Trade and the Topography of the Spatial Economy

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Goal

- Develop a framework that can find spatial equilibrium of economic activity over (nearly) any geographic surface
- Allow application of spatial structure to data

Applications

- Estimate fraction of income disparity due to geographic location
- Test impact of Interstate Highway System with framework

Combination of economic and geographic components

- Krugman (1991), gravity structure and labor mobility
- Micro-founded bilateral trade costs

Basic components

Continuum of locations $i \in S$

- Each produces unique variety of a good

Identical CES preferences, continuum of differentiated varieties

$$W(i) = \left(\int_{s \in S} q(s,i)^{\frac{\sigma-1}{\sigma}} ds \right)^{\frac{\sigma}{\sigma-1}} u(i),$$

- $q(s,i)$ per-capita quantity, $u(i)$ local amenity

Costly trade

- Iceberg $T(i,j)$, $T(i,i) = 1$

Free labor mobility

- $\bar{L}$ workers

Production

Factor of production - Labor

- Worker provides 1 unit inelastically, locally
  - Produces $A(i)$ (local productivity)
- Perfect competition
- L density of workers, ω wages

Productivity or congestion externalities

- $A(i) = \bar{A}(i)L(i)^{\alpha}$
  - $\bar{A}(i)$ exogenous component of local productivity
  - α extent productivity affected by worker density
- $u(i) = \bar{u}(i)L(i)^{\beta}$
  - $\bar{u}(i)$ exogenous utility from living in i
  - β extent amenities affected by worker density

Geography

Geography of S

- Local characteristics $\bar{A}, \bar{u}$
- Geographic location T

Distribution of economic activity

- ω
    - $\int_S \omega(s)ds = 1$
- L

Gravity

Bilateral trade flows

- $X(i,j)$

With P.C., price of good is

$$\frac{\omega(i)}{A(i)}T(i,j)$$

Value in j of imports from i

$$X(i,j) = \left(\frac{T(i,j)\omega(i)}{A(i)P(j)}\right)^{1-\sigma}\omega(j)L(j)$$

where $P(j)$ is CES price index

$$P(j)^{1-\sigma} = \int_S T(s,j)^{1-\sigma}A(s)^{\sigma-1}\omega(s)^{1-\sigma}ds$$

Spatial Equilibrium

Welfare equalized

$$W(i) = \frac{\omega(i)}{P(i)} u(i)$$

- Equalized if welfare the same in all inhabited locations (and uninhabited location welfare is no greater)

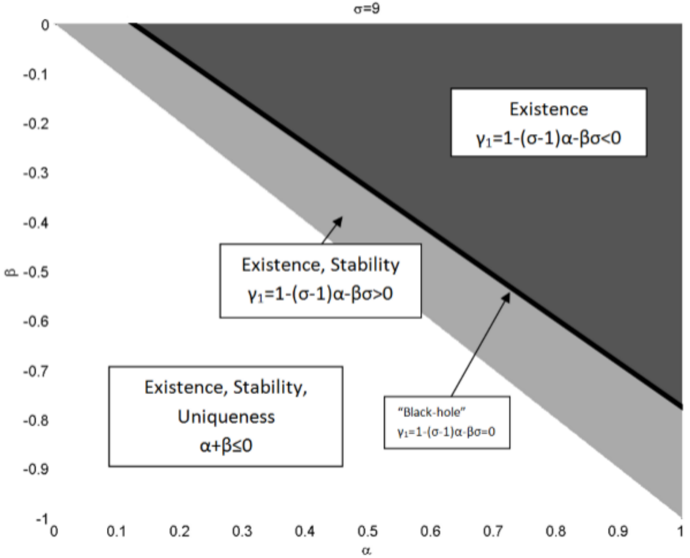
Markets clear: income = value of goods sold

