The Systematic Heterogeneity Gravity Model

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Agriculture & Structural Gravity

- Drawbacks of standard log-linear gravity equation
  - Impose strong restrictions on trade elasticity

    The Independence of Irrelevant Exporters (IIE): The ratio of two exporters' market share is unaffected by cuts in a third exporter's trade costs

  - Assume constant trade costs

    Instrinsic characteristics and product-specific policy make some products systematically more costly to trade

Agriculture & Structural Gravity

- Challenges of estimating gravity models by sub-sector
  - Defining sub-sectors so IIE holds is not straightforward
  - Data are often thin and measurement error less likely to be random at subsector level
- Systematic heterogeneity model overcomes standard gravity restrictions with single, sector-level equation
  - Requires little additional data
  - More complex estimation method, but well-established in marketing and other literature

Road Map

- Introduce systematic heterogeneity (SH) gravity model
  - Follow supply-side approach of Eaton and Kortum (2002)
- Present parameter estimates from example SH gravity model
  - Heerman and Sheldon 2017
- Present GE results from NAFTA rollback scenario
  - Heerman and Zahniser 2017

Systematic Heterogeneity Model Overview

About the Model

- I countries engaged in bilateral trade
  - Exporter indexed by i
  - Importer indexed by n
- Ag sector comprised of a continuum of products indexed by j
- Production technology is heterogeneous across products
  - Climate and land characteristics influence which products have the best technology
- Markets are perfectly competitive
- Trade occurs as buyers look for the lowest price

Model Overview

Production Technology Country i, product j technology

$$q_i(j) = z_i(j) \times (N_i^{\beta_i}(a_i(j)L_i)^{1-\beta_i})^{\alpha_i} Q_i^{1-\alpha_i}$$

- Input bundle is the same for all ag products
  - N_i is labor
  - L_i is land
  - Q_i is intermediate inputs

Model Overview

Production Technology Country i, product j technology

$$q_i(j) = z_i(j) \times (N_i^{\beta_i}(a_i(j)L_i)^{1-\beta_i})^{\alpha_i} Q_i^{1-\alpha_i}$$

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

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

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

Model Overview

Production Technology Country i, product j technology

$$q_i(j) = z_i(j) \times (N_i^{\beta_i}(a_i(j)L_i)^{1-\beta_i})^{\alpha_i} Q_i^{1-\alpha_i}$$

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

Trade

Model Overview

Comparative Advantage Probability country i has the lowest price in product j in market n

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

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

Model Overview

Market Share Exporter i share in country n ag expenditure

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

- $F_{\tilde{a}_n}(\tilde{\mathbf{a}})$ 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

Market Share Exporter i share in country n ag expenditure

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

- Gravity-like relationship between trade flows, exporter characteristics and trade costs
  - Cannot be log-linearized without imposing unnecessary additional assumptions

Estimation

Random Coefficients Logit Specification Example

Dependent variable: Market share (π_{ni})

- Calculated for 63 countries from year 2006 FAO production and bilateral trade flows

Random Coefficients Logit Specification Example

Dependent variable: Market share (π_{ni})

Land Productivity: Interact exporter characteristics and product requirements

- Exporter characteristics: Arable land per capita; rural elevation; and climate distribution (World Bank, CIESIN, GTAP)
- Product requirements: Constructed distribution of production across land & climate (Above sources + FAO); normal random variable

Random Coefficients Logit Specification Example

Dependent variable: Market share (π_{ni})

Land Productivity: Interact exporter characteristics and product requirements

Trade costs: Interact gravity variables and product costs

- Gravity variables: border, language, distance
- Product-specific costs: Normal random variable

Random Coefficients Logit Specification Example

Dependent variable: Market share (π_{ni})

Land Productivity: Interact exporter characteristics and product requirements

Trade costs: Interact gravity variables and product costs

Estimation methodology: Simulated method of moments

- Nevo (2000), Train (2003)
- Simulate integral drawing 900 products fom each country's distribution

