degrees of freedom available for such adjustment in future applications.

5.1. Trade and Production Patterns

The primary difference between the benchmark and alternative models is their implications for how production and trade patterns respond to changes in trade costs. In the benchmark model, the predicted change in an exporter's market share depends on the products in which its producers are competitive, and the number of other countries that offer competitive prices for those products. In the alternative model, the effect is determined solely by the value of the parameter θ and the exporter's market share.

To examine the differences in the two models' predictions, I calculate general equilibrium elasticities by simulating a 1% increase in an exporter's trade costs, then calculating the percent change in each competitor's agricultural market share over the base solution. Table 5 compares the indirect effects of changes in Canadian, French, and Costa Rican costs on US market share to their effects on the median competitor's share of select import markets. The first column under each exporter contains the benchmark model elasticity of US market share with respect to the exporter's trade costs, relative to the median cross-country elasticity. The second column contains US elasticity relative to the median predicted by the *alternative* model. Looking down each column one can see that cross-country elasticity with respect to each exporter varies significantly across competitors in the benchmark model, whereas the alternative model predicts that market share adjustment is virtually identical for every competitor.

In the benchmark model, US market share is more elastic than the median exporter to changes in Canadian trade costs in every market except the domestic market, and more elastic than the median to French trade costs in all but a few. In contrast, US market share is far less sensitive to changes in Costa Rican trade costs than the median in every import market. Thus the benchmark

Table 5: The Elasticity of US Market Share Relative to the Median Exporter

	Canada		Costa Rica		France	
	Bench.	Alt.	Bench.	Alt.	Bench.	Alt.
Canada	-	-	0.09	1.00	0.82	1.00
Chile	7.67	1.00	0.00	1.00	7.23	1.00
Costa Rica	1.43	1.00	-	-	1.42	1.00
Czech Republic	15.02	1.00	0.00	1.00	12.32	1.00
Ecuador	3.32	1.00	0.34	1.00	3.15	1.00
Finland	14.2	1.00	0.01	1.00	3.63	1.00
Hungary	13.83	1.00	0.00	1.00	7.55	1.00
Ireland	6.60	1.00	0.07	1.00	0.76	1.00
Israel	3.08	1.00	0.47	1.00	2.51	1.00
Japan	14.90	1.00	0.00	1.00	5.22	1.00
Malaysia	1.28	1.00	0.13	1.00	1.06	1.00
Mexico	56.25	1.00	0.25	1.00	0.20	1.00
Poland	14.86	1.00	0.01	0.95	4.56	1.00
Portugal	26.35	1.00	0.00	1.00	14.48	1.00
South Africa	7.15	1.00	0.00	0.98	0.62	1.00
Spain	17.48	1.00	0.03	1.00	1.25	1.00
Turkey	13.04	1.00	0.01	0.85	1.12	1.00
UK	18.67	1.00	0.02	1.00	0.67	1.00
Uruguay	6.68	1.00	0.02	1.00	6.62	1.00
USA	0.19	0.80	0.26	0.80	0.73	0.80

model consistently predicts the US is a closer substitute for Canada and France than for Costa Rica.

Notice that the few import markets in which the United States is less sensitive than the median with respect to changes in French trade costs are the most agro-ecologically similar to either France or the United States. In such markets, the comparative advantage of US and French producers is less likely to be driven by relatively high values of $a_i(j)$ and more likely to be driven by relatively high realizations of $z_i^A(j)$. Conversely, the markets in which US elasticity with respect to Costa Rican costs is *highest* relative to the median are those in which incentives to trade with Costa Rica are least likely to derive from agro-ecological differences.

6. Full vs. Partial Agricultural Trade Liberalization

In this section I explore the effects of full versus partial agricultural trade liberalization using the benchmark model. The ability to simulate changes in product-specific trade costs is critical for applied agricultural policy analysis, in which implications of changes in the dispersion of trade costs are of central interest. Such an experiment cannot be carried out using the alternative model without breaking it down into sub-sectors with common trade costs. This is a fine approach as long as the IIA holds at the sub-sector level and disaggregated data are available.

I simulate agricultural trade liberalization by setting average bilateral trade costs in the agricultural sector equal to bilateral manufacturing trade cost estimates. This represents an average cut in agricultural trade costs of 92%. To simulate partial liberalization I add the difference between average agricultural and manufacturing trade costs back for just two products: cotton lint and cattle meat. The implicit claim behind this experiment is that manufacturing trade is as close to free trade as it is possible to achieve, and that any difference in average trade costs between sectors represents barriers that could potentially be reduced. This is admittedly a simplified way to contemplate agricultural liberalization.

Full agricultural trade liberalization results in significant shifts in production and trade patterns from the base solution. The degree to which agricultural market share has been re-allocated across exporters in a given market can be measured by the rank correlation between market shares before and after liberalization. Table 6 reports the Spearman rank correlation coefficient between market shares of foreign producers in the base solution and after full liberalization for each import market. A smaller value implies greater reallocation of agricultural expenditure across exporters. The largest reallocations in market share across exporters are in Iran, Portugal, Malaysia and The Netherlands. Shifts in agricultural import patterns due to liberalization are smallest in Central and East European countries.

Table 6: Size of Shifts in Bilateral Ag Trade Patterns

Import Market	Rank correlation $\pi_{ni}^{A^*}, \pi_{ni}^{A^F}$	Import Market	Rank correlation $\pi_{ni}^{A^*}, \pi_{ni}^{A^F}$
Iran	0.50	Germany	0.75
Portugal	0.53	Turkey	0.75
Malaysia	0.53	Hungary	0.75
Netherlands	0.56	Czech Republic	0.75
Denmark	0.56	Brazil	0.76
Canada	0.57	Poland	0.77
Russia	0.57	Mexico	0.77
New Zealand	0.59	Slovakia	0.77
Israel	0.59	Austria	0.79

Table 7 compares the increase in agricultural imports under the two scenarios for selected import markets.[12] I denote domestic market share under the base solution, full liberalization and partial liberalization respectively as $\pi_{nn}^{A^*}$, $\pi_{nn}^{A^F}$ and $\pi_{nn}^{A^P}$. The first column displays the import penetration ratio under full liberalization relative to the base solution. This shows that total agricultural trade increases dramatically under agricultural liberalization. The second column displays the import penetration ratio under partial relative to full liberalization. The difference between full and partial liberalization is negligible for many import markets. For others the difference is more substantial. In particular, the share of imports in agricultural expenditure falls by more than one-third in Indonesia, Ecuador and Thailand under partial liberalization. This can be traced to the importance of cotton in these three countries' estimated import distributions and the fact that their ecological characteristics differ substantially from cotton's estimated agro-ecological production requirements.

