Drivers of Concentration: the Roles of Trade Access, Structural Transformation, and Local Fundamentals

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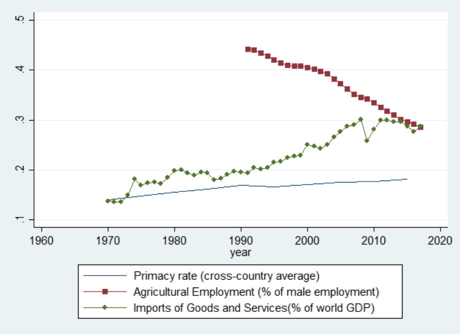
Introduction

- **Question**: which factors determine how concentrated in space a country's population is?
- **Importance**:
  - Modern spatial concentration associated with economic development (Glaeser '11).
  - Spatial responses may influence welfare effects of economic shocks.
    - e.g. trade shocks
  - Help predict effects of future events on world's economic geography.
    - Retreat of globalization (e.g. protectionism, pandemics).
    - Developing countries' transition away from agriculture.

Three Potential Drivers of Concentration

- Location-specific **fundamentals**: productivities and amenities
  - Traditional urban economics (e.g. Rosen-Roback)
- Differential access to **trade networks** (e.g. Redding Sturm 2008)
- **Structural transformation** (e.g. Eckert Peters '18)

- Globally, these factors correlate over time.
  - Spatial concentration metric: *primacy rate*
  - i.e. % of national population living in country's largest location.



This Paper

- Investigate roles of three drivers of spatial concentration through lens of modern quantitative spatial model (QSM).

1. Create **theoretical framework** featuring the three drivers:
   - Must add non-homothetic preferences to workhorse QSM.
   - Derive expression decomposing spatial concentration into each driver's contribution.
2. **Estimate** global **trade-cost** structure (1962-2019).
3. **Calibrate** model to world economy (1990, 2005).
   - i.e. find fundamentals that rationalize observed population/income.
   - World has 192 countries comprising 1611 subnational units.
4. Use model to perform **counterfactual** exercises:
   - Shock 2005 system with alternative trade-cost structures.
   - *Result*: trade integration *reduces* concentration for most countries.
5. **Accounting**: % of 1990-2005 concentration changes explained by each driver.
   - *Result*: changes in fundamentals account for 99% of variation.
   - Trade access and structural change play minor roles.

Literature

- Access to Trade Networks:
  - Redding Sturm '08, Ahlfeldt et al '14, Donaldson Hornbeck '16, Brulhart et al '19
- Structural transformation:
  - Boppart '14, Eckert Peters '18
- New Economic Geography (NEG):
  - Krugman Livas '96, Ades Glaeser '95, Krugman '91, Krugman Venables '95
- International trade and countries' internal structure:
  - Fajgelbaum Redding '14, Cosar Fajgelbaum '16, ECLAC '05
- Gravity trade models:
  - Anderson van Wincoop '03, Head Mayer '14, Santos-Silva Terneyro '06
- Quantitative spatial models:
  - Allen Arkolakis '14, Allen Donaldson '20, Caliendo et al '18, Desmet et al '18, Ramondo et al '12 '16, Redding '16, Adao et al '20

Outline

1. Framework
2. Estimating Global Trade Costs
3. Calibrating Local Fundamentals
4. Counterfactuals
5. Change Accounting
6. Conclusion

Outline

Model: Overview

- QSM (Allen Arkolakis '14, Allen Donaldson '22), applied to international context:
  - Many countries, partitioned into locations (e.g. states, provinces). Setting
- Non-homothetic preferences over two sectors (agriculture vs rest):
  - Price-Independent Generalized Linear (PIGL) form. PIGL
  - Structural transformation: agriculture to non-agriculture.
- Agents can migrate across domestic locations (but not internationally).
  - Decision considers real wages, amenities, idiosyncratic preference shocks. Migration
- Other assumptions are conventional:
  - Within-sector CES preferences for geographically differentiated goods (Armington).
  - Perfectly competitive firm only use labor input, incur "iceberg" trade costs. Firm
  - External economies of scale (i.e. agglomeration economies).
  - Local amenities are subject to congestion.
  - Heterogeneity in local fundamentals (productivities/amenities).
- Given assumptions, trade/migration flows take a "gravity" form. Gravity

Equilibrium Conditions

Model: Equilibrium System

- Equilibrium determined by a system of equations:

$$ {w_i}^{\sigma_s}(L_i^s)^{1-\alpha_s(\sigma_s-1)} = (\bar{A}_i^s)^{\sigma_s-1} \sum_{j\in\mathcal{S}} (\tau_{ij}^s)^{1-\sigma_s} (P_j^s)^{\sigma_s-1} \upsilon_j^s L_j w_j \quad (1) $$

$$ (P_j^s)^{1-\sigma_s} = \sum_{i\in\mathcal{S}} (\tau_{ij}^s w_i)^{1-\sigma_s} (\bar{A}_i^s (L_i^s)^{\alpha_s})^{\sigma_s-1} \quad (2) $$

$$ L_i^A + L_i^N = L_i = \frac{{W_i}^\theta}{\sum_{k\in c} W_k^\theta} \bar{L}_c \quad (3) $$

$$ W_j = \bar{u}_j {L_j}^\beta \left[\frac{1}{\eta} \left(w_j (P_j^A)^{-\phi} (P_j^N)^{\phi-1} \right)^\eta - \frac{\nu}{\gamma} (P_j^A / P_j^N)^\gamma + \frac{\nu}{\gamma} - \frac{1}{\eta} \right] \quad (4) $$

- **Equilibrium**: set of endogenous variables (w, L, L^s, W, P^s, υ^s) that satisfies equations (1)-(4) given parameters (σ_s, θ, α_s, β, ν, η, γ) and exogenous variables ($\bar{A}^s$, $\bar{u}$), (τ^s), $\{\bar{L}_c\}_{c\in\mathcal{C}}$. Equilibrium Conditions