Land Productivity Distribution Parameters

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

▸ Trade Cost Parameters

Land Productivity Distribution Parameters

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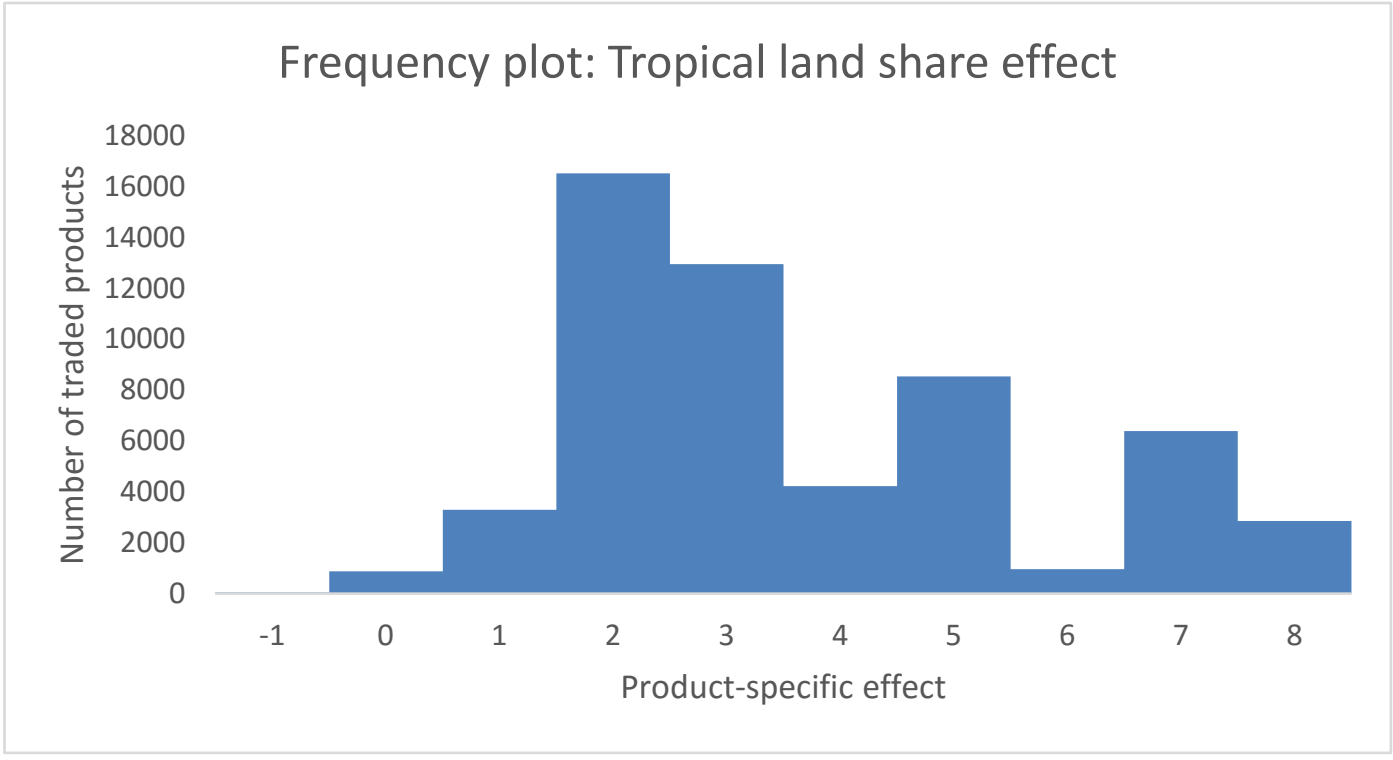
Tropical Climate Share	0.7***	-0.16**	-3.96***	0.73***	6.86***	0.19	-7.04



Multisector General Equilibrium

General Equilibrium

Model Solution

- Estimate structural gravity for agriculture and other sectors
- Use parameter estimates with data to solve structural equations for equilibrium prices, bilateral market share and resource allocation

Scenario Analysis: NAFTA Rollback*

- Increase bilateral trade costs within North America
  - MFN tariff increase applied by product (UNCTAD TRAINS)
  - Not possible in standard gravity with constant trade costs
- Solve model for new equilibrium

