Agricultural Trade Patterns under Heterogeneous Productivity, Endowments and Policies

Kari Heerman and Stephanie Riche

Selected Paper prepared for presentation at the International Agricultural Trade Research Consortium's (IATRC's) 2014 Annual Meeting: Food, Resources and Conflict, December 7-9, 2014, San Diego, CA.

USDA

United States Department of Agriculture

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Kari E.R. Heerman and Stephanie Riche[1]

[1]Economic Research Service, USDA

The analysis and views expressed are the authors' and do not represent the views of the Economic Research Service or USDA.

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- Goal: A more nuanced view of how global production & trade patterns shift in response to policy
  - Existing models make simplifying assumptions on intra-sector production structure
  - Assumptions deliver convenient analytical solutions for structural equations ...

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- Goal: A more nuanced view of how global production & trade patterns shift in response to policy
  - Existing models make simplifying assumptions on intra-sector production structure
  - Assumptions deliver convenient analytical solutions for structural equations BUT impose strong restrictions on trade elasticities

Introduction and Motivation

- Novel approach to quantitative general equilibrium modeling with focus on agriculture
- Goal: A more nuanced view of how global production & trade patterns shift in response to policy
- Needed: A tractable model of ag trade with a more flexible production structure

Introduction and Motivation

Point of Departure

- Eaton and Kortum (2002) "Probabilistic Ricardian" model
  - Endogenous specialization $\rightarrow$ trade affects the set of goods produced
  - Simplifying assumption: Set of competitive goods is randomly determined by R&D process

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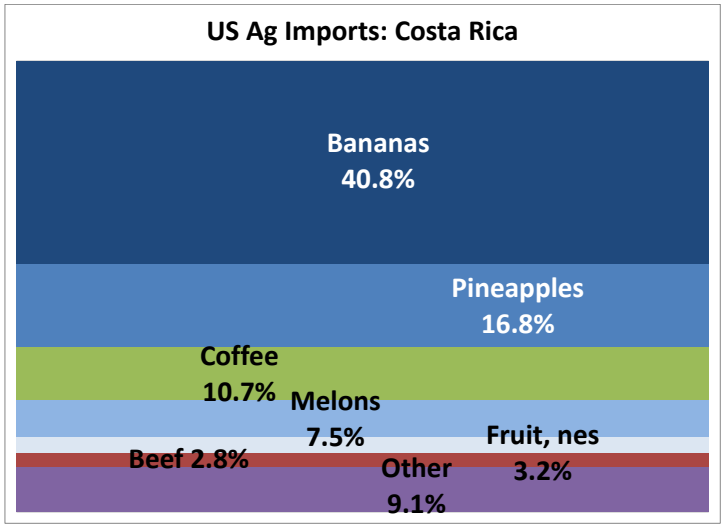
  - Simplifying assumption: Set of competitive goods is randomly determined by R&D process
    - Canada & Colombia are equally likely to specialize in coffee
    - Imposes stiff patterns of elasticities

Price increase of Costa Rican ag goods in the US market



EK model predict equal increases in trade flows for any two exporters with the same share of the US ag market

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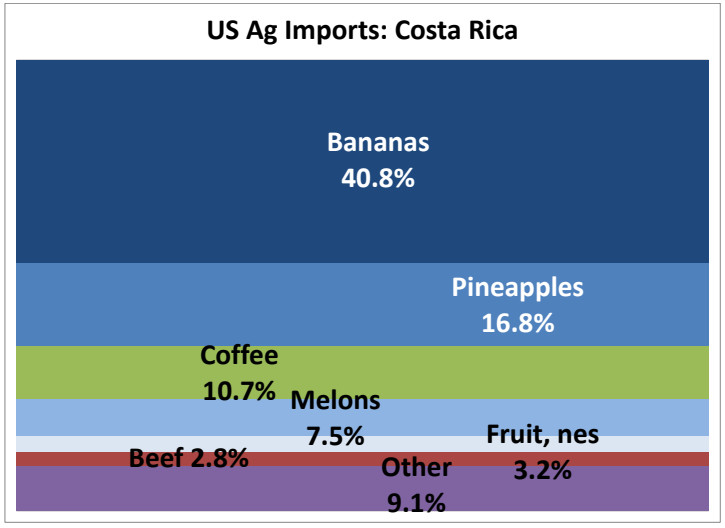