Back: counterfactuals

Model: Primacy Rate

- Under parametric assumptions ($\sigma_s = \sigma$, $\alpha_s = \alpha$) primacy rate is:

$$Primacy_c \equiv \frac{L_{p(c)}}{\bar{L}_c} = \frac{\left(\bar{u}_{p(c)} \rho_{p(c)} \zeta_{p(c)}^{-\frac{\eta}{\Omega}}\right)^{\frac{\theta}{1-\theta(\beta+\eta/\Omega)}}}{\sum_{k \in c} \left(\bar{u}_k \rho_k \zeta_k^{-\frac{\eta}{\Omega}}\right)^{\frac{\theta}{1-\theta(\beta+\eta/\Omega)}}} \tag{5}$$

where:

- L is population, and $p(c)$ is primate location of country c
- $\bar{u}$ is fundamental amenity, $\bar{A}$ is fundamental productivity, υ^A is agricultural expenditure share
- $\rho_i = \frac{1}{\eta}(P_i^A)^{-\eta\phi}(P_i^N)^{\eta(\phi-1)} - \frac{1}{\gamma}(\upsilon_i^A - \phi)$ is consumer trade access
- $\Pi_i^s = \sum_{j \in \mathcal{S}} (\tau_{ij}^s)^{1-\sigma}(P_j^s)^{\sigma-1} \upsilon_j^s w_j L_j$ is producer trade access
- $\zeta_i = \sum_s [(\bar{A}_i^s)^{\sigma-1} \Pi_i^s]^{\frac{1}{1-\alpha(\sigma-1)}}$
- $\Omega \equiv \sigma/(\alpha(\sigma-1)-1)$

- **Intuition**: primacy increasing in primate's fundamentals (productivities and amenities) and trade access relative to other domestic locations.

Model: Primacy Rate (Differential Version)

- This differential version will later be brought to the data ("change accounting"):

$$\left(\frac{1-\theta(\beta+\frac{\eta}{\Omega})}{\theta}\right) d\ln(Primacy_c) = contrib_c^{ST} + contrib_c^{DTA} + contrib_c^{LF} \tag{6}$$

where:

$$contrib_c^{ST} = \underbrace{\kappa_{p(c)}(-d\upsilon_{p(c)}^{A}) - \sum_{k\in c}\left(\frac{L_k}{\bar{L}_c}\right)\kappa_k(-d\upsilon_k^{A})}_{\text{Structural Transformation}}$$

$$contrib_c^{DTA} = \underbrace{\left[\Gamma_{p(c)} d\ln(I_{p(c)}) - \sum_{k\in c}\left(\frac{L_k}{\bar{L}_c}\right)\Gamma_k d\ln(I_k)\right]}_{\text{Differential Trade Access \#1: Consumer Trade Access}} + \underbrace{\frac{\eta}{\sigma}\left[\sum_s \mu_{p(c)}^s d\ln(\Pi_{p(c)}^s) - \sum_{k\in c}\left(\frac{L_k}{\bar{L}_c}\right)\sum_s \mu_k^s d\ln(\Pi_k^s)\right]}_{\text{Differential Trade Access \#2: Producer Trade Access}}$$

$$contrib_c^{LF} = \underbrace{\left[d\ln(\bar{u}_{p(c)}) - \sum_{k\in c}\left(\frac{L_k}{\bar{L}_c}\right)d\ln(\bar{u}_k)\right]}_{\text{Local Fundamental \#1: Amenities}} + \underbrace{\frac{\eta(\sigma-1)}{\sigma}\left[\sum_s \mu_{p(c)}^s d\ln(\bar{A}_{p(c)}^s) - \sum_{k\in c}\left(\frac{L_k}{\bar{L}_c}\right)\sum_s \mu_k^s d\ln(\bar{A}_k^s)\right]}_{\text{Local Fundamental \#2: Sectoral Productivities}}$$

and: $\mu_i^s \equiv (\zeta_i)^{-1}[(\bar{A}_i^s)^{\sigma-1}\Pi_i^s]^{\frac{1}{1-\alpha(\sigma-1)}}$, $I_i = (P_i^A)^{-\phi}(P_i^N)^{\phi-1}$, $\kappa_i = \frac{1}{\gamma\rho_i}$, $\Gamma_i = \frac{I_i^{\eta}}{\rho_i}$

Back: change accounting

Outline

Estimating Trade Costs

- To bring model to the data, first step is to estimate global trade costs.
- Impose functional form for trade costs (Ramondo et al '14):

$$\tau_{ijt}^{s} = \left(E_t^s\right)^{\mathbb{1}_{j \notin c(i)}} \prod_{z=1}^{B} \left(C^{s,z}\right)^{\mathbb{1}_{dist_{ij} \in b_z}}$$

  - E_t^s: border-crossing parameter
  - $\{b_z\}_{z=1}^{B}$: set of distance "bins" Computing distances

- In consequence, the model's gravity trade equation becomes estimable:

$$\ln(X_{ijt}^s) = \sum_{z=1}^{B} \underbrace{(1-\sigma_s)\ln(C^{s,z})}_{\tilde{C}^{s,z}} \mathbb{1}_{dist_{ij} \in b_z} + \underbrace{(1-\sigma_s)\ln(E_t^s)}_{\tilde{E}_t^s} \mathbb{1}_{j \notin c(i)} + \omega_{it}^{s,X} + \omega_{jt}^{s,M} + \eta_{ijt}^s \quad (7)$$

Gravity trade equation | Trade data | Infrastructure data

Results: Trade Costs (1/2)

- Estimate gravity trade equation (7) using PPML (Santos-Silva Tenreyro '06)
  - Recover $\{\hat{\hat{E}}_t^s, \hat{\hat{C}}^{s,z}\} \Rightarrow$ compute $\{\hat{E}_t^s, \hat{C}^{s,z}\} \Rightarrow$ compute $\{\hat{\tau}_{ijt}^s\}$.

