Lecture 4: Regional Economics

Economics 522

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Spring 2014

Allen and Arkolakis (2013)

- Enormous degree of spatial inequality of economic activity
  - McLeod County, MN: 26 persons/km^2 and payroll \$13.5k per capita.
  - Mercer County, NJ: 591 persons/km^2 and payroll \$20.8k per capita.
- Why?
  - Local characteristics (climate, natural resources, institutions, etc.).
  - Geographic location.
- How important is geographic location?
- Much recent advancement in theory of economic geography.
- But the stylized nature of geography in these models make it difficult to take them directly to the data.

Geography

- Compact set S of locations inhabited by $\bar{L}$ workers.
- Location $i \in S$ is endowed with:
  - Differentiated variety (Armington assumption).
  - Productivity $\bar{A}(i)$.
  - Amenity $\bar{u}(i)$.
- For all $i, j \in S$, let the iceberg bilateral trade cost be $T(i, j)$.

- Terminology
  - $\bar{A}$ and $\bar{u}$ are the **local characteristics**.
  - T determines **geographic location**.
  - Together, $\bar{A}$, $\bar{u}$, and T comprise the **geography** of S.

- A geography is **regular** if $\bar{A}$, $\bar{u}$ and T are continuous and bounded above and below by strictly positive numbers.

Workers

- Endowed with identical CES preferences over differentiated varieties with elasticity of substitution $\sigma > 1$.
- Can choose to live/work in any location $i \in S$.
- Receive wage $w(i)$ for their inelastically supplied unit of labor.
- Welfare in location i is:

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

where $q(s,i)$ is the per capita quantity consumed in location i of the good produced in location s and $u(i)$ is the local amenity.

Production

- Labor is the only factor of production, $L(i)$ is the density of workers.
- Productivity of worker in location i is $A(i)$.
- Perfect competition implies price of good from i is $\frac{w(i)}{A(i)} T(i, j)$ in location j.
- Functions w and L comprise the **distribution of economic activity**.

Productivity and Amenity Spillovers

- Productivity is potentially subject to externalities:

$$A(i) = \bar{A}(i) L(i)^{\alpha}$$

- Amenities are potentially subject to externalities:

$$u(i) = \bar{u}(i) L(i)^{\beta}$$

- Isomorphisms:
  - Monopolistic competition with free entry: $\alpha = \frac{1}{\sigma - 1}$.
  - Cobb-Douglas preferences over non-tradable sector: $\beta = -\frac{1-\gamma}{\gamma}$.
  - Heterogeneous (extreme-value) worker preferences: $\beta = -\frac{1}{\theta}$.

Equilibrium

- A **spatial equilibrium** is a distribution of economic activity such that:
- Markets clear: for all $i \in S$:

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

  where $X(i,j)$ is the value of trade flows from $i \in S$ to $j \in S$.
- Welfare is equalized**:** there exists $W \in \mathbb{R}_{++}$ such that for all $i \in S$, $W(i) \leq W$, with the equality strict if $L(i) > 0$.
- The aggregate labor market clears, i.e. $\int_S L(s)\, ds = \bar{L}$.
- Characterization
  - A spatial equilibrium is **regular** if L and w are strictly positive and continuous.
  - A spatial equilibrium is **point-wise locally stable** if $\frac{dW(i)}{dL(i)} < 0$ for all $i \in S$.

Equilibrium without Spillovers

- Suppose $\alpha = \beta = 0$ so that $A(i) = \bar{A}(i)$ and $u(i) = \bar{u}(i)$. Then from welfare equalization:

$$w(i)^{1-\sigma} = W^{1-\sigma} \int_S T(s,i)^{1-\sigma} u(i)^{\sigma-1} A(s)^{\sigma-1} w(s)^{1-\sigma} ds$$

and from balanced trade

$$L(i) w(i)^{\sigma} = W^{1-\sigma} \int_S T(i,s)^{1-\sigma} A(i)^{\sigma-1} u(s)^{\sigma-1} L(s) w(s)^{\sigma} ds$$

Theorem

For any regular geography with exogenous productivity and amenities:

1. *There exists a unique equilibrium.*
2. *The equilibrium is regular and point-wise locally stable.*
3. *Equilibrium can be determined using an iterative procedure.*