$$\omega(i)L(i) = \int_S X(i,s)ds$$

Aggregate labor market clears

$$\int_S L(s)ds = \bar{L}$$

Equilibria with amenity and productivity spillovers



Bilateral trade cost micro-foundation

Total trade costs along least-cost route

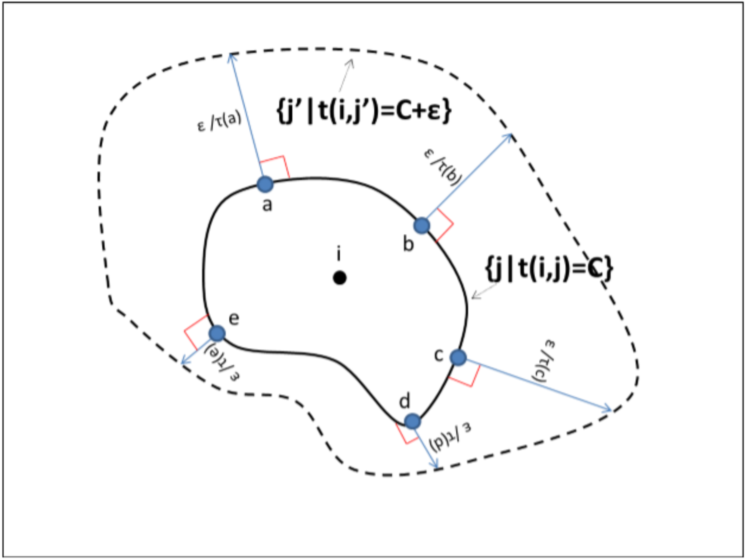
$$t(i,j) = \inf_{g \in \Gamma(i,j)} \int_0^1 \tau(\kappa(t)) \left\| \frac{dg(t)}{dt} \right\| dt$$

- Path $g : [0,1] \to S$
- Set of all continuous, once-differentiable paths from i to j $\Gamma(i,j)$
- Instantaneous trade cost τ

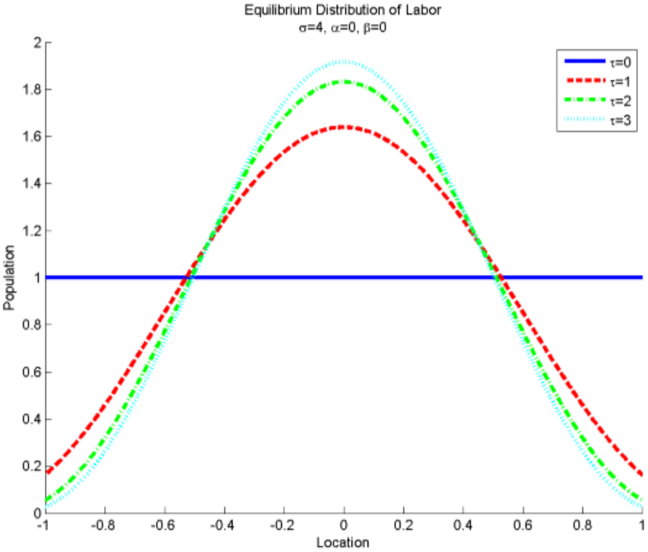
Geographic trade costs

- $T(i,j) = f(t(i,j)) = e^{t(i,j)}$
  1. $T(i,j) = T(j,i)$
  2. $\lim_{s \to i} T(s,j) = T(i,j)$