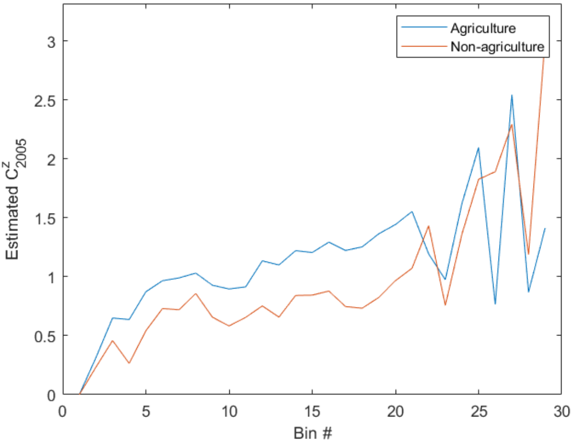
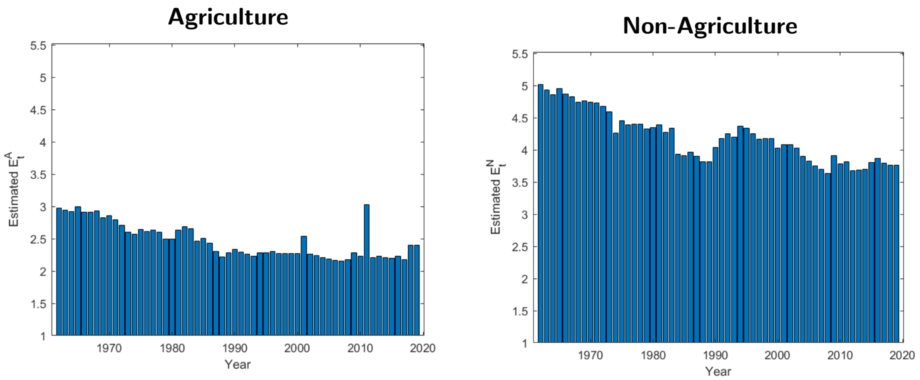


Figure: Estimated cost of distance bins ($\hat{C}^{s,z}$)

Results: Trade Costs (2/2)

Figure: Estimated border-crossing costs ($\hat{E}_t^s$)



- Substantial decline in border-crossing costs over the decades (but still high in 2019).

Robustness of results

Outline

1. Framework
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3. **Calibrating Local Fundamentals**
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Calibrating Local Fundamentals

- We already have:
  - Estimated trade costs $\hat{\tau}_t$ for each year t.
  - Data in year t (wages, populations, sectoral employment). Data
  - Parameter values (from literature). Parameters Normalization

- Given these inputs, can solve system of equilibrium equations to recover fundamentals $(\bar{A}_t^A, \bar{A}_t^N, \bar{u}_t)$ that rationalize data from year t:

$$(w_{it})^{\sigma_s}(L_{it}^s)^{1-\alpha_s(\sigma_s-1)} = \sum_{j\in\mathcal{S}}(\hat{\tau}_{ijt}^s)^{1-\sigma_s}(\bar{A}_{it}^s P_{jt}^s)^{\sigma_s-1}\upsilon_{jt}^s L_{jt} w_{jt}$$

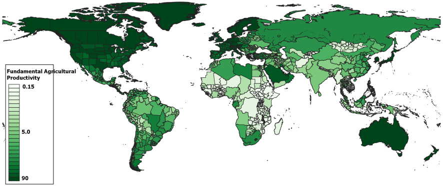
$$(P_{jt}^s)^{1-\sigma_s} = \sum_{i\in\mathcal{S}}(\hat{\tau}_{ijt}^s w_{it})^{1-\sigma_s}(\bar{A}_{it}^s (L_{it}^s)^{\alpha_s})^{\sigma_s-1}$$

$$\upsilon_{jt}^A = \phi + \nu(P_{jt}^A/P_{jt}^N)^\gamma w_{jt}^{-\eta}, \;\; L_{it} = \frac{{W_{it}}^\theta}{\sum_{k\in c}{W_{kt}}^\theta}\bar{L}_{c(i),t},$$

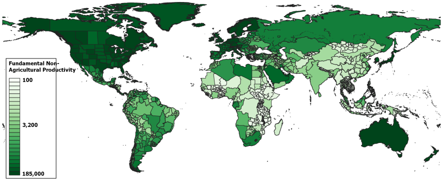
$$W_{jt} = \bar{u}_{jt}L_{jt}^\beta\left[\frac{1}{\eta}\left(w_{jt}(P_{jt}^A)^{-\phi}(P_{jt}^N)^{\phi-1}\right)^\eta - \frac{\nu}{\gamma}(P_{jt}^A/P_{jt}^N)^\gamma + \frac{\nu}{\gamma} - \frac{1}{\eta}\right]$$

Results: Calibrated Fundamental Productivities (2005)

Agriculture



Non-Agriculture



Calibrated Fundamental Amenities

- Intuitive: high productivities in developed/oil-rich locations.

Outline

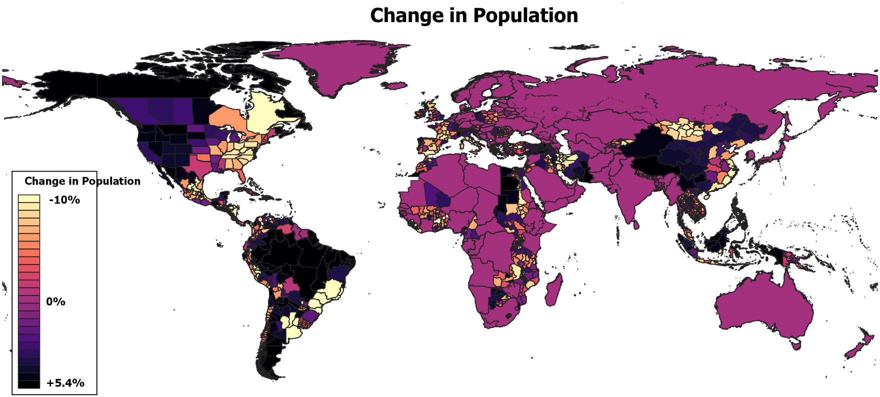
Counterfactuals

- Choose counterfactual trade-cost matrix τ^{cf}:
  - **CF #1**: remove all border-crossing costs.
  - **CF #2**: roll back trade-cost structure to 1971.
- Given τ^{cf} and fundamentals $(\bar{A}_t^s, \bar{u}_t)$, solve system of equilibrium equations (1)-(4)
  - Recover counterfactual endogenous variables (population, wage, welfare, etc).