Equilibrium with Spillovers

Can rewrite balanced trade and utility equalization as:

$$L(i)^{1-\alpha(\sigma-1)} w(i)^{\sigma} = W^{1-\sigma} \int_S T(i,s)^{1-\sigma} \bar{A}(i)^{\sigma-1} \bar{u}(s)^{\sigma-1} L(s)^{1+\beta(\sigma-1)} w(s)^{\sigma} ds$$

$$w(i)^{1-\sigma} L(i)^{\beta(1-\sigma)} = W^{1-\sigma} \int_S T(s,i)^{1-\sigma} \bar{A}(s)^{\sigma-1} \bar{u}(i)^{\sigma-1} w(s)^{1-\sigma} L(s)^{\alpha(\sigma-1)} ds$$

If $T(i,s) = T(s,i)$ for all $i, s \in S$ then the solution can be written as:

$$A(i)^{\sigma-1} w(i)^{1-\sigma} = \phi L(i) w(i)^{\sigma} u(i)^{\sigma-1}$$

$$L(i)^{\tilde{\sigma}\gamma_1} = K_1(i) W^{1-\sigma} \int_S T(s,i)^{1-\sigma} K_2(s) \left(L(s)^{\tilde{\sigma}\gamma_1} \right)^{\frac{\gamma_2}{\gamma_1}} ds,$$

where $K_1(i)$ and $K_2(i)$ are functions of $\bar{A}(i)$ and $\bar{u}(i)$, γ_1, γ_2, and $\tilde{\sigma}$ are functions of α, β, and σ.

Equilibrium with Spillovers

Theorem

Consider any regular geography with endogenous productivity and amenities with T symmetric. Define $\gamma_1 \equiv 1 - \alpha(\sigma - 1) - \beta\sigma$ and $\gamma_2 \equiv 1 + \alpha\sigma + (\sigma - 1)\beta$. If $\gamma_1 \neq 0$, then:

1. *There exists a regular equilibrium.*
2. *If $\gamma_1 < 0$, no regular equilibria are point-wise locally stable.*
3. *If $\gamma_1 > 0$, all equilibria are regular and point-wise locally stable.*
4. *If $\frac{\gamma_2}{\gamma_1} \in [-1, 1]$, the equilibrium is unique.*
5. *If $\frac{\gamma_2}{\gamma_1} \in (-1, 1]$, the equilibrium can be determined using an iterative procedure.*

Equilibrium Distribution of Labor

- When trade costs are symmetric, equilibrium distribution of labor can be written as a log-linear function of the underlying geography:

$$\gamma_1 \ln L(i) = C_L + (\sigma - 1) \ln \bar{A}(i) + \sigma \ln \bar{u}(i) + (1 - 2\sigma) \ln P(i)$$

- Implications:
  - When equilibrium is point-wise locally stable, population is increasing in $\bar{A}$ and $\bar{u}$.
  - Price index is a sufficient statistic for geographic location.
  - Conditional on price index, productivity and amenity spillovers only affect elasticity of $L(i)$ to geography.

Trade Costs

- Suppose S is a compact surface (e.g. a line, plane, or sphere).
- Let $\tau : S \to R_+$ be a continuous function, where $\tau(i)$ is the instantaneous trade cost of traveling over location $i \in S$.
- Define the **geographic trade cost** $T(i,j) = f(t(i,j))$, $f' > 0$, $f(0) = 1$ to be the total iceberg trade cost incurred traveling along the least cost route from i to j, i.e.

$$t(i,j) = \min_{\gamma \in \Gamma(i,j)} \int_0^1 \tau(\gamma(t)) \left|\left| \frac{d\gamma(t)}{dt} \right|\right| dt$$

  where $\gamma : [0,1] \to S$ is a path and $\Gamma(i,j) \equiv \{\gamma \in C^1 | \gamma(0) = i, \gamma(1) = j\}$ is the set of all paths.
- $f(t) = \exp(t)$ natural choice since $\prod_0^1 (1 + \tau(x)\, dx) = \exp\left(\int_0^1 \tau(x)\, dx\right)$, but can show T satisfied triangle inequality $\iff$ f is log subadditive.

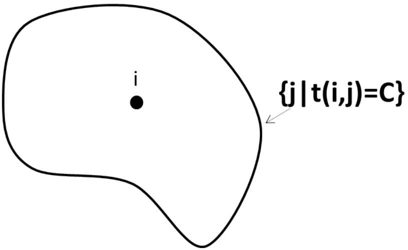
Optimal Path

- Previous equation appears in a number of branches of physics. A necessary condition for its solution is the following *eikonal* equation:

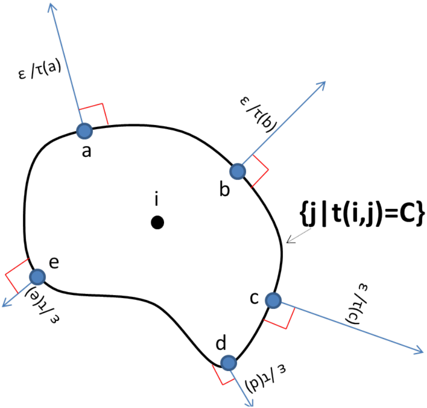
$$||\nabla t\left(i,j\right)|| = \tau\left(j\right)$$

  where the gradient is taken with respect to j.
- Simple geometric interpretation: the trade cost contour expands outward in the direction orthogonal to the contour at a rate inversely proportional to the instantaneous trade cost.