Table 8 examines the difference between full and partial agricultural liberalization from the perspective of countries as exporters.[13] The first column contains the average percent increase in π_{ni}^{A} $(i \neq n)$ in moving from the base

[12]Full results are listed in Appendix E.
[13]Full results are listed in Appendix E.

Table 7: Increase in Ag Trade - Full vs. Partial Liberalization

Country	Full Liberalization $(1-\pi_{nn}^{A^F})/(1-\pi_{nn}^{A^*})$	Partial /Full Liberalization $(1-\pi_{nn}^{A^P})/(1-\pi_{nn}^{A^F})$
Indonesia	32.01	0.54
Ecuador	50.29	0.65
Thailand	6.15	0.66
Chile	15.30	0.79
South Africa	96.79	0.93
Netherlands	35.19	0.99
Italy	7.49	1.00
Costa Rica	2.23	1.00
Austria	27.50	1.00

solution to full liberalization. The biggest increases are generally among the poorest countries and Central and East European countries. The magnitude of some countries' exports expansion is dramatic, but bear in mind that initial values of π_{ni}^A tend to be very small—the median value of π_{nn}^A in the base solution is 0.88. The second column compares the average percent increase in each exporter's foreign market share under partial relative to full liberalization.

Table 8: Increase in Ave. Foreign Market Share - Full vs. Partial Liberalization

	Ave. % Change in π_{ni}^A from Base Solution, $(i \neq n)$	
Exporter	Full Liberalization	Partial /Full Liberalization
Costa Rica	384.07	0.95
Thailand	413.55	0.98
Malaysia	902.61	1.00
USA	68.92	1.00
Italy	192.5	1.00
Netherlands	165.44	1.01
Colombia	245.63	1.02
Ecuador	192.12	1.02

While Table 8 reveals that producers in a handful of countries may benefit from partial liberalization, Table 9 shows that consumer gains are uniformly smaller. The first column lists the percent increase in real income under full agricultural liberalization for selected countries.[14] While the increase is small for most countries, considering that agricultural products only represent an average of 5% of consumption expenditure, this is not insubstantial. The second column contains real income gains under partial relative to full liberalization. For many countries, leaving cotton lint and cattle meat highly protected has a negligible impact on gains from liberalization while for others—particularly Indonesia and Thailand—the loss in real income is considerable.

Table 9: Increase in Real Income from Ag Liberalization

Country	Full Liberalization	Partial /Full Liberalization
Indonesia	16.16%	0.78
Thailand	10.14%	0.85
Netherlands	4.22%	1.00
Malaysia	3.41%	0.99
Italy	2.63%	1.00
Chile	0.62%	0.99
Ecuador	0.51%	0.96
Costa Rica	0.39%	1.00
USA	0.37%	1.00

7. Evaluating a Menu of Product-Specific Tariff Cuts

Trade agreements that cover agriculture tend to be characterized by product-specific policy commitments that are much more complicated than the foregoing experiment. To demonstrate the ease with which the model can accommodate more complex policy changes, I use the benchmark model to compare a 50% cut to all agricultural products to a set of cuts that comprise a mean-preserving spread of 50%. Tables 10 and 11 contain selected results. Since the purpose of this exercise is to demonstrate a feature of the model rather than examine a real policy change I do not include the full set of results.

Table 10 contains information on the change in the import penetration ratio.

[14] Full results are listed in Appendix E.

Like Table 7, the results demonstrate that cutting tariffs increases total agricultural trade. The biggest increases in imports from a uniform tariff cut of 50% on all agricultural tariffs tend to be in the poorest countries, whereas the United States and Canada see the smallest increase in agricultural imports. The second column of Table 10 reveals that in many markets there is a dramatic difference between the trade effects of an across the board 50% tariff cut compared to a set of product-specific cuts that come to 50% on average. In many markets, the increase in agricultural imports under the mean-preserving spread is less than one-quarter of the increase predicted for an across the board cut.

Table 10: Increase in Ag Trade - 50% Cut vs. Mean-Preserving Spread

Country	Increase in Ag Imports over Base Solution	
	Uniform 50% Cut $(1-\pi_{nn}^{A^U})/(1-\pi_{nn}^{A^*})$	Spread / Uniform Cut $(1-\pi_{nn}^{A^S})/(1-\pi_{nn}^{A^U})$
Estonia	837%	0.20
Kenya	779%	0.28
Ecuador	665%	0.22
Israel	558%	0.24
South Africa	672%	0.24
Argentina	108%	0.95
Russia	105%	0.97
USA	104%	0.98
Canada	103%	0.98

Table 11: Increase in Real Income - Uniform Cut vs. Mean-Preserving Spread

	Percent Change in Real Income over Base Solution	
Country	Uniform 50% Cut	Spread /Uniform Cut
Malaysia	2.17%	0.31
Portugal	2.99%	0.28
Argentina	2.84%	0.23
Russia	5.83%	0.22
Costa Rica	0.34%	0.25
Israel	0.22%	0.00
Ecuador	0.23%	0.00
Finland	0.50%	0.00

Table 11 corresponds to Table 9. It compares the change in real income predicted for a 50% cut to all agricultural products versus a mean-preserving spread. What is remarkable here is the sizeable drop in real income gains under the mean-preserving spread. The mean-preserving spread of the 50% tariff cut produces at most 31% of the real income gains that the across the board cut delivers. This is a striking result from a very simple experiment. It suggests that uneven cuts in tariffs across products can potentially eliminate gains from trade liberalization.

8. Conclusion

A critical weakness of the standard EK framework and other models that feature the CES import demand system lies in their strong and often counter-intuitive implications for the elasticity of bilateral trade flows with respect to changes in trade costs. The model introduced in this paper provides a richer picture of the competitive structure facing agricultural producers around the world. The method used to parameterize the productivity and trade costs distribution allows for quantitative analysis of a product-level conceptual model using easily accessible, mostly sector-level data. This product heterogeneity approach delivers more precise predictions for the effects of policy on patterns of bilateral trade and production, in addition to traditional measures of welfare gains.

The primary advantage of this framework is its flexible treatment of the production structure. However, along with that flexibility comes a degree of complexity, which I have kept minimal for the purposes of explication. Central to a successful application of this framework will be a more careful calibration and specification of productivity and trade cost distributions.