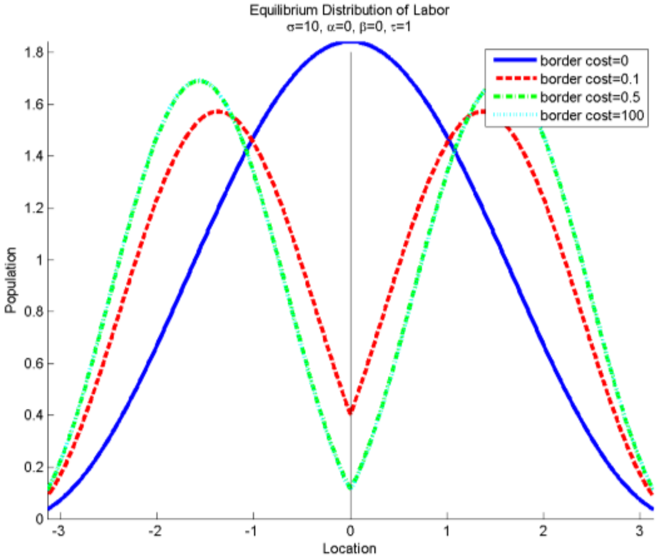
Propogation of geographic trade costs



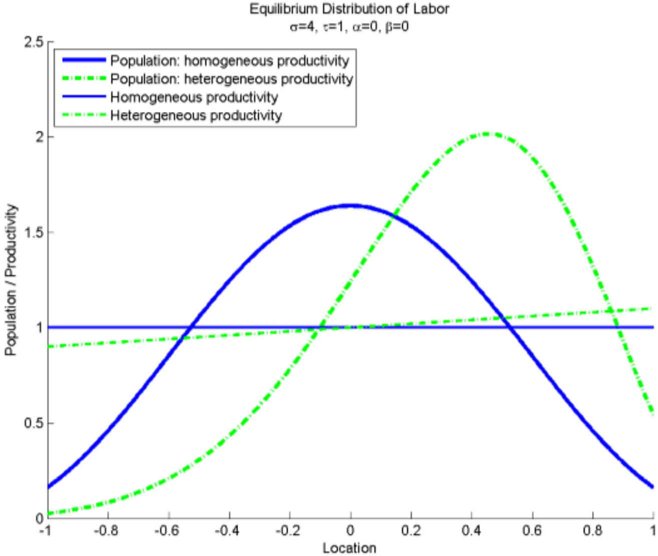
Spatial equilibrium of a line



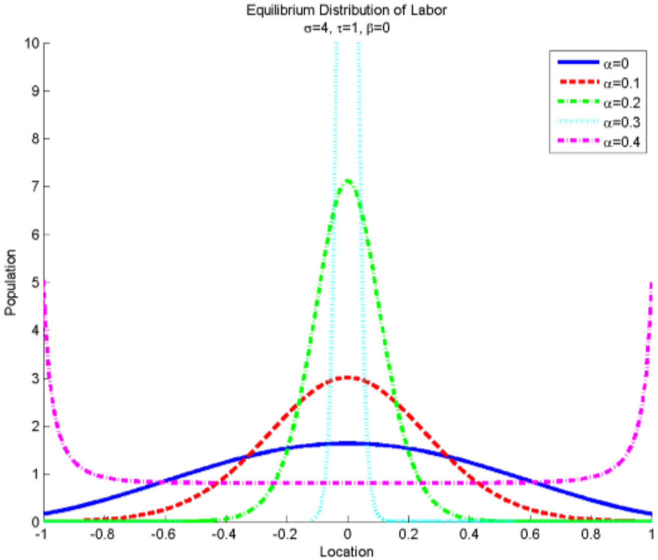
Border


Equilibrium Distribution of Labor
σ=10, α=0, β=0, τ=1
border cost=0
border cost=0.1
border cost=0.5
border cost=100
Population
Location
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-3
-2
-1
0
1
2
3

Heterogeneous productivities and amenities



Productivity spillovers



Real World Geography

Estimate geography of US

- Bilateral trade cost function T
- Topography of exogenous productivities $\bar{A}$
- Topography of exogenous amenities $\bar{u}$

Two steps

1. Estimate trade costs along transportation networks
    - Best match to observed bilateral trade flows
2. Estimate A and u that generate observed distribution of wages and population

Data

1. Highway, rail, navigable water networks in US from Navigation Data Center, 1999; Center for Transport Analysis, 2003; National Highway Planning Network, 2005
2. Bilateral trade flows from 2007 Commodity Flow Survey
3. County-level income and demographics from 2000 US Census.