Optimal Path



Optimal Path



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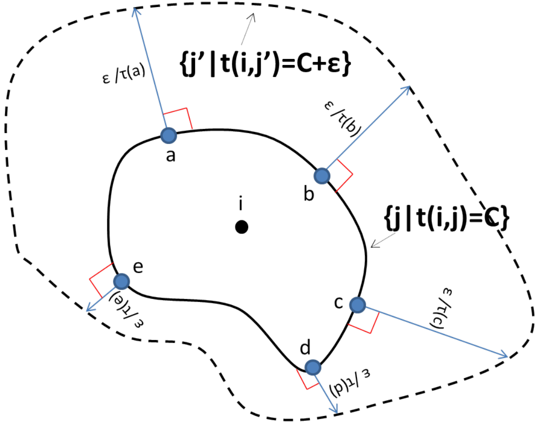

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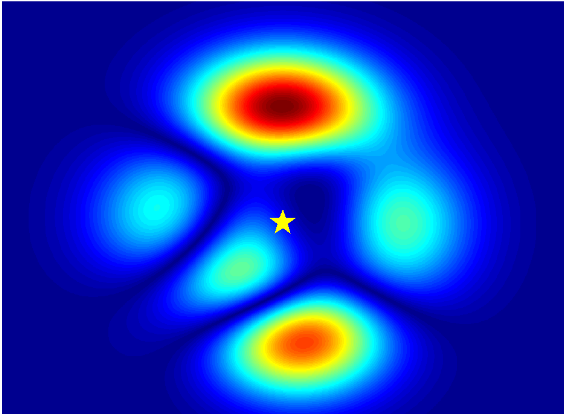

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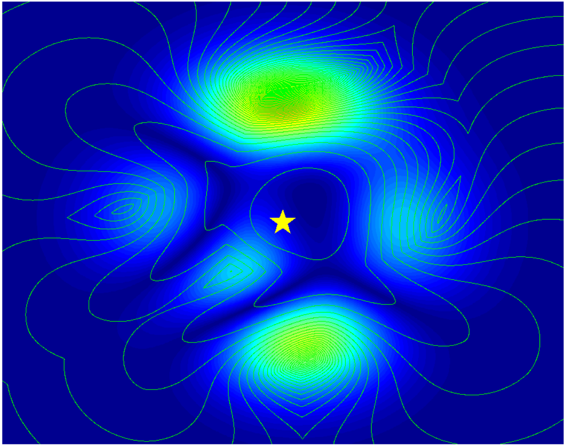

Estimating Trade Costs

- Goal: Find trade costs that best rationalize the bilateral trade flows observed in 2007 Commodity Flow Survey (CFS).
- Three step process:
  - Using **Fast Marching Method** (which operationalizes the Eikonal equation) and observed **transportation network**, calculate the (normalized) distance between every CFS area for each major mode of travel (road, rail, air, and water).
  - Using a **discrete choice** framework and observed **mode-specific bilateral trade shares**, estimate the relative cost of each mode of travel.
  - Using a **gravity** model and observed **total bilateral trade flows**, pin down normalization (and incorporate non-geographic trade costs).

Estimating Trade Costs

- For any $i, j \in S$, suppose $\exists$ traders $t \in T$ choosing mode $m \in \{1, ..., M\}$ of transit where cost is:

$$\exp\left(\tau_m d_m(i,j) + f_m + \nu_{tm}\right)$$

- Then mode-specific bilateral trade shares are:

$$\pi_m(i,j) = \frac{\exp\left(-a_m d_m(i,j) - b_m\right)}{\sum_k \left(\exp\left(-a_k d_k(i,j) - b_k\right)\right)},$$

where $a_m \equiv \theta\tau_m$ and $b_m \equiv \theta f_m$.