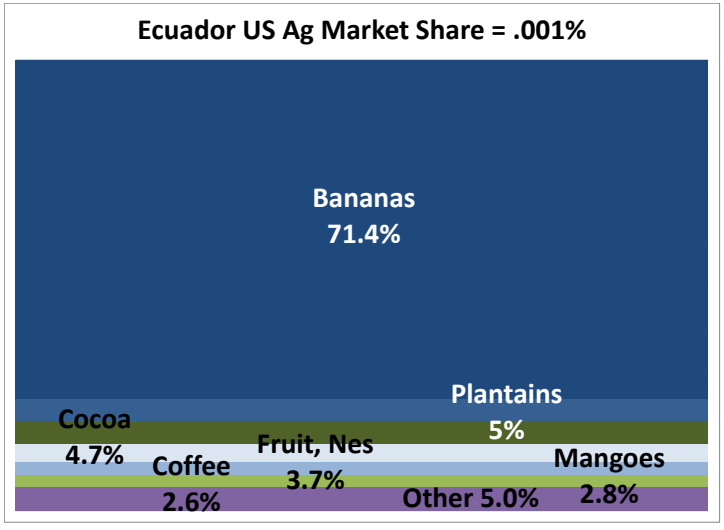

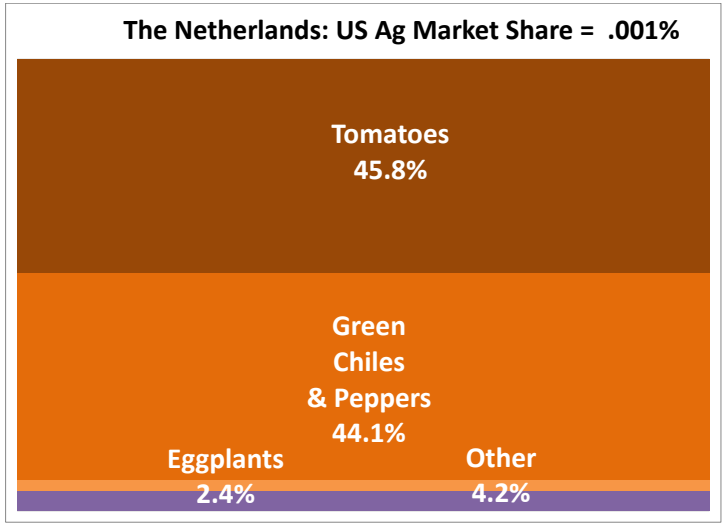

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Analytical Contribution

- Allow agro-ecology to drive specialization in agriculture
  - Predicts "like" countries more sensitive to each other
- Allow product-specific trade costs

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Analytical Contribution

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Empirical Contribution

- E&K estimate key parameters describing trade patterns from structural gravity model
- Specify new model equation as random coefficients logit
  - More flexible production structure
  - Little additional data

Roadmap

- Model overview
- Selected general equilibrium results
- Work in progress
- Conclusion

Model Overview

About the Model

- I countries engaged in bilateral trade
  - Exporter indexed by i
  - Importer index by n
- Two tradable sectors: Agriculture and Manufacturing
- Production technology is heterogeneous across products
- All markets are perfectly competitive
- Trade occurs as buyers look for the lowest price

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Production Technology

Model Overview

Agricultural Technology Country i, product j technology

$$q_i^A(j) = z_i^A(j) \times (N_i{}^{\beta_i^A}(a_i(j)L_i)^{1-\beta_i^A})^{\alpha_i^A}\mathbf{Q}_i^{A\,1-\alpha_i^A}$$

- Input bundle is the same for all ag products
  - N_i is labor
  - L_i is land
  - $\mathbf{Q}_i^k$ is an aggregate of intermediate inputs from all sectors

Model Overview

Agricultural Technology Country i, product j technology

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- $z_i^A(j)$ Technological productivity-enhancing Frechet r.v.

$$F_i^A(z) = exp\{-T_i^A z^{-\theta}\}$$

  - T_i^A drives average technological productivity in country i ag
  - θ drives dispersion of technological productivity
  - Independently distributed across products

Model Overview

Agricultural Technology Country i, product j technology

$$q_i^A(j) = z_i^A(j) \times (N_i{}^{\beta_i^A}(a_i(j)L_i)^{1-\beta_i^A})^{\alpha_i^A}\mathbf{Q}_i{}^{A\,1-\alpha_i^A}$$

- $a_i(j)$ is deterministic variable representing land productivity
  - Value reflects the coincidence of product requirements and country ecological characteristics
    - E.g., coffee
  - Country-specific parametric density, independent of $z_i^A(j)$

Trade

Model Overview

Comparative Advantage Probability country i has comparative advantage in product j in market n

$$\pi_{ni}^{A}(j) \equiv Pr(p_{ni}^{A}(j) = min_{l}\{p_{nl}^{A}(j)\})$$

Model Overview

Comparative Advantage Probability country i has comparative advantage in product j in market n

$$\pi_{ni}^{A}(j) = \frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\sum_{l=1}^{N} T_l^A(\tilde{a}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}}$$

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Absolute Advantage

- T_i^A is average ag sector technological productivity
- c_i^A is cost of ag input bundle

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Random Source of Comparative Advantage

- Realization of $z_i^A(j)$
  - Independent across products

Model Overview

Comparative Advantage Probability country i has comparative advantage in product j in market n

$$\pi_{ni}^{A}(j) = \frac{T_i^A(\tilde{a}_i(j)c_i^A\tau_{ni}^A(j))^{-\theta}}{\sum_{l=1}^{N} T_l^A(\tilde{a}_l(j)c_l^A\tau_{nl}^A(j))^{-\theta}}$$