The model is expressly intended for applied policy analysis, including but not limited to evaluations of preferential trade agreements. As such, an important contribution is its ability to handle changes in the distribution of tariffs or other policies within a sector. The results of the simulated partial liberalization confirm that the distribution of tariff cuts across products can have non-trivial effects on the distribution of both trade and welfare gains from trade liberalization.

Improved forecasts for shifts in trade and production patterns have significant value beyond policy analysis. The structure presented here may be adapted by industrial users and traders of agricultural commodities to analyze how changes in agricultural production cost structure affect optimal sourcing and marketing decisions. Additionally, researchers may find this framework's ability to more precisely predict shifts in production patterns useful in evaluations of environmental consequences of policy, technology and other factors that influence agricultural production costs. Future work will focus on these and other applications.

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Appendix A. Detailed Derivation of π_{ni}^A and p_n^A, Benchmark Model

Appendix A.1. Market n agriculture sector price distribution

Claim: The prices of agricultural products purchased in market n are distributed following:

$$G_n^A(p) = 1 - \int exp\{-\sum_{m=1}^{I} T_m^k(\tilde{a}_m(j)c_m^k\tau_{nm}^k(j))^{-\theta}p^\theta\}dF_{a_n}(\tilde{\mathbf{a}})dF_{\tau_n}^k(\boldsymbol{\tau})dp$$

Proof: First, the probability country i offers a price less than p for product j in market n is:

$$\begin{aligned} Pr\left(p_{ni}^A(j) \leq p\right) &= Pr\left(\frac{\tilde{a}_i(j)c_i^A\tau_{ni}^A(j)}{z_i^A(j)} \leq p\right) \\ &= 1 - F_{z_i}^A\left(\frac{\tilde{a}_i(j)c_i^A\tau_{ni}^A(j)}{p}\right) \\ &= 1 - exp\{-T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}p^\theta\} \equiv G_{ni}^A(p(j)) \end{aligned}$$

The price actually paid for product j is:

$$p_n^A(j) = min_i\{p_{ni}^A(j)\}$$

Therefore, $p_n^A(j) \leq p$ unless all countries' price offers are greater than p. Given the density of $\tilde{a}(j) = [\tilde{a}_1(j), \ldots, \tilde{a}_I(j)]$ and $\tau_n^A(j) = \left[\tau_{n1}^A(j), \ldots, \tau_{nI}^A(j)\right]$:

$$\begin{aligned} Pr\left(p_n^A(j) > p\right) &= Pr\left(p_{nl}^A(j) > p \ \ \forall l\right) \\ &= \prod_{l=1}^{I}\left(1 - G_{ni}^A(p(j))\right) \\ &= \prod_{l=1}^{I} exp\{-T_l^A(\tilde{a}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}p^\theta\} \end{aligned}$$

The probability product j is purchased at a price less than p in market n is therefore:

$$Pr\left(p_{nl}^A(j) \leq p \ \ \forall l\right) = 1 - exp\{-\sum_{l=1}^{I} T_l^A(\tilde{a}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}p^\theta\}$$

Since $\tilde{a}_i(j)$, $\tau_{ni}^A(j)$ and $z_i^A(j)$ follow independent distributions in each country, the distribution of agricultural prices in market n is the integral of this expression over the density of $\tilde{\mathbf{a}} = [\tilde{\mathbf{a}}(0), \ldots, \tilde{\mathbf{a}}(1)]$ and $\boldsymbol{\tau}_n^A = \left[\boldsymbol{\tau}_n^A(0), \ldots, \boldsymbol{\tau}_n^A(1)\right]$ over all products purchased in market n. Therefore,

$$G_n^A(p) = 1 - \int exp\{-\sum_{l=1}^{I} T_l^A(\tilde{\mathbf{a}}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}p^\theta\}dF_{a_n}(\tilde{\mathbf{a}})dF_{\tau_n}^A(\tau)$$

Appendix A.2. Exporter i share of agricultural products purchased in market n

Claim: The share of agricultural products purchased from exporter i in market n is:

$$\bar{\pi}_{ni}^A = \int \frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}dF_{a_n}(\tilde{\mathbf{a}})dF_{\tau_n}^k(\boldsymbol{\tau})$$

Proof: By invoking a law of large numbers as in EK, the unconditional probability that exporter i offers the lowest price for an agricultural product in market n is also the fraction of goods that market n buyers purchase from country i producers. The probability that the lowest offer for product j comes from exporter i is the probability all of its competitor offer higher prices. Let $p_{ni}^A(j) = p^*$.

$$Pr\left(p_{nl}^A(j) > p^* \;\; \forall l \neq i\right) = \prod_{l\neq i} Pr(p_{nl}^A(j) > p^*) = exp\{-\sum_{l\neq i} T_l^A(\tilde{a}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}{p^*}^\theta\}$$

Now, integrating over all possible realizations of $p_{ni}^A(j)$:

$$Pr\left(p_{nl}^A(j) > p_{ni}^A(j) \;\; \forall l \neq i\right) = \int exp\{-\sum_{l\neq i} T_l^A(\tilde{a}_i(j)c_l^A\tau_{nl}^A(j))^{-\theta}p^\theta\}dG_{ni}^A(p(j))$$

Note:

$$dG_{ni}^A(p(j)) = e^{-T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}p^\theta}\theta T_i^k(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}p^{\theta-1}$$

Therefore:

$$Pr\left(p_{nl}^A(j) > p_{ni}^A(j) \;\; \forall l \neq i\right) = \frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}\int_0^\infty exp\{-\Omega_n^A(j)p^\theta\}\Omega_n^A(j)\theta p^{\theta-1}dp$$

Notice that the expression under the integral is $dG_n^k(p)$, so this is:

$$Pr\left(p_{nl}^A(j) > p_{ni}^A(j) \;\; \forall l \neq i\right) = \frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}$$

The unconditional probability exporter i offers the lowest price in market n is then:

$$\bar{\pi}^A_{ni} = \int \frac{T^A_i(\tilde{a}_i(j)c^A_i\tau^A_{ni}(j))^{-\theta}}{\Omega^A_n(j)} dF_{a_n}(\tilde{\mathbf{a}})dF^k_{\tau_n}(\boldsymbol{\tau})$$

Appendix A.3. Market n agricultural price index

Claim:

$$p^A_n = \gamma \left(\int \Omega^A_n(j)^{\frac{\sigma-1}{\theta}} dF_{a_n}(\tilde{\mathbf{a}})dF^A_{\tau_n}(\boldsymbol{\tau}) \right)^{\frac{1}{1-\sigma}}$$