- Combined with model, yields gravity equation:

$$\ln X_{ij} = \frac{\sigma - 1}{\theta} \ln \sum_m \left(\exp\left(-a_m d_{mij} - b_m\right)\right) + (1-\sigma)\beta' \ln \mathbf{C}_{ij} + \delta_i + \delta_j$$

- Estimate a_m and b_m using bilateral trade shares, θ using gravity equation.
- Note:
  - No mode switching and assume $f_{road} = 0$ to pin down scale.

Estimating A and u

- Can identify a topography of productivities A and amenities u consistent with the estimated T and observed distribution of economic activity (w and L)
- See Theorem 3 in the paper
- Intuition: consider locations a and b with identical bilateral trade costs, i.e. for all $s \in S$, $T(a,s) = T(b,s)$. Then:
  - Utility equalization implies $\frac{u(b)}{u(a)} = \frac{w(a)}{w(b)}$.
  - Balanced trade implies $\frac{A(a)}{A(b)} = \left(\frac{L(a)w(a)^{\sigma}}{L(b)w(b)^{\sigma}}\right)^{\frac{1}{\sigma-1}}$.
- Note: $\bar{A}$ and $\bar{u}$ cannot be identified without knowledge of α and β.

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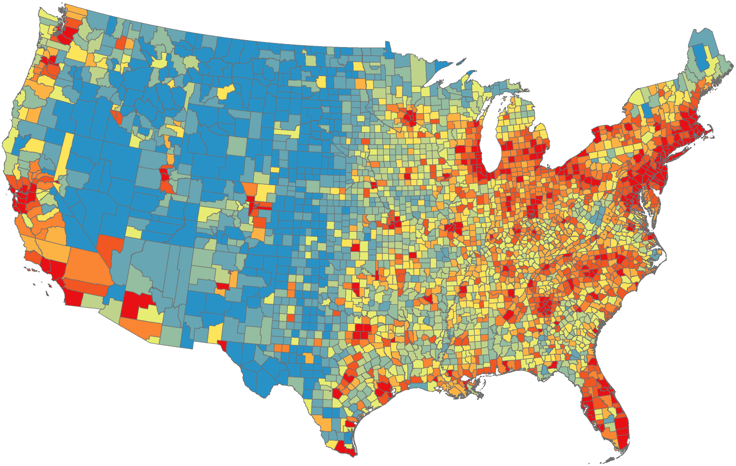
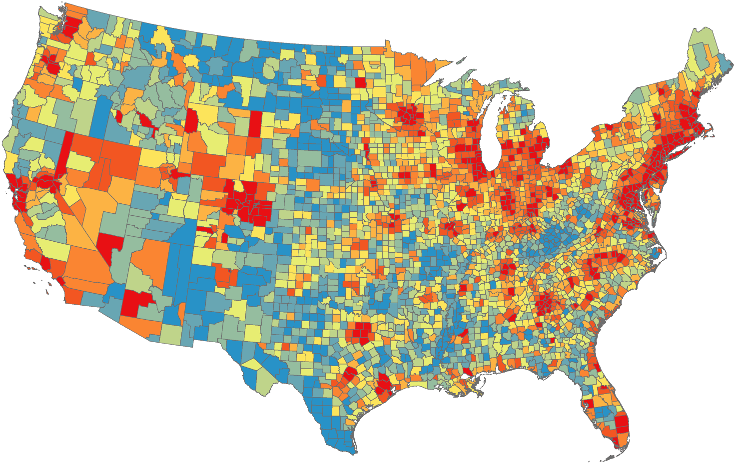
Observed L