Equilibrium System

- **Interpretation**: how would the world economy look like if...
  - trade costs were different...
  - but the other fundamentals (productivities, amenities) remained the same as in the 2005 baseline?

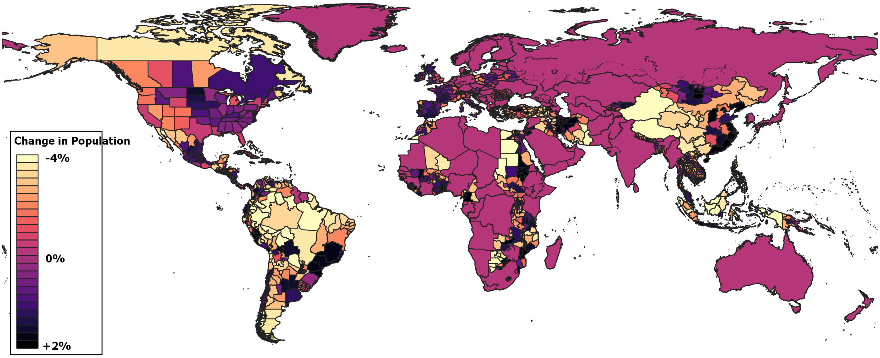
Results: Counterfactual #1 (no border-crossing costs)



- Counterfactual trade costs are: $\tau_{ij}^{s,cf} = \prod_{z=1}^{B} (\hat{C}^{s,z})^{\mathbb{1}_{dist_{ij} \in b_z}}$
- Spatial concentration **falls**: $\rho\left(\ln(L_{i,baseline}^{sh}), \Delta \ln(L_i) \right) = -0.227$
  - Initially large locations shrink.

Results: Counterfactual #2 (1971 trade costs)

Change in Population



- Counterfactual trade costs are: $\tau_{ij}^{s,cf} = \hat{\tau}_{ij,1971}^{s}$
- Spatial concentration **rises**: $\rho\left(\ln(L_{i,baseline}^{sh}), \Delta\ln(L_i)\right) = 0.249$
  - Initially large locations grow.

Results: Counterfactual Trade and Welfare

- International trade (as % of world GDP):

Scenario	CF #1	CF #2
Baseline	0.21	0.21
Long-Run CF	**0.78**	**0.14**
CF (strong immobility)	0.78	0.16
CF (weak immobility)	0.78	0.14

- Cross-country average of national welfare ($\pi_c \equiv (\sum_{k \in c} W_k^{\theta})^{\frac{1}{\theta}}$):

Scenario	CF #1	CF #2
Baseline	1	1
Long-Run CF	**1.569**	**0.949**
CF (strong immobility)	1.568	0.956
CF (weak immobility)	1.569	0.949

- Even from 2005 starting point, further trade integration would still yield large gains.

Outline

Change Accounting

- How much of observed 1990-2005 changes in concentration is accounted for by:
  - Structural transformation (**ST**)?
  - Differential trade access (**DTA**)?
  - Local fundamentals (**LF**): productivities/amenities?

- Calibrate world economy separately for 1990 and 2015.

- Then use equation (6) to separate contributions of three factors:

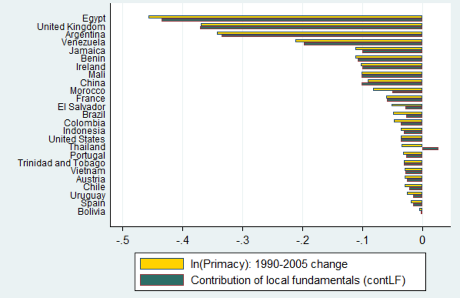
$$\ln(Primacy_{c,2005}) - \ln(Primacy_{c,1990}) = contrib_c^{ST} + contrib_c^{DTA} + contrib_c^{LF}$$

Equation: primacy rate

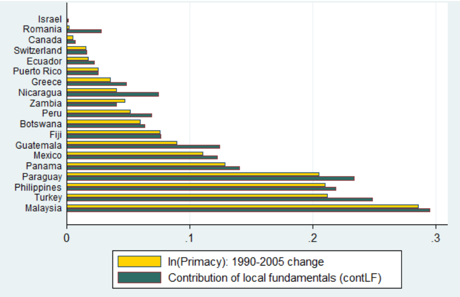
- Can also decompose cross-country variance of primacy changes ($d\ln(Primacy_c)$) into sum of variances of three factors (plus bilateral covariances).

Results: Change Accounting (1/2)

$dPrimacy_c < 0$



$dPrimacy_c > 0$



Country-by-country table

Results: Change Accounting (2/2)

- Decomposition of Var($d\ln(Primacy)$):

		in %
$\text{Var}(contrib^{ST})$	0.000002	0.008%
$\text{Var}(contrib^{DTA})$	.0002	0.99%
$\text{Var}(contrib^{LF})$	.0202	103.7%
$2\text{cov}(contrib^{ST}, contrib^{DTA})$	-0.000005	-.03%
$2\text{cov}(contrib^{ST}, contrib^{LF})$	.00005	0.25%
$2\text{cov}(contrib^{DTA}, contrib^{LF})$	-.001	-4.93%
$\text{Var}(d\ln(Primacy))$	.0195	100%

$$\begin{aligned}\text{Var}(d\ln(Primacy)) &= \text{Var}(contrib^{ST}) + \text{Var}(contrib^{DTA}) + \text{Var}(contrib^{LF}) \\ &\quad + 2\text{cov}(contrib^{ST}, contrib^{DTA}) + 2\text{cov}(contrib^{ST}, contrib^{LF}) + 2\text{cov}(contrib^{DTA}, contrib^{LF})\end{aligned}$$

- *Bottom line*: dominant influence of local fundamentals.