Transportation network

Figure 9: U.S. transportation networks

Estimating trade costs T

First, estimate mode-specific distance

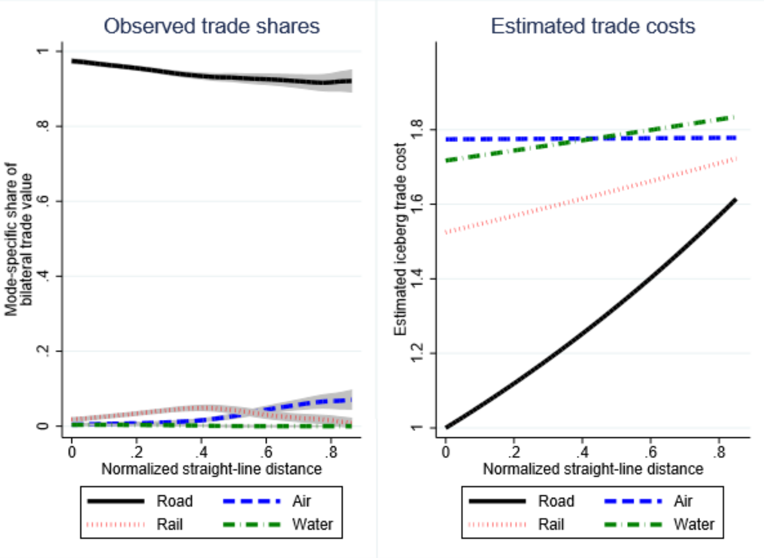
- Low τ_m if i on network
- Fast Marching Method algorithm applied to observed transportation network for each mode
- Bilateral trade flows negatively correlated with estimated distances

Then, compare mode-specific distances to mode-specific bilateral trade shares

- Let f_m be mode-specific fixed cost, μ_{tm} be trader-mode specific idiosyncratic cost
- Iceberg cost: $\exp(\tau_m d_m(i,j) + f_m + \nu_{tm})$
- Assume Gumbel distribution for ν_{tm} (thus e^{ν} is Frechet with shape θ), then

$$\pi_m(i,j) = \frac{exp(-\theta \tau_m d_m(i,j) - \theta f_m)}{\sum_k (exp(-\theta \tau_k d_k(i,j) - \theta f_k))}$$

Trade shares and costs

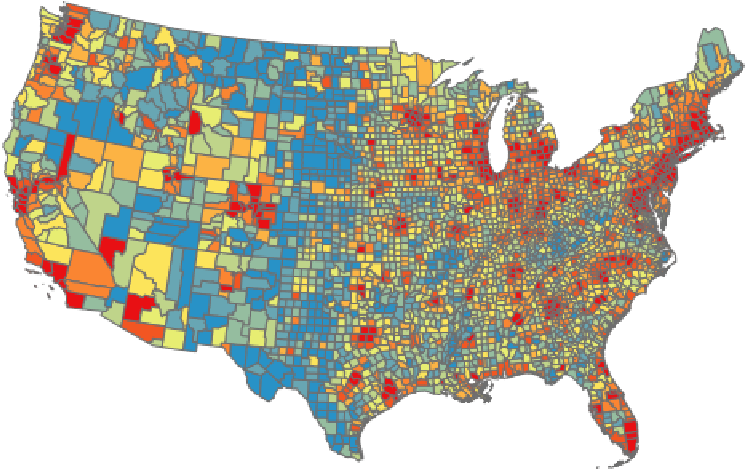


Topography of productivities and amenities

There exists a unique topography that generates an observed spatial equilibrium.