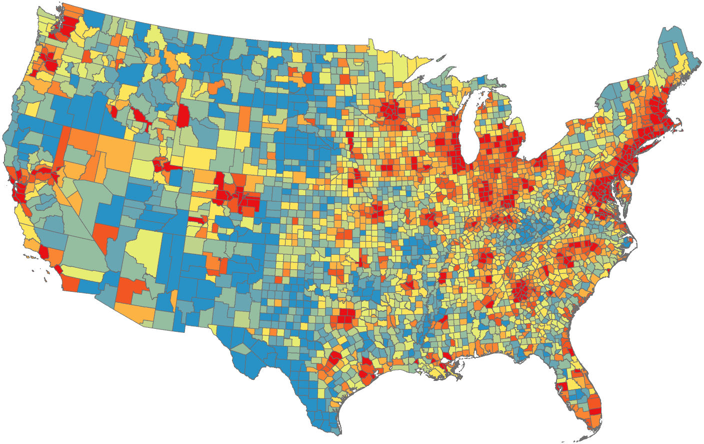


Observed w



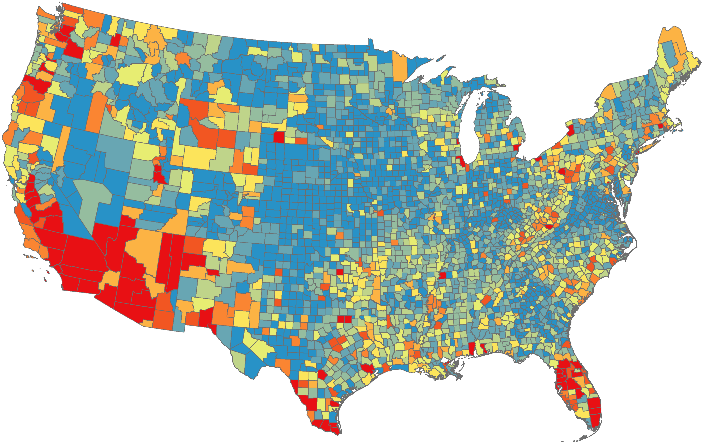
Exogenous A

- $\alpha = 0.1$

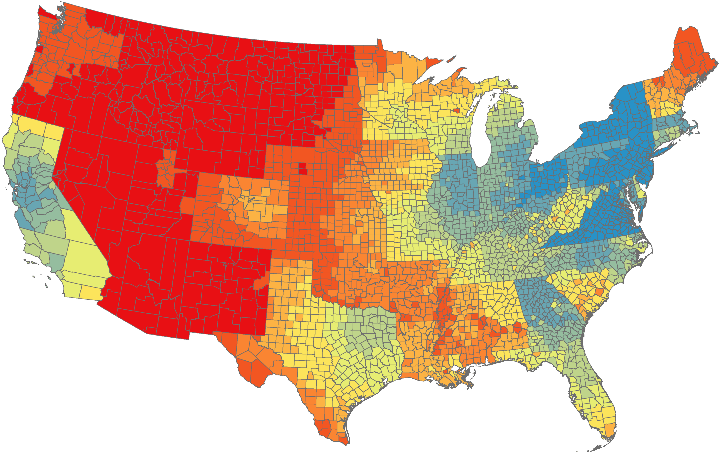


Exogenous u

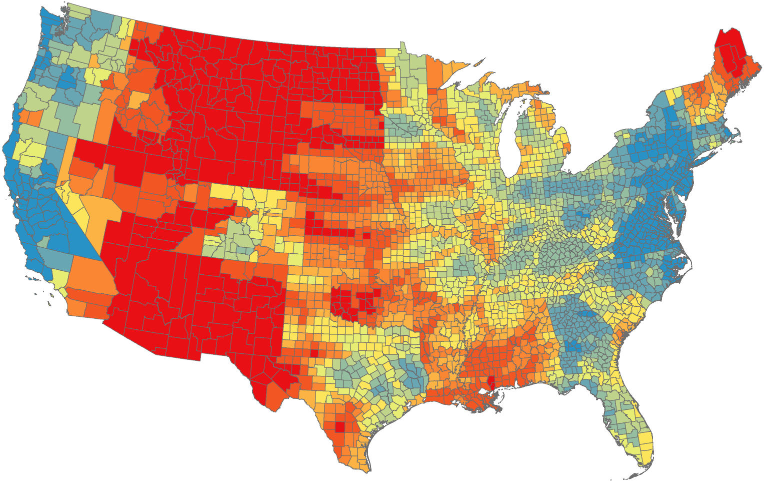
- $\beta = -0.3$



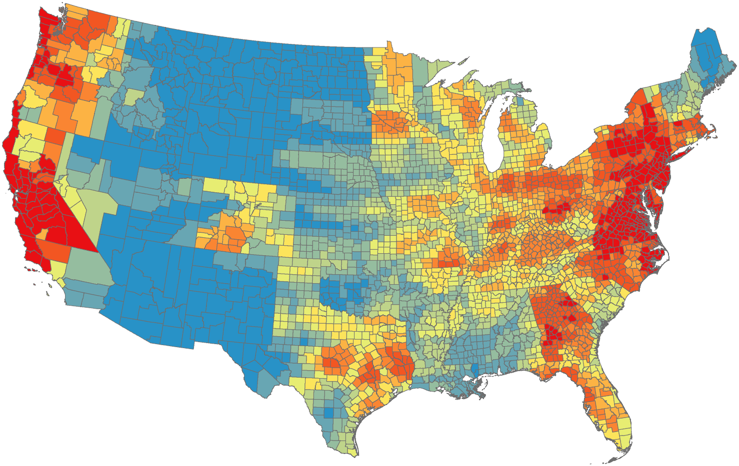
Estimated P



Removing the Interstate Highway System: P



Removing the Interstate Highway System: L



Removing the Interstate Highway System: Costs and Benefits

- Estimated annual cost of the IHS: $\approx$ \$100 billion
- Annualized cost of construction: $\approx$ \$30 billion (\$560 billion @5%/year) (CBO, 1982)
- Maintenance: $\approx$ \$70 billion (FHA, 2008)
- Estimated annual gain of the IHS: $\approx \$150 - 200$ billion
- Welfare gain of IHS: $1.1 - 1.4\%$.
- Given homothetic preferences and holding prices fixed, can multiply welfare gain by U.S. GDP.
- Suggests gains from IHS substantially greater than costs.

Conclusion

- Theoretical contributions
  - Unified GE framework combining gravity, labor mobility, flexible spillovers.
  - Microfoundation of trade costs as "geographic trade costs" .
  - Combine those two and develop appropriate tools to determine equilibrium economic activity on any surface with (nearly) any geography.
- Empirical contributions
  - Calculate bilateral trade costs based on observable geographical features and trade flows.
  - Disentangle productivities and amenities.
  - Quantify the importance of geographic location.
  - Perform counterfactual analysis based on changes in geography.

Caliendo, Parro, Sarte and R-H (2013)

- Fluctuations in aggregate economic activity are the result of a wide variety of disaggregated TFP changes
  - Sectoral: process or product innovations
  - Regional: natural disasters or changes in local regulations
  - Sectoral *and* regional: large corporate bankruptcy or bailout
- What are the mechanisms through which these changes affect the aggregate economy? What is their quantitative importance?
  - Heterogeneity of productivity across sectors and locations, regional trade, local factors, migration, and input-output linkages
  - The geographic component has been mostly ignored
- We model and calibrate these mechanisms for all 50 U.S. states and 26 traded and non-traded industries
- The geography of economic activity, and of TFP changes, is relevant
  - A 10% productivity change in N.Y. increases aggregate GDP by 0.64% while it reduces it by -0.3% if the change is in Florida