Outline

Conclusion

- Augment a quantitative spatial model with non-homothetic preferences to study three drivers of spatial concentration:
    - Structural transformation, differential trade access, and local fundamentals.
- Bring model to the data:
    - Estimate global trade-cost structure between 1962-2019.
    - Calibrate model to the world economy in 1990 and 2005.
- Perform counterfactual exercises to assess effect of trade shocks:
    - For most countries, trade decreases concentration.
- Decompose 1990-2005 changes in concentration into roles of the three factors:
    - Local fundamentals were the dominant factor.
    - Only 1% of variance is explained by trade access.

Model: Setting

- World is a set $\mathcal{S}$ of locations.
  - Locations: $i \in \mathcal{S} = \{1, ..., N\}$.
- World is partitioned into set of countries $\mathcal{C}$.
  - Countries: $c \in \mathcal{C} = \{1, ..., C\}$.
  - Function $c : \mathcal{S} \to \mathcal{C}$ maps locations to countries.
- Define the primacy function $p : \mathcal{C} \to \mathcal{S}$
  - Maps each country to its largest city (primate).
  - It is an equilibrium object.
- Two sectors:
  - Agriculture ($s = A$) and non-agriculture ($s = N$).

Back

Model: Agents (1/2)

- Agent who is born in location i and moves to j receives welfare:

$$W_j(\epsilon) = \underbrace{C_j u_j}_{\equiv W_j} \epsilon_j$$

where C_j is PIGL indirect utility function (Eckert Peters '18):

$$C_j = \frac{1}{\eta}\left(\frac{w_j}{(P_j^A)^{\phi}(P_j^N)^{1-\phi}}\right)^{\eta} - \frac{\nu}{\gamma}\left(\frac{P_j^A}{P_j^N}\right)^{\gamma} + \frac{\nu}{\gamma} - \frac{1}{\eta}$$

  - $P_j^s = (\sum_{k \in \mathcal{S}} (p_{kj}^s)^{1-\sigma_s})^{\frac{1}{1-\sigma_s}}$ is CES price index for sector s.
  - w_j is local wage, p_{kj}^s is local price of sector-s good from k.

- Non-homothetic preferences and structural transformation:
  - Agricultural spending share υ_j^A decreases with income.

$$\upsilon_j^A = \phi + \nu(P_j^A / P_j^N)^{\gamma} w_j^{-\eta}$$

Back

Model: Agents (2/2)

- Agent who is born in location i and moves to j receives welfare:

$$W_j(\epsilon) = \underbrace{C_j u_j}_{\equiv W_j} \epsilon_j$$

  - $u_j = \bar{u}_j L_j^{\beta}$ is local amenity ($\beta \leq 0$).
  - ϵ_j is idiosyncratic taste shock for location j.
    - i.i.d. Frechet distribution: $\Pr(\epsilon_j \leq x) = \exp(-x^{-\theta})$

- Migration decision:
  - Agent born in i migrates to highest-welfare destination:

$$\max_j W_{ij}(\epsilon)$$

Back

Model: Firm

- Sector s in location i has continuum of perfectly competitive firms with production function:

$$q_i^s = A_i^s l_i^s, \text{ with: } A_i^s = \bar{A}_i^s (L_i^s)^{\alpha_s}$$

  - A_i^s is local productivity of sector s
  - l_i^s is firm employment.
  - L_i^s is local employment in sector s.
  - External economies of scale ($\alpha_s \geq 0$): related to NEG

- Firm sells good worldwide paying "iceberg" shipping cost:
  - $\tau_{ij}^s \geq 1$, with $\tau_{ii}^s = 1$

- Assumptions imply the pricing equation:

$$p_{ij}^s = \frac{\tau_{ij}^s w_i}{A_i^s} \tag{8}$$

Back

Model: Gravity Flows

- Bilateral trade flows (X_{ij}^s) assume "gravity" form:

$$X_{ij}^s = \left[\frac{\tau_{ij}^s w_i}{A_i^s P_j^s}\right]^{1-\sigma_s} \upsilon_j^s w_j L_j \tag{9}$$

where L_j is local population and $\upsilon_j^N = 1 - \upsilon_j^A$.

- So do bilateral migration flows (L_{ij}):

$$L_{ij} = \left(\frac{(W_j)^\theta}{\sum_{k \in \mathcal{S}} (W_k)^\theta}\right) L_i \tag{10}$$

Back: model overview Back: estimating trade costs

Model: Equilibrium Conditions

- **(I)** Goods markets clear:

$$w_i L_i^s = \sum_{j \in \mathcal{S}} X_{ij}^s, \ \forall (i, s) \tag{11}$$

- **(II)** Local labor markets clear:

$$L_i = \sum_{j \in \mathcal{S}} L_{ij} = \sum_{j \in \mathcal{S}} L_{ji}, \ \forall i \tag{12}$$

  - Like steady-state of dynamic spatial migration model

- **(III)** Local population adds up:

$$L_i = L_i^A + L_i^N, \ \forall i \tag{13}$$

- **(IV)** National population adds up:

$$\bar{L}_c = \sum_{i \in c} L_i, \ \forall c \in \mathcal{C} \tag{14}$$

Back

Microfoundation: Trade Costs

- Path from i to j, partitioned into B segments with lengths $\{dx_b\}_{b=1}^{B}$.
- The final amount of goods is approximately given by:

$$q_f \approx q_0 \prod_{k=1}^{B} r(x_k)^{\frac{dx_k}{s(x_k)}} \tag{15}$$

  - x_k: arbitrarily chosen point in segment k.
  - $r(x)$: "Net-of-melting" rate (per unit of time).
  - $s(x)$: speed.

- Take limit: infinitesimal partitioning yields iceberg trade cost:

$$\tau_{ij} = \frac{q_0}{q_f} = \lim_{dx \to 0} \prod_{k=1}^{B} \left(r(x_k)^{\frac{1}{s(x_k)}} \right)^{dx_k} = \pi_i^j \left(r(x)^{\frac{1}{s(x)}} \right)^{dx} \tag{16}$$

  where π indicates the geometric integral.