Proof: A standard unit price index given the CES technology with which agricultural products are aggregated by country n buyers (Equation 15) is:

$$p^A_n = \left(\int\limits_0^1 p^A_n(j)^{-(\sigma-1)} dj \right)^{\frac{1}{1-\sigma}}$$

This can be written:

$$p^A_n = \left(\int\limits_0^\infty p^{1-\sigma} dG^A_n(p)dp \right)^{\frac{1}{1-\sigma}} = \left(\int\limits_0^\infty \int\limits_0^1 p^{1-\sigma} e^{-\Omega^A_n(j)p^\theta} \theta \Omega^A(j) p^{\theta-1} dF_{a_n}(\tilde{\mathbf{a}})dF^A_{\tau_n}(\boldsymbol{\tau})dp \right)^{\frac{1}{1-\sigma}}$$

where $\Omega^A_n(j) = \sum\limits_{l=1}^{I} T^A_l(\tilde{a}_l(j)c^A_l\tau^A_{nl}(j))^{-\theta}$.

Define $x = \Omega^A_n(j)p^\theta$, then $dx = \theta\Omega^A_n(j)p^{\theta-1}$ and $p^{1-\sigma} = \left(\frac{x}{\Omega^A_n(j)}\right)^{\frac{1-\sigma}{\theta}}$. Then:

$$p^A_n = \left(\int\limits_0^\infty \int\limits_0^1 \left(\frac{x}{\Omega^A_n(j)} \right)^{\frac{1-\sigma}{\theta}} e^x dx dF_{a_n}(\tilde{\mathbf{a}})dF^A_{\tau_n}(\boldsymbol{\tau}) \right)^{\frac{1}{1-\sigma}}$$

Using the definition of the gamma function, $\Gamma(z) = \int\limits_0^\infty t^{z-1}e^t dt$:

$$p^A_n = \gamma \left(\int \Omega^A(j)^{\frac{\sigma-1}{\theta}} dF_{a_n}(\tilde{\mathbf{a}})dF^A_{n}(\boldsymbol{\tau}) \right)^{\frac{1}{1-\sigma}}$$

where $\gamma = \Gamma\left[\frac{1-\sigma+\theta}{\theta}\right]^{\frac{1}{1-\sigma}}$ so we must have $\theta > (\sigma - 1)$.

Appendix A.4. Exporter i share of market n agricultural expenditure

Claim: The unconditional probability exporter i offers the lowest price for an agricultural product in market n is equal to the fraction of market n agricultural expenditure spent on products from country i:

$$\bar{\pi}^A_{ni} = \pi^A_{ni} \equiv \frac{X^A_{ni}}{X_n}$$

Proof: Bilateral trade shares in expenditure terms are:

$$\pi^A_{ni} = \frac{X^A_{ni}}{X^A_n} = \frac{\bar{\pi}^A_{ni}\bar{X}^A_{ni}}{\sum\limits_{l=1}^{I} \bar{\pi}^A_{nl}\bar{X}^A_{nl}}$$

where $\bar{X}^A_{ni}$ is market n's average expenditure per good on agricultural products from exporter i. Cost-minimizing buyers purchase individual agricultural products to satisfy:

$$q^A_n(j) = \left(\frac{p^A_n(j)}{p^A_n}\right)^{-\sigma} Q^A_n$$

where p^A_n is the price index and Q^A_n is the total quantity of agricultural products purchased in market n. Multiply the right-hand side by $\frac{p^A_n(j)}{p^A_n} \times \frac{p^A_n}{p^A_n(j)} = 1$ and we get:

$$p^A_n(j)q^A_n(j) = \left(\frac{p^A_n(j)}{p^A_n}\right)^{1-\sigma} p^A_n Q^A_n \quad \Leftrightarrow \quad X^A_n(j) = \left(\frac{p^A_n(j)}{p^A_n}\right)^{1-\sigma} X^A_n$$

Therefore, average spending per agricultural good from country i in country n is:

$$\bar{X}^A_{ni} = \int\limits_0^1 X^A_n(j)dj = X^A_n \int\limits_0^\infty \left(\frac{p}{p^A_n}\right)^{1-\sigma} d\tilde{G}^A_{ni}(p)$$

The function $\tilde{G}^A_{ni}(p)$ is the distribution of agricultural price offers made by exporter i and accepted in market n. I claim that $\tilde{G}^A_{ni}(p) \equiv G^A_n(p)\ \forall i$. To see this, note that if country n buys good j from country i, then country i must be the low–cost supplier: $p^A_{ni}(j) = p^A_n(j)$. Suppose $p^A_n(j) = q(j)$. The probability country i is the low–cost supplier of product j is the probability that all other suppliers have prices higher than $q(j)$:

$$Pr\left(p^A_{nl}(j) > q(j)\ \ \forall l \neq i\right) = exp\{-\sum_{l\neq i} T^A_l(\tilde{a}_l(j)c^A_l\tau_n l^A(j))^{-\theta}q(j)^\theta\}$$

Integrating over this for all possible realizations of $p_{ni}^A(j) \le q(j)$:

$$\int_0^{q(j)} exp\{-\sum_{l\neq i} T_l^A(\tilde{a}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}p(j)^\theta\}dG_{ni}^A(p(j)) =$$

$$\frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}\int_0^{q(j)} exp\{-\Omega_n^A(j)p(j)^\theta\}\Omega_n^A(j)\theta p(j)^{\theta-1}dp(j) =$$

$$\frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}G_n^A(q(j))$$

The probability country i offers the lowest price for good j in market n is $\frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}$. Therefore, the probability good j is purchased for a price less than or equal to $q(j)$ conditional on it having been purchased from exporter i is:

$$\tilde{G}_{ni}^A(p(j)) = \frac{\frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}G_n^A(q(j))}{\frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}} = G_n^A(q(j))$$

Notice, this does not depend on exporter i. Even though the variation price offers varies across countries based on their distributions of $\tilde{a}_i(j)$ and $\tau_{ni}^A(j)$, the variation in offers actually accepted by market n is the same for every country. The unconditional probability that an agricultural product was purchased for a price less than or equal to $q(j)$, conditional on its having been purchased from exporter i is the integral over all possible realizations of $q(j)$:

$$\tilde{G}_{ni}^A(p) = \int_0^1 G_n^A(p(j))dj = \int_0^\infty G_n^A(q)dF_{a_n}(\tilde{a})dF_{\tau_n}^A(\boldsymbol{\tau})dq \equiv G_n^A(p)$$