Heterogeneity across U.S. states

- Differences in GDP and employment go beyond geographic size
  ▸ GDP by regions ▸ Regional employment
- GDP and Employment levels vary over time differentially across regions
  ▸ GDP change 2002 - 2007 ▸ Employment change 2002 - 2007
- Why?
  Local characteristics are essential to the answer
  - *Differences in TFP*
    Heterogeneity in changes in regional measured TFP
    ▸ Regional TFP ▸ Regional TFP contrib.
    Distribution of sectors across regions is far from uniform
    ▸ Petroleum ▸ Wood ▸ Concentration
    ... and changes in sectoral TFP varies widely across sectors
    ▸ Sectoral TFP ▸ Sectoral TFP contrib.
  - *Differences in local factors*
    ▸ Local Factors
  - *Differences in access to products from other regions*
    ▸ Regional Trade

Literature

- Literature has focused mainly on aggregate shocks as in Kydland and Prescott (1982) and the many papers that followed
- When disaggregated, focus has been on sectors: Long and Plosser (1983), and Horvath (1998, 2000), Foerster, Sarte, and Watson (2012), Acemoglu, et al. (2012), Oberfield (2012)

  ... and sometimes firms: Jovanovic (1987), and Gabaix (2011)
- Some papers have underscored labor mobility: Blanchard and Katz (1992), Fogli, Hill and Perri (2012), Hamilton and Owyang (2012)
- Recent literature on international trade based on Eaton and Kortum (2002) uses static, multi-sector, multi-country quantitative models to assess the gains from international trade
  - We adapt Caliendo and Parro (2012) to introduce labor mobility and local factors
  - Large scale quantitative exercise for 50 states and 26 industries

The Model

- The economy consists of N regions, J sectors, and two factors
  - Labor, L_n^j: mobile across regions and sectors
  - Land and structures, H_n: fixed across region but mobile across sectors
- The problem of an agent in region n is given by

$$v_n \equiv \max_{\left\{c_n^j\right\}_{j=1}^J} \prod_{j=1}^J \left(c_n^j\right)^{\alpha^j} \text{ with } \sum_{j=1}^J \alpha^j = 1$$

$$s.t. \sum_{j=1}^J P_n^j c_n^j = r_n H_n / L_n + w_n \equiv I_n$$

- In equilibrium households are indifferent about living in any region so

$$v_n = I_n / P_n = U \text{ for all } n \in \{1, ..., N\}$$

where $P_n = \prod_{j=1}^J \left(P_n^j / \alpha^j\right)^{\alpha^j}$ is the ideal price index in region n