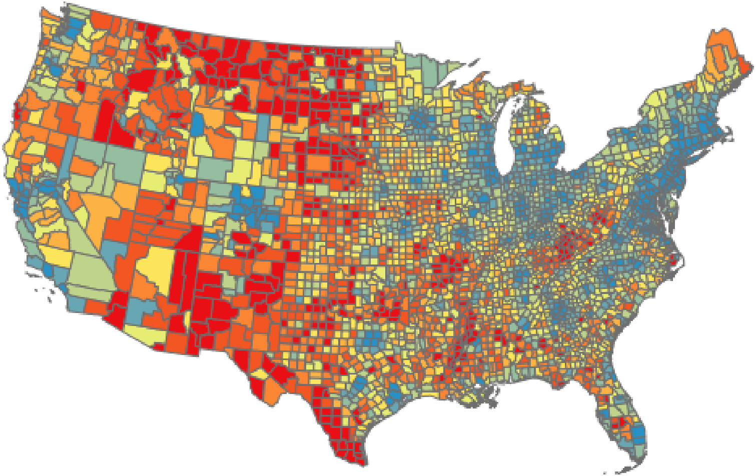
- Identified for each US county
- Applies for any strength of spillovers
- Use $\alpha = 0.1$, $\beta = -0.3$
  - Rosenthal and Strange (2004)

Productivities of counties



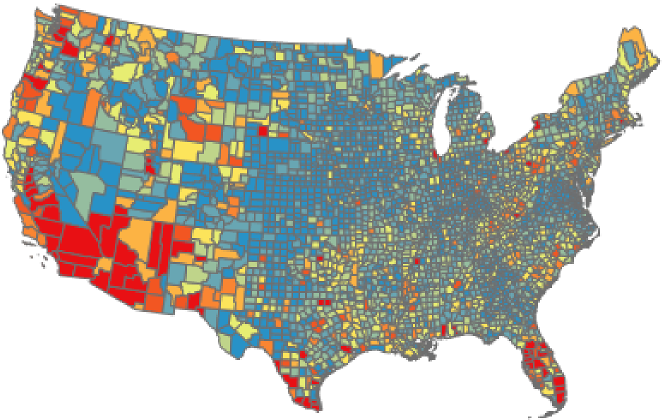
Composite productivity

Amenities of counties



Composite amenity

Exogenous amenities of counties



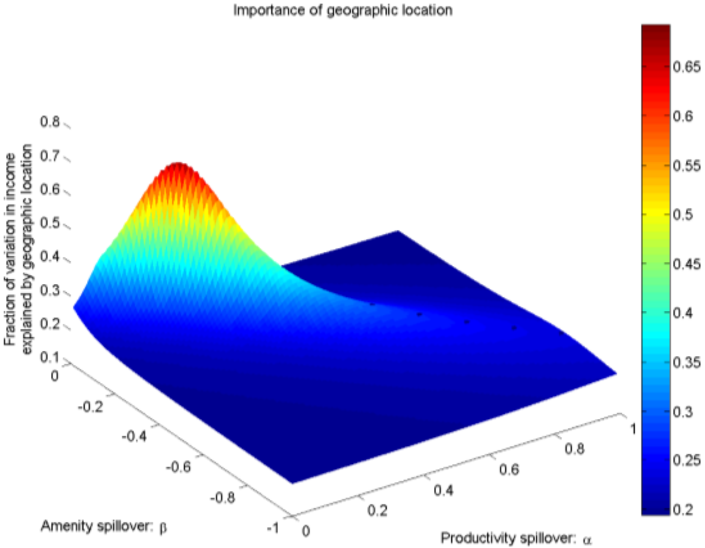
Exogenous amenity

Importance of geography

What fraction of variation in incomes is due to geographic location?

- Solve for income ($\omega(i)L(i)$) as function of productivities, amenities, and the price index
- Decompose using Shapley decomposition

Importance of geography



Removal of IHS

Suppose there were no interstate highways

- Re-estimate T using FMM
- Keep estimated $\bar{A}$ and $\bar{u}$ from before
- Re-estimate labor, wages, and welfare

Decline in welfare between 1.1-1.4%

- Cost of building and maintaining IHS annually $100 billion
- Cost of removing IHS $150-$200 billion