Non-Random Sources of Comparative Advantage

- $\tilde{a}_i(j)$ product j land productivity
- $\tau_{ni}^k(j) \geq 1$ is exporter i's cost to export products to market n
  - Deterministic variable with parametric density
  - Independent of $z_i^A(j)$ and $\tilde{a}_i(j)$

Model Overview

Market Share Exporter i share in country n ag expenditure

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

- $F_{\tilde{\mathbf{a}}_n}(\tilde{\mathbf{a}})$ is the distribution of $\tilde{\mathbf{a}_n} = [\tilde{a}_1, ..., \tilde{a}_I]$ across all products consumed in market n
- $F_{\boldsymbol{\tau}_n}(\boldsymbol{\tau})$ is the distribution of $\boldsymbol{\tau} = [\tau_{n1}, ..., \tau_{nI}]$ across all products consumed in market n

Model Overview

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- This is the structural equation from which productivity and trade cost distribution parameters are estimated

Trade Elasticities

Trade Elasticities

Elasticity P.E. elasticity of market share with respect to competitor trade costs

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

- Ecuador's market share is more sensitive to Costa Rican trade costs because they have high probability of comparative advantage in the same products
- Countries with similar distributions of $\tilde{a}_i(j)$ will systematically specialize in similar products
- E&K elasticity is constant across competitors

Estimating Trade and Productivity Distribution Parameters

Trade & Productivity Distribution Parameters

- Specify bilateral market share as random coefficients logit

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  - Absolute Advantage: Exporter fixed effect

Trade & Productivity Distribution Parameters

- Specify bilateral market share as random coefficients logit

  Absolute Advantage: Exporter fixed effect

  Land Productivity: Interact exporter characteristics and product requirements

  - Exporter characteristics: Arable land and distribution of total land across climate zones (World Bank, GTAP)
  - Product requirements: Constructed distribution of production across climate zones (FAO & GTAP) and normal random variable

Trade & Productivity Distribution Parameters

- Specify bilateral market share as random coefficients logit

  Absolute Advantage: Exporter fixed effect

  Land Productivity: Interact exporter characteristics and product requirements

  Trade costs: Interact gravity variables and product costs

  - Gravity variables: border, language distance, EU, NAFTA (CEPII)
  - Product costs: Normal random variable

Trade & Productivity Distribution Parameters

- Specify bilateral market share as random coefficients logit

  Absolute Advantage: Exporter fixed effect

  Land Productivity: Interact exporter characteristics and product requirements

  Trade costs: Interact gravity variables and product costs

- Bilateral market share from FAO trade & production data

Does it Matter?

Counterfactual 1: GE Ag Elasticities

The Experiment Simulate GE elasticities

1. Solve for global equilibrium in two models
   - New model
   - EK model
2. Simulate 1% increase in a single exporter's trade costs
3. Calculate percent change in each competitor's market share relative to base

Counterfactual 1: GE Ag Elasticities

Key Result: Substantially different implications for effects of policy on patterns of production and trade

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The Elasticity of US Market Share Relative to the Median Exporter

General equilibrium elasticity with respect to trade costs of …

	Canada		Costa Rica		France	
Import Market	Modified Model	EK Model	Modified Model	EK Model	Modified Model	EK Model
Chile	5.94	1.00	0.00	1.00	5.75	1.00
Ecuador	3.31	1.00	0.37	1.00	3.14	1.00
Mexico	39.20	1.00	0.24	1.00	0.16	1.00
Malaysia	1.27	1.00	0.09	1.00	1.07	1.00
Hungary	8.93	1.00	0.00	1.04	5.53	1.00
Spain	20.85	1.00	0.03	1.00	1.05	1.00
Turkey	11.58	1.00	0.01	1.13	0.99	1.00
UK	8.42	1.00	0.03	1.00	0.77	1.00

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- EK model - US market share sensitivity = median for all three competitors' trade costs

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- Modified model - US more sensitive than the median
  - Always - with respect to Canadian costs
  - Almost always - with respect to French costs

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  - Always - with respect to Canadian costs
  - Almost always - with respect to French costs
  - Never - with respect to Costa Rican costs

Work in Progress

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Making product-level predictions

- Use science-based estimates of product requirements
  - Climate requirements for key products available from GTAP and GAEZ
- Allow for systematic differences in plant vs. animal products
  - Minor change to interaction in land productivity distribution
- Improve precision with additional moments as in Petrin (2002)
  - Include product-specific market shares for key products

Conclusion

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Large Potential Benefits of the Model

- Transparent approach to estimate parameters that define trade patterns
- Delivers elasticities that reflect expected cross-country substitution patterns
- Offers opportunity to evaluate how country and product characteristics affect trade