Model - Intermediate goods

- Representative firms in each region n and sector j produce a continuum of intermediate goods with *idiosyncratic* productivities z_n^j
  - Drawn independently across goods, sectors, and regions from a Fréchet distribution with shape parameter θ^j
  - Productivity of all firms is also determined by a deterministic productivity level T_n^j
- The production function of a variety with z_n^j and T_n^j is given by

$$q_n^j(z_n^j) = z_n^j \left[T_n^j h_n^j(z_n^j)^{\beta_n} l_n^j(z_n^j)^{(1-\beta_n)} \right]^{\gamma_n^j} \prod_{k=1}^{J} M_n^{jk}(z_n^j)^{\gamma_n^{jk}}$$

- Importantly, T_n^j affects value added and not gross output

Model - Intermediate good prices

- The cost of the input bundle needed to produce varieties in (n, j) is

$$x_n^j = B_n^j \left[r_n^{\beta_n} w_n^{1-\beta_n} \right]^{\gamma_n^j} \prod_{k=1}^{J} \left(P_n^k \right)^{\gamma_n^{jk}}$$

- The unit cost of a good of a variety with draw z_n^j in (n, j) is then given by

$$\frac{x_n^j}{z_n^j} \left(T_n^j \right)^{-\gamma_n^j}$$

and so its price under competition is given by

$$p_n^j \left(z^j \right) = \min_i \left\{ \frac{\kappa_{ni}^j x_i^j}{z_i^j} \left(T_i^j \right)^{-\gamma_i^j} \right\},$$

where $\kappa_{ni}^j \geq 1$ are "iceberg" bilateral trade cost

Model - Final goods

- The production of final goods is given by

$$Q_n^j = \left[\int \tilde{q}_n^j (z^j)^{1-1/\eta_n^j} \phi^j \left(z^j \right) dz^j \right]^{\eta_n^j / \left(\eta_n^j - 1 \right)},$$

where $z^j = (z_1^j, z_2^j, ...z_N^j)$ denotes the vector of productivity draws for a given variety received by the different n regions

- The resulting price index in sector j and region n, given our distributional assumptions, is given by

$$P_n^j = \xi_n^j \left[\sum_{i=1}^{N} \left[x_i^j \kappa_{ni}^j \right]^{-\theta^j} \left(T_i^j \right)^{\theta^j \gamma_i^j} \right]^{-1/\theta^j},$$

where ξ_n^j is a constant

Migration

- Labor market clearing

$$\sum_n \sum_{j=1}^{J} \int_0^\infty l_n^j(z)\phi_n^j(z)\,dz = \sum_n L_n = L$$

... plus firm optimization

$$w_n L_n = \frac{1-\beta_n}{\beta_n} r_n H_n$$

- Implies that

$$L_n = \frac{H_n \left[\frac{\omega_n}{P_n U}\right]^{1/\beta_n}}{\sum_{i=1}^{N} H_i \left[\frac{\omega_i}{P_i U}\right]^{1/\beta_i}} L$$

where $\omega_n \equiv (r_n/\beta_n)^{\beta_n} (w_n/(1-\beta_n))^{(1-\beta_n)}$

Regional trade

- Total expenditure on final good j in region n

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{kj} \sum_i \pi_{in}^k X_i^k + \alpha^j I_n L_n,$$

where π_{ni}^j denote the share of region n's total expenditures on sector j's intermediate goods purchased from region i

- Then, as in Eaton and Kortum (2002),

$$\pi_{ni}^j = \frac{X_{ni}^j}{X_n^j} = \frac{\left[x_i^j \kappa_{ni}^j\right]^{-\theta^j} \left(T_i^j\right)^{\theta^j \gamma_i^j}}{\sum_{i'=1}^{N} \left[x_{i'}^j \kappa_{ni'}^j\right]^{-\theta^j} \left(T_{i'}^j\right)^{\theta^j \gamma_{i'}^j}}$$

- We impose balanced trade

Changes in measured TFP

- Using firm optimization and aggregating over all produced intermediate goods, total gross output in (n, j) is given by

$$\frac{Y_n^j}{P_n^j} = \frac{x_n^j}{P_n^j}\left[\left(H_n^j\right)^{\beta_n}\left(L_n^j\right)^{(1-\beta_n)}\right]^{\gamma_n^j}\prod_{k=1}^{J}\left(M_n^{jk}\right)^{\gamma_n^{jk}}$$