- By properties of geometric integral:

$$\tau_{ij} = e^{\int_i^j \ln(r(x)^{\frac{1}{s(x)}})dx} = e^{\int_i^j \frac{1}{s(x)} \ln(r(x))dx}$$

Back

Calibration of Modal Traversal Costs

- Consider trade costs $T(i,j)$ in Allen Arkolakis '14, assuming:
  - $\theta = 1$
  - A single model of transportation m
  - No fixed cost ($b_m = 0$)

- Yields: $T(i,j) = e^{a_m d_m(i,j)}$

- Distance $d_m(i,j)$ can be represented as $\int_i^j \tau_{mode}(x)dx$
  - $\tau_{mode}(x)$: relative "slowness" of mode m

- Matching terms in integral $e^{\int_i^j \frac{1}{s(x)} \ln(r(x))dx}$, obtain:

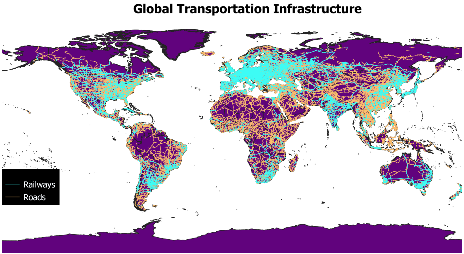
$$a_m \tau_{mode}(x) = \frac{1}{s(x)} \ln(r(x)) \tag{17}$$

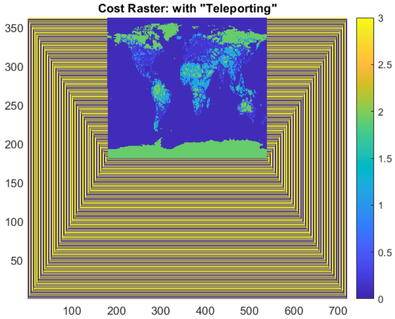
- Therefore, can calibrate by using:
  - a_m from Row 1, Table II
  - $\tau_{mode}(x)$ from Appendix B3

Back

Measuring Distances (1/2)

- Bilateral distances ($dist_{ij}$) are key inputs for gravity estimation.
  - How do we measure them?
- Generate *cost raster* using infrastructure network maps:
  - Assign traversal cost $T(x)$ to each 1°-by-1° pixel x.
  - Mode-specific traversal costs adapted from Allen Arkolakis '14. Details





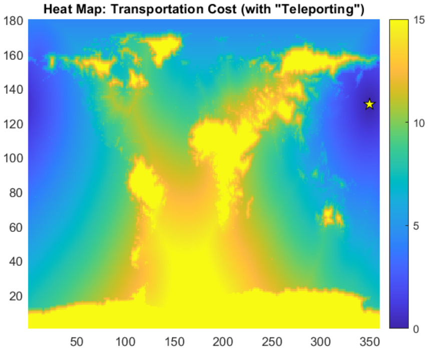
Back

Measuring Distances (2/2)

- Define $\mathcal{P}_{ij}$ as set of continuous paths $\mathbb{p}$ on world map starting at pixel i and ending at j. Then:

$$dist_{ij} = \min_{\mathbb{p} \in \mathcal{P}_{ij}} \sum_{x \in \mathbb{p}} T(x)$$

- How to solve minimization?
  - Use FMM algorithm
  - (from Allen Arkolakis '14)



Back

Data Sources (1/2)

- IPUMS International: location-level population, sectoral employment.
  - Harmonized censuses (88 countries, 1605 locations).
  - Locations are typically states or provinces.
  - Covers 1960-2015 period.
  - Use year closest to 2005 (or 1990).
- World Bank Open Data:
  - Country-level data.
  - Population, GDP per capita, agricultural employment share.
  - Covers 1960-2017 period.
- G-Econ 4.0: income per capita (Desmet et al '18)
  - Data at 1° x 1° grid-cell level.
  - Proxy for wages.
  - Covers 1990, 1995, 2000, 2005.

Data Adjustments   Back: calibrating local fundamentals

Data Sources (2/2)

- WITS: World Integrated Trade Solutions data set.
  - Country-level bilateral trade flows (total and in agriculture).
  - Covers 1962-2019 period, 222 countries.
  - But no intranational flows (X^s_{nn}):
    - Augment data using import share and agricultural share of GDP (World Bank Open Data). Data Adjustments
- IPUMS maps: geographic coordinates
  - Polygon's centroids.
- Natural Earth: global transportation infrastructure (Desmet et al '18)
  - Maps: roads, railway lines, oceans, landmasses.
- Final calibration sample (2005):
  - 1611 locations across 192 countries.

Back: estimating trade costs

Data Adjustments (1/2)

- Scale local IPUMS populations to match national WBOD population:

$$L^{s}_{i,2005} = L^{s,IPUMS}_{i,2005} \frac{\bar{L}^{WBOD}_{c(i),2005}}{\sum_{j \in c(i)} L^{IPUMS}_{j,2005}}$$

- Impute locations' wages using per capita income data from G-Econ:

$$w_{i,2005} = \sum_{g=1}^{G} wagecell^{G-Econ}_{g,2005} \left(\frac{Area_{g \cap i}}{Area_i} \right)$$

Back

Data Adjustments (2/2)

- To obtain intranational trade flows ($X^s_{ii,t}$):
  - Use WITS data to obtain country-year sectoral exports and country-year imports:

$$EXP^s_{it} = \sum_{j \neq i} X^{s,WITS}_{ijt}, \; IMP_{it} = \sum_{j \neq i} (X^{A,WITS}_{jit} + X^{N,WITS}_{jit})$$

  - Use country-year imports and import share to compute implied GDP

$$Y_{it} = \frac{IMP_{it}}{Msh_{it}}$$

  - Divide GDP between sectors using agricultural share of GDP:

$$Y^A_{it} = Y_{it} \times Agsh_{it}, \; Y^N_{it} = Y_{it} \times (1 - Agsh_{it})$$

  - Subtract sectoral exports from sectoral GDP:

$$X^s_{iit} = Y^s_{it} - EXP^s_{it}$$

Back

Robustness of Trade Cost Results (1/2)

- German Survey *Verkehrsverflechtungsprognose 2030* (GSV)
  - 265 regions in 24 European countries, plus 16 non-European countries.
  - Includes intranational trade flows (helps identify border-crossing cost).
  - 15 sectors, aggregated into agriculture vs non-agriculture.
  - Richer than WITS but covers 2010 only.