*Heerman and Zahniser, *forthcoming*

NAFTA Rollback

Effect of Mexico, U.S. trade cost increase in Canada

- Standard gravity IIE $\Rightarrow$ no direct effect on $\frac{\pi_{ni}}{\pi_{nn}}$
  - Small indirect GE effect
- SH gravity, effect on $\frac{\pi_{ni}}{\pi_{nn}}$ depends on exporter specialization
  - Close competitors with U.S., Mexico gain disproportionately

Percent change in π_{ni}/π_{nn}	
Median	***-0.35***
Argentina	-0.30
Australia	**2.29**
Brazil	-0.12
Chile	-0.41
China	-0.35
Colombia	-0.39
Costa Rica	-0.15
Ecuador	-0.33
Honduras	-0.09
Indonesia	-0.23
Italy	-0.38
New Zealand	-0.39
South Africa	-0.40
Spain	-0.32
Thailand	-0.04

NAFTA Rollback

Effect of Mexico, U.S. trade cost increase in Canada

- Negative change $\Rightarrow$ domestic expenditure increase $>$ imported
  - Canadian producers benefit disproportionately
- Australian producers gain relative to domestic

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Spain	-0.32
Thailand	-0.04

NAFTA Rollback

Comparison: Unilateral U.S. withdrawal from NAFTA

- Costa Rica, Honduras, Argentina gain disproportionately from lost Mexican market access
  - Unlike other countries, decline in $\frac{\pi_{ni}}{\pi_{nn}}$ is larger when Mexico maintains access

Percent change in π_{ni}/π_{nn}

	NAFTA Ends	U.S. Out	U.S. Out NAFTA Ends
Median	***-0.35***	***-0.17***	***2.01***
Argentina	**-0.30**	**-0.12**	**0.38**
Australia	2.29	2.49	0.92
Brazil	-0.12	0.07	-1.68
Chile	-0.41	-0.23	1.73
China	-0.35	-0.19	1.84
Colombia	-0.39	-0.22	1.78
Costa Rica	**-0.15**	**-0.19**	**0.80**
Ecuador	-0.33	-0.15	2.10
Honduras	**-0.09**	**-0.12**	**0.73**
Indonesia	-0.23	-0.06	3.68
Italy	-0.38	-0.20	1.87
South Africa	-0.40	-0.23	1.71
Spain	-0.32	-0.16	1.98
Thailand	-0.04	0.14	-0.28

Future Work

- Explore land productivity specification
- Include observable sources of heterogeneity to trade costs
  - Tariffs
  - Non-tariff measures
  - Perishability
- Improve distribution of products consumed
- Update econometric methodology for product-level analysis

Resources

- Published and in-review
  - Heerman, Kari E.R. "Technology, Ecology and Agricultural Trade," *In review, most recent version available from author by request*
  - Heerman, Kari E.R., Shawn Arita, and Munisamy Gopinath. "Asia-Pacific integration with China versus the United States: examining trade patterns under heterogeneous agricultural sectors." American Journal of Agricultural Economics 97.5 (2015): 1324-1344.
- Working papers
  - Heerman, Kari E.R. and Steven Zahniser. "Trade and production impacts of rolling back NAFTA's agricultural preferences: An application of the systematic heterogeneity general equilibrium gravity model", *prepared for 2018 ASSA annual meeting*
  - Heerman, Kari E.R. and Ian Sheldon. "Gravity and Comparative Advantage: Estimation of Trade Elasticities for the Agricultural Sector"

Trade Cost Distribution Parameters

▸ Land Productivity

Country Pair Characteristics	Mean Effect (β)	Unobserved Heterogeneity (Σ_t)
Common Border	-1.76***	3.13***
Common Language	1.24***	0.95***
Common RTA	0.19**	-0.11
Distance 1	-5.28***	2.36***
Distance 2	-7.67***	2.33***
Distance 3	-7.43***	-0.16
Distance 4	-9.95***	1.37***
Distance 5	-11.56***	-0.04
Distance 6	-12.94***	0.64***