Therefore:

$$\bar{X}_{ni}^A = X_n^A\int_0^\infty \left(\frac{p}{p_n^A}\right)^{1-\sigma} dG_n^A(p)\ \forall i$$

Therefore, the average price offer accepted by market n buyers is the same for all exporters, and:

$$\pi_{ni}^A = \bar{\pi}_{ni}^A = \int \frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\Omega_n^A(j)}dF_{a_n}(\tilde{\mathbf{a}})dF_{\tau_n}^k(\boldsymbol{\tau}) = \int \pi_{ni}^A(j)dF_{a_n}(\tilde{\mathbf{a}})dF_{\tau_n}^k(\boldsymbol{\tau})$$

Appendix B. Country-Specific Parameter Estimates: Manufacturing Sector

Table B.12: Country-Specific Estimates: Manufacturing Sector

Country	Producer Effects S_i^M	T_i^M/T_{USA}^M		Exporter Effects ex_i^M
		Benchmark	Alternative	
Argentina	0.29*	0.003	0.005	-0.17
	(0.20)			(0.29)
Australia	-0.9***	0.030	0.062	1.51***
	(0.20)			(0.29)
Austria	0.04	0.289	0.714	0.41*
	(0.20)			(0.29)
Brazil	0.38**	0.002	0.004	1.13***
	(0.19)			(0.28)
Canada	0.13	0.338	0.711	1.03***
	(0.20)			(0.29)
Chile	-0.33**	0.004	0.009	-0.37*
	(0.20)			(0.29)
Colombia	0.16	0.000	0.000	-2.54***
	(0.19)			(0.28)
Costa Rica	-1.66***	0.001	0.003	-1.43***
	(0.19)			(0.28)
Denmark	-0.26*	1.020	1.858	0.55**
	(0.20)			(0.29)
Ecuador	0.18	0.000	0.000	-3.78***
	(0.20)			(0.28)
Estonia	-0.47***	0.003	0.006	-2.24***
	(0.20)			(0.29)
Finland	0.14	0.653	1.432	0.79***
	(0.20)			(0.29)
France	0.29*	0.070	0.158	2.08***
	(0.20)			(0.29)
Germany	0.02	0.115	0.275	3.04***
	(0.20)			(0.29)
Hungary	-0.46***	0.001	0.003	-0.25
	(0.20)			(0.29)
India	0.88***	0.000	0.000	-0.08
	(0.20)			(0.28)

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Table B.12 – continued from previous page

Country	Producer Effects S_i^M	T_i^M/T_{USA}^M		Exporter Effects ex_i^M
		Benchmark	Alternative	
Indonesia	-0.52***	0.000	0.000	1.69***
	(0.20)			(0.28)
Iran	2.7***	58.436	126.020	-5.86***
	(0.20)			(0.29)
Ireland	-0.98***	1.098	2.573	1.51***
	(0.20)			(0.29)
Israel	1.04***	0.240	0.562	-2.08***
	(0.20)			(0.29)
Italy	0.25*	0.161	0.369	2.17***
	(0.20)			(0.29)
Japan	1.31***	20.596	58.493	2.24***
	(0.20)			(0.28)
Kenya	0.51***	0.000	0.000	-6.30***
	(0.20)			(0.28)
Malaysia	-0.80***	0.027	0.065	2.27***
	(0.19)			(0.28)
Mexico	-1.27***	0.001	0.003	1.85***
	(0.20)			(0.29)
Netherlands	-1.27***	0.033	0.064	2.85***
	(0.20)			(0.29)
New Zealand	-0.18	0.310	0.379	-0.40*
	(0.20)			(0.29)
Czech Republic	0.06	0.003	0.006	-0.73***
	(0.20)			(0.29)
Poland	0.50***	0.007	0.015	-1.03***
	(0.20)			(0.29)
Portugal	0.06	0.007	0.014	-0.55**
	(0.20)			(0.29)
Romania	0.51***	0.001	0.002	-2.17***
	(0.02)			(0.29)
Russia	0.11	0.000	0.001	0.37*
	(0.20)			(0.29)
Slovenia	0.04	0.190	0.525	-1.85***
	(0.20)			(0.29)
Slovakia	-0.31*	0.001	0.002	-1.51***
	(0.20)			(0.29)
South Africa	0.00	0.003	0.007	0.24

Continued on next page

Table B.12 – continued from previous page

Country	Producer Effects S_i^M	T_i^M/T_{USA}^M		Exporter Effects ex_i^M
		Benchmark	Alternative	
	(0.20)			(0.29)
Spain	0.20	0.034	0.069	1.26***
	(0.20)			(0.29)
Sweden	-0.07	0.631	1.576	1.53***
	(0.20)			(0.29)
Thailand	-0.72***	0.001	0.003	1.99***
	(0.19)			(0.28)
Turkey	0.32*	0.003	0.005	-0.59**
	(0.20)			(0.29)
UK	0.01	0.214	0.583	2.21***
	(0.20)			(0.29)
USA	0.50***	1.000	1.000	3.11***
	(0.20)			(0.30)
Uruguay	-0.42**	0.001	0.004	-1.91***
	(0.20)			(0.29)

Appendix C. Calibrated Production and Utility Function Parameters

Appendix C.1. Production Function Parameters

Table C.13: Value Added and Consumption Shares

Country	α^A	α^M	α^S	λ^A	λ^M	λ^S
Australia	0.50	0.35	0.54	0.01	0.22	0.77
Austria	0.47	0.35	0.57	0.02	0.25	0.73
Brazil	0.53	0.31	0.61	0.06	0.33	0.61
Denmark	0.42	0.39	0.56	0.01	0.21	0.78
Estonia	0.40	0.23	0.48	0.04	0.34	0.62
Finland	0.55	0.3	0.56	0.02	0.19	0.79
France	0.48	0.27	0.59	0.03	0.29	0.68
Germany	0.48	0.33	0.6	0.02	0.31	0.67
Hungary	0.34	0.21	0.53	0.05	0.31	0.64
India	0.78	0.28	0.60	0.30	0.27	0.43
Indonesia	0.49	0.32	0.56	0.13	0.44	0.43
Ireland	0.49	0.33	0.53	0.03	0.31	0.66

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Table C.13 – continued from previous page