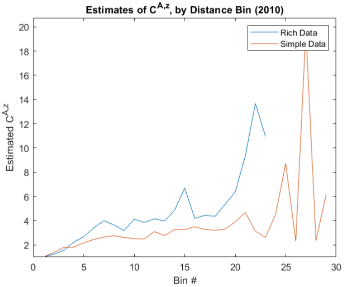
- Rerun gravity regressions with GSV (for 2010 only):
  - Compare results to WITS'.
  - If they are similar, that is reassuring.

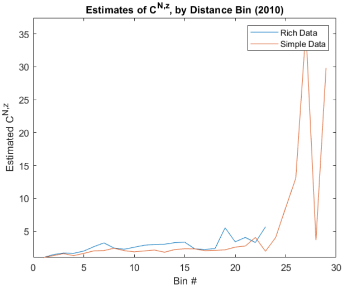
- Adjust GSV so that country-level flows match WITS:

$$X_{ij}^{s,GSV_1} = X_{ij}^{s,GSV_0} \frac{X_{c(i),c(j)}^{s,WITS}}{\sum_{i \in c(i)} \sum_{j \in c(j)} X_{ij}^{s,GSV_0}}$$

Back

Robustness of Trade Cost Results (2/2)





Estimate: Border-Crossing Parameters (2010)

	"Rich"		"Simple"	
	(1)	(2)	(3)	(4)
$\hat{E}^A_{2010}$	1.871		2.39	
$\hat{E}^N_{2010}$		3.73		3.81
N	32,483	34,165	18,357	18,394
WITS?	Yes	Yes	No	No
GSV?	No	No	Yes	Yes

Back

Parameters and Normalization

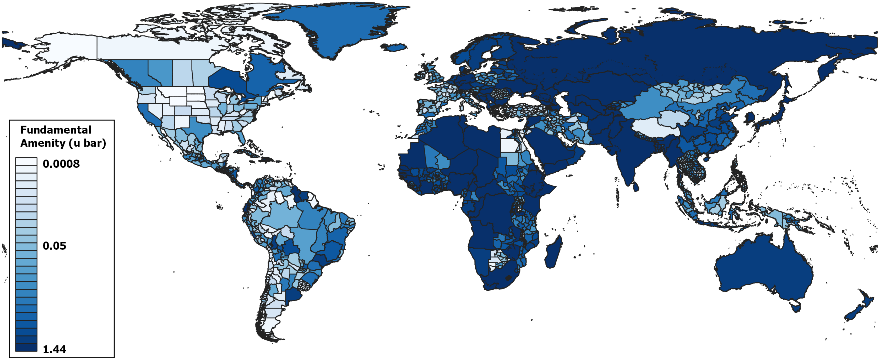
- Parameter values taken from the literature:

Parameter	Description	Value
σ_A, σ_N	Elasticities of substitution	4
θ	Dispersion of taste shock	1.2
α_A, α_N	Agglomeration elasticities	0.1
β	Congestion elasticity	-0.345
ϕ	Asymptotic agricultural share of consumption	0.01
ν	Degree of non-homotheticity	0.5
γ	Concavity of non-homothetic part of utility	0.35
η	Concavity of Cobb-Douglas part of utility	0.31

- *Normalization*: $\pi_c \equiv \left(\sum_{k \in c} W_{kt}^{\theta}\right)^{\frac{1}{\theta}} = 1$ for all countries $c \in \mathcal{C}$
  - Reason: country's average welfare levels and amenity levels not separately identifiable.

Back

Results: Calibrated Fundamental Amenities (2005)



Back

Effects: Primacy, Trade, Welfare

- Given counterfactual equilibrium allocation, recover counterfactual variables of interest:
  - Country's primacy rate and average welfare:

$$Primacy_c^{cf} = L_{p_{cf}(c)}^{cf} / \bar{L}_c$$

$$\pi_c^{cf} = \Big(\sum_{k \in c} (W_k^{cf})^{\theta} \Big)^{\frac{1}{\theta}}$$

  - International trade (as % of world GDP):

$$\left(\frac{M}{Y}\right)^{cf} = \frac{\sum_{s \in \{A,N\}} \sum_{i \in \mathcal{S}} \sum_{j \notin c(i)} X_{ij}^{s,cf}}{\sum_{s \in \{A,N\}} \sum_{i \in \mathcal{S}} \sum_{j \in \mathcal{S}} X_{ij}^{s,cf}}$$

- Effect of on variable y obtained by comparing y^{cf} to y_t.

Counterfactuals With Immobility (1/2)

- How much does worker spatial/sectoral reallocation influence the effects of trade shocks on welfare and trade volume?

- Compare long-run counterfactual to "immobility" counterfactuals:
  - **Strong** immobility: no reallocation across sectors or locations.
  - **Weak** immobility: reallociation across sectors but not locations.