Country	α^A	α^M	α^S	λ^A	λ^M	λ^S
Italy	0.63	0.29	0.55	0.02	0.27	0.71
Japan	0.55	0.30	0.61	0.02	0.23	0.75
Netherlands	0.44	0.30	0.55	0.01	0.23	0.76
New Zealand	0.40	0.32	0.50	0.02	0.27	0.71
Czech Republic	0.43	0.25	0.45	0.04	0.38	0.58
Poland	0.34	0.32	0.52	0.05	0.34	0.61
Portugal	0.54	0.27	0.54	0.04	0.39	0.57
Romania	0.52	0.34	0.54	0.14	0.37	0.49
Russia	0.54	0.38	0.60	0.12	0.37	0.51
Slovenia	0.45	0.50	0.61	0.05	0.33	0.62
Slovakia	0.39	0.25	0.44	0.08	0.39	0.53
South Africa	0.49	0.34	0.61	0.03	0.41	0.56
Spain	0.61	0.28	0.56	0.03	0.24	0.73
Sweden	0.49	0.32	0.56	0.01	0.26	0.73
Turkey	0.64	0.39	0.66	0.19	0.36	0.45
UK	0.42	0.38	0.50	0.02	0.30	0.68
USA	0.39	0.36	0.60	0.01	0.20	0.79
Average	0.49	0.32	0.56	0.05	0.30	0.65

Table C.14: Intermediate Input Shares

Country	ξ^A_A	ξ^A_M	ξ^A_S	ξ^M_A	ξ^M_M	ξ^M_S	ξ^S_A	ξ^S_M	ξ^S_S
Australia	0.24	0.35	0.41	0.09	0.57	0.34	0.01	0.26	0.73
Austria	0.43	0.29	0.28	0.06	0.64	0.30	0.01	0.26	0.73
Brazil	0.34	0.42	0.24	0.13	0.65	0.22	0.01	0.41	0.58
Canada	0.31	0.36	0.33	0.06	0.67	0.27	0.02	0.26	0.72
Denmark	0.30	0.33	0.37	0.13	0.61	0.26	0.01	0.22	0.77
Estonia	0.29	0.34	0.37	0.10	0.68	0.22	0.01	0.30	0.69
Finland	0.44	0.20	0.36	0.08	0.67	0.25	0.00	0.33	0.67
France	0.34	0.40	0.26	0.06	0.63	0.31	0.01	0.23	0.76
Germany	0.18	0.38	0.44	0.04	0.64	0.32	0.00	0.21	0.79
Hungary	0.27	0.47	0.26	0.06	0.74	0.20	0.02	0.37	0.61
India	0.48	0.28	0.24	0.15	0.54	0.31	0.04	0.40	0.56
Indonesia	0.28	0.48	0.24	0.20	0.57	0.23	0.04	0.44	0.52
Ireland	0.35	0.46	0.19	0.07	0.49	0.44	0.01	0.24	0.75
Italy	0.33	0.39	0.28	0.05	0.62	0.33	0.01	0.27	0.72
Japan	0.25	0.37	0.38	0.04	0.62	0.34	0.02	0.27	0.71

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Table C.14 – continued from previous page

Country	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
Netherlands	0.28	0.35	0.37	0.08	0.68	0.24	0.00	0.24	0.76
New Zealand	0.33	0.26	0.41	0.18	0.47	0.35	0.02	0.26	0.72
Czech Republic	0.33	0.44	0.23	0.06	0.72	0.22	0.01	0.28	0.71
Poland	0.42	0.31	0.27	0.09	0.58	0.33	0.01	0.34	0.65
Portugal	0.29	0.37	0.34	0.10	0.64	0.26	0.01	0.28	0.71
Romania	0.56	0.29	0.15	0.13	0.55	0.32	0.01	0.49	0.50
Russia	0.48	0.34	0.18	0.08	0.61	0.31	0.02	0.40	0.58
Slovenia	0.43	0.30	0.27	0.04	0.71	0.25	0.02	0.32	0.66
Slovakia	0.47	0.28	0.25	0.04	0.72	0.24	0.01	0.27	0.72
South Africa	0.08	0.59	0.33	0.10	0.62	0.28	0.00	0.34	0.66
Spain	0.18	0.56	0.26	0.08	0.67	0.25	0.02	0.33	0.65
Sweden	0.14	0.51	0.35	0.05	0.58	0.37	0.02	0.26	0.72
Turkey	0.50	0.27	0.23	0.11	0.64	0.25	0.02	0.45	0.53
UK	0.17	0.34	0.49	0.03	0.58	0.39	0.00	0.21	0.79
USA	0.37	0.31	0.32	0.05	0.59	0.36	0.02	0.23	0.75
Average	0.33	0.37	0.30	0.08	0.62	0.30	0.01	0.31	0.68

Appendix D. Base Solutions

Appendix D.1. Wages

Table D.15: Wages (Relative to the United States)

Country	Modified	EK Model	Country	Modified	EK Model
Japan	5.36	5.42	Portugal	0.35	0.36
Iran	3.07	3.19	Estonia	0.35	0.39
Ireland	2.33	2.45	Australia	0.29	0.32
Finland	1.78	1.92	Slovakia	0.25	0.27
Sweden	1.47	1.60	Chile	0.21	0.21
Austria	1.21	1.34	Poland	0.21	0.22
Denmark	1.18	1.19	South Africa	0.21	0.21
Italy	1.10	1.24	Mexico	0.16	0.18
Netherlands	1.09	1.10	Argentina	0.15	0.17
Germany	1.02	1.19	Costa Rica	0.14	0.14
USA	1.00	1.00	Turkey	0.14	0.14
Canada	0.96	1.13	Thailand	0.13	0.16
Israel	0.93	0.94	Uruguay	0.13	0.13

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Table D.15 – continued from previous page

Country	Modified	EK Model	Country	Modified	EK Model
France	0.92	1.11	Brazil	0.12	0.14
UK	0.82	0.87	Romania	0.09	0.09
Slovenia	0.76	0.75	Russia	0.06	0.06
Malaysia	0.60	0.61	Indonesia	0.04	0.05
New Zealand	0.59	0.66	Colombia	0.03	0.03
Spain	0.55	0.65	Ecuador	0.03	0.03
Czech Republic	0.44	0.49	India	0.03	0.03
Hungary	0.36	0.42	Kenya	0.00	0.00

Appendix D.2. Price Indices

Table D.16: Tradable Sector Price Indices (Relative to the United States)