- *Strong*: solve system for $(w^{cf,SI,s}, P^{cf,SI,s}, \upsilon^{cf,SI,s\times s'})$:

$$(w_i^{cf,SI,s})^{\sigma_s}(L_{i,2005}^s)^{1-\alpha_s(\sigma_s-1)} = (\bar{A}_{i,2005}^s)^{\sigma_s-1}\sum_{j\in\mathcal{S}}(\tau_{ij}^{cf,s})^{1-\sigma_s}(P_j^{cf,SI,s})^{\sigma_s-1}\sum_{r\in\{A,N\}}\upsilon_j^{cf,SI,s\times r}L_{j,2005}^r w_j^{cf,SI,r}$$

$$(P_j^{cf,SI,s})^{1-\sigma_s} = \sum_{i\in\mathcal{S}}(\hat{\tau}_{ij,2005}^s w_i^{cf,SI,s})^{1-\sigma_s}(\bar{A}_{i,2005}^s(L_{i,2005}^s)^{\alpha_s})^{\sigma_s-1}$$

$$\upsilon_j^{cf,SI,A\times s} = \phi + \nu(P_j^{cf,SI,A}/P_j^{cf,SI,N})^{\gamma}(w_j^{cf,SI,s})^{-\eta}$$

Back

Counterfactuals With Immobility (2/2)

- *Weak*: solve system for $(w^{cf,WI}, L^{cf,WI,s}, P^{cf,WI,s}, \upsilon^{cf,WI,s})$:

$$(w_i^{cf,WI})^{\sigma_s}(L_i^{cf,WI,s})^{1-\alpha_s(\sigma_s-1)} = (\bar{A}^s_{i,2005})^{\sigma_s-1}\sum_{j\in\mathcal{S}}(\tau_{ij}^{cf,s})^{1-\sigma_s}(P_j^{cf,WI,s})^{\sigma_s-1}\upsilon_j^{cf,WI,s}L_{j,2005}w_j^{cf,WI}$$

$$(P_j^{cf,WI,s})^{1-\sigma_s} = \sum_{i\in\mathcal{S}}(\tau_{ij}^{cf,s}w_i^{cf,WI})^{1-\sigma_s}(\bar{A}^s_{i,2005}(L_i^{cf,WI,s})^{\alpha_s})^{\sigma_s-1}$$

$$\upsilon_j^{cf,WI,A} = \phi + \nu(P_j^{cf,WI,A}/P_j^{cf,WI,N})^{\gamma}(w_j^{cf,WI})^{-\eta}$$

$$L_{i,2005} = L_i^{cf,WI,A} + L_i^{cf,WI,N}$$

Back

Results: Counterfactuals With Immobility

- International trade (as % of world GDP):

Counterfactual #	CF1	CF2
Baseline	0.21	0.21
Long-Run CF	0.78	0.14
CF (strong immobility)	0.78	0.16
CF (weak immobility)	0.78	0.14

- Cross-country average of national welfare ($\pi_c \equiv (\sum_{k \in c} W_k^{\theta})^{\frac{1}{\theta}}$):

Counterfactual #	CF1	CF2
Baseline	1	1
Long-RUn CF	1.569	0.949
CF (strong immobility)	1.568	0.956
CF (weak immobility)	1.569	0.949

- Welfare/trade volumes in immobility CFs similar to long-run CF.
    - Worker sectoral/spatial mobility are secondary factors mediating trade-shock effects on welfare/trade volumes.

Back

Results: Change Accounting, country-by-country (1/2)

Country	$Primacy_{c,2005}$	$d\ln(Primacy_c)$	$cont_c^{ST}$	$cont_c^{DTA}$	$cont_c^{LF}$
Argentina	0.371	-0.342	0.000	-0.008	-0.334
Austria	0.203	-0.029	-0.000	-0.003	-0.026
Bolivia	0.295	-0.005	0.000	-0.003	-0.002
Botswana	0.193	0.060	-0.000	-0.003	0.064
Brazil	0.227	-0.049	-0.000	-0.022	-0.027
Canada	0.384	0.005	-0.000	-0.002	0.007
Chile	0.345	-0.029	-0.000	-0.007	-0.022
China	0.092	-0.091	-0.000	0.011	-0.101
Colombia	0.229	-0.048	0.000	-0.012	-0.036
Benin	0.112	-0.111	-0.000	-0.003	-0.108
Ecuador	0.649	0.018	-0.000	-0.005	0.023
El Salvador	0.332	-0.052	0.000	-0.024	-0.028
Fiji	0.427	0.076	-0.000	-0.001	0.077
France	0.206	-0.061	0.000	-0.002	-0.059
Greece	0.268	0.036	0.001	-0.014	0.049
Guatemala	0.291	0.090	-0.000	-0.035	0.125
Indonesia	0.201	-0.037	0.001	-0.006	-0.032
Ireland	0.288	-0.103	0.000	-0.003	-0.100
Israel	0.242	0.000	0.000	-0.001	0.001
Jamaica	0.230	-0.112	0.000	-0.012	-0.100
Malaysia	0.284	0.286	-0.000	-0.009	0.296
Mali	0.182	-0.101	0.001	-0.000	-0.102
Mexico	0.138	0.111	-0.001	-0.011	0.123

Back

Results: Change Accounting, country-by-country (2/2)

Country	$Primacy_{c,2005}$	$d\ln(Primacy_c)$	$cont_c^{ST}$	$cont_c^{DTA}$	$cont_c^{LF}$
Morocco	0.130	-0.082	-0.000	-0.032	-0.050
Nicaragua	0.330	0.041	-0.000	-0.035	0.075
Panama	0.567	0.129	0.000	-0.012	0.141
Paraguay	0.279	0.205	0.000	-0.029	0.234
Peru	0.355	0.052	0.000	-0.017	0.069
Philippines	0.054	0.210	0.008	-0.016	0.219
Portugal	0.203	-0.032	0.000	-0.005	-0.027
Puerto Rico	0.728	0.026	0.000	0.000	0.026
Romania	0.094	0.003	0.001	-0.027	0.028
Vietnam	0.107	-0.030	0.000	-0.002	-0.028
Spain	0.173	-0.020	0.000	-0.005	-0.015
Switzerland	0.184	0.016	0.000	-0.001	0.017
Thailand	0.090	-0.034	0.001	-0.062	0.027
Trinidad and Tobago	0.875	-0.031	0.000	0.001	-0.031
Turkey	0.186	0.212	0.000	-0.037	0.249
Egypt	0.198	-0.456	0.000	-0.022	-0.434
United Kingdom	0.144	-0.369	0.000	0.000	-0.370
United States	0.117	-0.037	-0.000	0.000	-0.037
Uruguay	0.455	-0.026	-0.000	-0.010	-0.015
Venezuela	0.120	-0.212	0.002	-0.016	-0.198
Zambia	0.304	0.047	0.000	0.006	0.041

Back