	Agriculture (p_n^A)		Manufacturing (p_n^M)	
Country	Modified	EK Model	Modified	EK Model
Canada	112.84	2.82	0.95	0.94
Thailand	68.12	3.71	1.25	1.24
Germany	49.34	2.65	1.09	1.08
Indonesia	33.60	2.27	1.26	1.24
Russia	26.86	0.86	1.09	1.07
France	18.38	1.34	1.05	1.03
Sweden	16.94	4.66	1.16	1.15
Spain	16.02	1.49	1.08	1.06
Argentina	13.63	0.81	1.10	1.08
Austria	13.48	2.03	0.97	0.95
UK	12.80	3.09	1.07	1.07
New Zealand	11.18	1.69	1.17	1.15
Italy	9.81	1.78	1.07	1.06
Iran	9.30	5.50	0.37	0.36
Australia	8.95	1.01	1.31	1.30
Brazil	8.22	1.46	1.09	1.08
Finland	7.66	2.91	1.12	1.11
Colombia	6.62	3.10	0.98	0.98
Mexico	6.28	1.85	1.09	1.08
Japan	6.09	7.68	0.81	0.81
India	5.93	1.52	0.92	0.91
Slovenia	4.96	1.52	0.98	0.98

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Table D.16 – continued from previous page

Country	Agriculture (p_n^A)		Manufacturing (p_n^M)	
	Modified	EK Model	Modified	EK Model
Kenya	4.39	2.61	0.90	0.89
Estonia	4.25	2.05	1.08	1.07
Romania	4.04	1.13	0.95	0.94
Ireland	3.75	2.09	1.10	1.09
Uruguay	3.65	1.32	1.18	1.17
Costa Rica	3.25	5.35	1.16	1.16
Hungary	3.24	1.21	1.07	1.05
Slovakia	3.14	1.65	1.03	1.02
Israel	3.07	3.21	0.87	0.87
Poland	2.99	1.08	0.92	0.91
Denmark	2.97	2.25	1.07	1.06
Czech Republic	2.85	1.42	0.94	0.93
Ecuador	2.81	2.86	1.00	1.00
Malaysia	2.79	2.52	1.30	1.29
Portugal	2.16	2.61	1.07	1.07
South Africa	2.09	1.10	1.12	1.12
Turkey	1.89	0.81	1.01	1.01
Netherlands	1.83	3.71	1.15	1.14
USA	1.00	1.00	1.00	1.00
Chile	0.87	1.61	1.15	1.15

Appendix D.3. Labor Allocations

Table D.17: Sector Share of Labor Force*

Country	Agriculture %		Manufacturing %		Services %	
	Models	Data	Models	Data	Models	Data
Argentina	2.12	0.70	51.61	22.7	46.28	76.20
Australia	1.97	5.00	53.87	21.70	44.16	73.30
Austria	2.08	5.80	53.95	30.30	43.96	64.00
Brazil	2.00	NA	50.78	NA	47.23	NA
Canada	2.29	3.30	54.95	22.50	42.76	74.20
Chile	2.12	14.40	51.61	23.40	46.28	62.20
Colombia	2.12	1.10	51.61	25.50	46.28	73.30
Costa Rica	2.12	20.40	51.61	22.30	46.28	56.70
Denmark	2.13	3.30	57.51	25.20	40.36	71.40

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Table D.17 – continued from previous page

Country	Agriculture % Models	Agriculture % Data	Manufacturing % Models	Manufacturing % Data	Services % Models	Services % Data
Ecuador	2.12	29.30	51.61	19.90	46.28	50.80
Estonia	3.01	7.10	46.19	33.30	50.80	59.60
Finland	1.95	6.00	50.02	27.20	48.02	66.40
France	2.36	4.10	48.26	26.30	49.37	69.60
Germany	2.12	2.60	52.38	33.50	45.51	63.80
Hungary	3.57	6.50	45.39	33.70	51.05	59.70
India	1.27	59.90	48.16	16.00	50.57	24.00
Indonesia	2.12	45.30	51.61	17.40	46.28	37.30
Iran	2.08	NA	52.35	NA	45.57	NA
Ireland	2.12	6.50	51.61	27.70	46.28	65.40
Israel	2.12	2.20	51.61	23.70	46.28	73.00
Italy	1.70	5.20	49.14	31.80	49.16	63.00
Japan	1.95	5.10	50.02	31.20	48.02	63.10
Kenya	2.12	NA	51.61	NA	46.28	NA
Malaysia	2.12	18.40	51.61	32.20	46.28	49.50
Mexico	2.12	18.00	51.61	26.80	46.28	55.20
Netherlands	2.41	3.00	50.35	20.20	47.23	70.40
New Zealand	2.51	8.70	51.90	23.20	45.60	67.70
Czech Republic	2.72	5.10	47.22	39.50	50.07	55.40
Poland	2.81	18.80	52.12	30.80	45.07	50.40
Portugal	2.10	12.50	48.08	34.40	49.82	53.00
Romania	1.93	42.80	53.02	26.20	45.04	31.00
Russia	1.74	14.50	56.28	28.40	41.98	57.10
Slovenia	1.69	9.50	69.69	37.40	28.62	52.30
Slovakia	2.94	6.70	47.37	37.30	49.69	56.10
South Africa	2.04	15.60	53.11	24.20	44.85	59.4
Spain	1.80	6.70	48.53	30.80	49.67	62.50
Sweden	2.12	2.40	51.61	24.50	46.28	73.00
Thailand	2.12	48.80	51.61	19.00	46.28	32.20
Turkey	1.42	36.00	56.94	24.00	41.64	40.00
UK	2.17	1.50	56.62	25.10	41.21	73.10
USA	2.37	2.60	55.02	23.20	42.61	74.30
Uruguay	2.12	4.10	51.61	24.70	46.28	71.30

*Both models predict an identical allocation of labor across sectors

Appendix E. Results of Agricultural Liberalization Counterfactual

Appendix E.1. Increase in Agricultural Imports

Table E.18: Increase in Ag Imports over Base Solution

Country	Full Liberalization $\frac{1-\pi_{nn}^{A\ F}}{1-\pi_{nn}^{A\ *}}$	Partial / Full Liberalization $\frac{1-\pi_{nn}^{A\ P}}{1-\pi_{nn}^{A\ F}}$
Argentina	1.07	1.00
Australia	3.37	1.00
Austria	27.50	1.00
Brazil	6.96	0.98
Canada	1.03	1.00
Chile	15.30	0.79
Colombia	13.76	0.92
Costa Rica	2.23	1.00
Denmark	22.35	1.00
Ecuador	50.29	0.65
Estonia	85.36	0.98
Finland	39.84	1.00
France	2.18	1.00
Germany	2.58	0.99
Hungary	5.27	0.99
India	1.69	0.98
Indonesia	32.01	0.54
Iran	1.00	1.00
Ireland	93.89	0.99
Israel	29.30	1.00
Italy	7.49	1.00
Japan	2.05	0.98
Kenya	265.28	0.95
Malaysia	4.68	1.00
Mexico	1.87	1.00
Netherlands	35.19	0.99
New Zealand	2526.35	1.00
Czech Republic	4.61	1.00
Poland	1.25	1.00
Portugal	42.46	0.98
Romania	3.29	1.00
Russia	1.07	1.00

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Table E.18 – continued from previous page

Country	Full Liberalization $\frac{1-\pi_{nn}^{A\ F}}{1-\pi_{nn}^{A\ *}}$	Partial / Full Liberalization $\frac{1-\pi_{nn}^{A\ P}}{1-\pi_{nn}^{A\ F}}$
Slovenia	6.83	1.00
Slovakia	9.32	0.99
South Africa	96.79	0.93
Spain	4.62	0.99
Sweden	6.18	0.99
Thailand	6.15	0.66
Turkey	1.90	0.89
UK	3.75	1.00
USA	1.08	1.00
Uruguay	25.61	0.95

Appendix E.2. Increase in Average Foreign Market Share

Table E.19: Increase in Average Foreign Market Share –Full vs. Partial Liberalization

	Ave. % Change in π_{ni}^{A} from Base Solution, $(i \neq n)$	
Exporter	Full Liberalization	Partial/Full Liberalization
Argentina	116%	1.00
Australia	252%	1.00
Austria	528%	1.00
Brazil	302%	1.00
Canada	-72%	1.02
Chile	73%	1.00
Colombia	246%	1.02
Costa Rica	384%	0.95
Denmark	730%	1.00
Ecuador	124%	1.00
Estonia	192%	1.02
Finland	770%	1.00
France	930%	0.99
Germany	213%	1.00
Hungary	178%	1.00
India	513%	1.00
Indonesia	269%	1.00

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Table E.19 – continued from previous page

Exporter	Ave. % Change in π_{ni}^{A} from Base Solution, $(i \neq n)$ Full Liberalization	Partial/Full Liberalization
Iran	318%	1.00
Ireland	41%	1.06
Israel	815%	1.00
Italy	227%	1.00
Japan	513%	1.00
Kenya	68%	0.97
Malaysia	903%	1.00
Mexico	603%	1.00
Netherlands	165%	1.01
New Zealand	213%	1.00
Czech Republic	785%	1.00
Poland	179%	1.00
Portugal	528%	1.00
Romania	939%	1.00
Russia	1089%	1.00
Slovenia	932%	1.00
Slovakia	329%	1.00
South Africa	116%	1.00
Spain	473%	1.00
Sweden	414%	0.98
Thailand	283%	1.00
Turkey	166%	1.00
UK	450%	1.00
USA	69%	1.00
Uruguay	903%	1.00

Appendix E.3. Size of Shifts in Bilateral Agricultural Trade Patterns

Table E.20: Rank Correlation between Base and Liberalized Market Shares

Import Market	Rank Correlation ${\pi_{ni}^{A}}^{*}$, ${\pi_{ni}^{A}}^{F}$	Import Market	Rank Correlation ${\pi_{ni}^{A}}^{*}$, ${\pi_{ni}^{A}}^{F}$
Argentina	0.73	Japan	0.66
Australia	0.70	Kenya	0.61
Austria	0.79	Malaysia	0.53
Brazil	0.76	Mexico	0.77

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Table E.20 – continued from previous page

Import Market	Rank Correlation $\pi_{ni}^{A\,*}$, $\pi_{ni}^{A\,F}$	Import Market	Rank Correlation $\pi_{ni}^{A\,*}$, $\pi_{ni}^{A\,F}$
Canada	0.57	Netherlands	0.56
Chile	0.69	New Zealand	0.59
Colombia	0.70	Poland	0.77
Costa Rica	0.74	Portugal	0.53
Czech Republic	0.75	Romania	0.74
Denmark	0.56	Russia	0.57
Ecuador	0.73	Slovakia	0.77
Estonia	0.62	Slovenia	0.70
Finland	0.67	South Africa	0.64
France	0.75	Spain	0.68
Germany	0.75	Sweden	0.64
Hungary	0.75	Thailand	0.61
India	0.66	Turkey	0.75
Indonesia	0.69	UK	0.71
Iran	0.50	Uruguay	0.69
Ireland	0.62	USA	0.62
Israel	0.59	Japan	0.66

Appendix E.4. Increase in Real Income from Ag Liberalization

Table E.21: Percent Change in Real Income over Base Solution

Country	Full Liberalization	Partial/Full Liberalization
Argentina	2.84%	0.99
Australia	0.75%	1.00
Austria	3.14%	1.00
Brazil	3.08%	0.99
Canada	6.67%	1.00
Chile	0.62%	0.99
Colombia	1.18%	0.96
Costa Rica	0.39%	1.00
Denmark	1.72%	1.00
Ecuador	0.51%	0.96
Estonia	0.86%	1.00
Finland	2.44%	1.00
France	4.99%	1.00

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Table E.21 – continued from previous page

Country	Full Liberalization	Partial/Full Liberalization
Germany	5.30%	1.00
Hungary	1.99%	1.00
India	10.88%	0.97
Indonesia	16.16%	0.78
Iran	8.96%	1.00
Ireland	1.40%	1.00
Israel	0.70%	1.00
Italy	2.63%	1.00
Japan	2.57%	1.00
Kenya	0.80%	0.99
Malaysia	3.41%	0.99
Mexico	11.09%	1.00
Netherlands	4.22%	1.00
New Zealand	0.37%	1.00
Czech Republic	3.17%	1.00
Poland	2.65%	1.00
Portugal	6.57%	1.00
Romania	6.70%	1.00
Russia	16.59%	1.00
Slovenia	1.26%	1.00
Slovakia	6.03%	1.00
South Africa	0.26%	0.97
Spain	2.37%	0.99
Sweden	3.86%	1.00
Thailand	10.14%	0.85
Turkey	1.58%	0.83
UK	3.08%	1.00
USA	0.37%	1.00
Uruguay	1.52%	0.99