  - $Y_n^j / P_n^j = Q_n^j$ when j is a non-tradable good
- So the change in measured TFP as a result of $\hat{T}_n^j$ is

$$\ln \hat{A}_n^j = \ln \frac{\widehat{x}_n^j}{\hat{P}_n^j} = \ln \frac{\left(\hat{T}_n^j\right)^{\gamma_n^j}}{\left(\hat{\pi}_{nn}^j\right)^{1/\theta^j}}$$

- Aggregate measured TFP changes using gross output revenue shares
  - Leads to aggregate TFP measures similar to those of the OECD

GDP

- The Cobb-Douglas production function in intermediates implies that

$$\ln \widehat{GDP}_n^j = \ln \frac{\hat{w}_n \hat{L}_n^j}{\hat{P}_n^j}$$
$$= \ln \hat{A}_n^j + \ln \hat{L}_n^j + \ln \left(\frac{\hat{w}_n}{\widehat{x}_n^j} \right)$$

  - In the case without materials, the last term is simply

$$\ln \left(\hat{w}_n / \widehat{x}_n^j \right) = \beta_n \ln \left(\hat{w}_n / \widehat{r}_n \right) = \beta_n \ln 1 / \hat{L}_n$$

    ... otherwise, a function of all final-good price changes

- We aggregate real GDP changes using value added shares

Welfare

- Welfare changes are given by

$$\ln \hat{U} = \sum_{j=1}^{J} \alpha^j \left(\ln \widehat{GDP}_n^j - \ln \hat{L}_n^j \right) = \sum_{j=1}^{J} \alpha^j \left(\ln \hat{A}_n^j + \ln \frac{\hat{w}_n}{\widehat{x}_n^j} \right)$$

- Arkolakis, Costinot and Rodriguez-Clare (2012) emphasize the case with one sector and no factor mobility where $\ln \hat{U}_n = \ln \hat{A}_n$

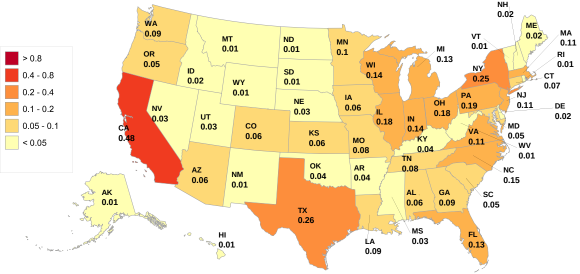
Counterfactuals

- We need to calibrate and compute the model to assess the aggregate effect of regional shocks
  - We only compute the model in changes as a result of $\hat{T}_n^j$, parallel to Dekle, Eaton and Kortum (2008)
  - Abstract from wealth effects and the implied heterogeneity that results from productivity changes
  - System of $2N + 3JN + JN^2 = 69000$ equations and unknowns
- Some issues:
  - Regional trade imbalances: Calibrate to 2007 imbalances, but use counterfactual without deficits to compute the effect of $\hat{T}_n^j$
  - No international trade: CFS provides data of expenditures on domestically produced goods

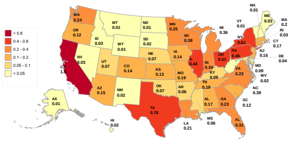
Data

- We need to find data for $I_n, L_n^j, S_n, \pi_{ni}^j$ as well as values for the parameters $\theta^j, \alpha^j, \beta_n, \gamma_n^{jk}$
  - L_n^j : BEA, with aggregate employment across all states summing to 137.3 million in 2007
  - I_n : Total value added in each state in 2007
  - π_{ni}^j and S_n : CFS with total trade equal to 5.2 trillion in 2007
  - θ^j : We use the numbers in Caliendo and Parro (2012)
  - α^j : Calculated as the aggregate share of consumption
  - β_n : Labor share by region adjusted by $\beta_n = (\bar{\beta}_n - .17)/.83$
    - ⋆ Share of equipment equal to .17 Greenwood, Hercowitz and Krusell (1997), which we group with materials
  - γ_n^{jk} : Get γ_n^j from BEA value added shares and use national IO table to compute $\gamma_n^{jk} = (1 - \gamma_n^j)\gamma^{jk}$

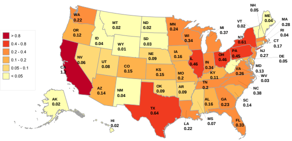
Aggregate impact of 10% local change: TFP



NRNS Model



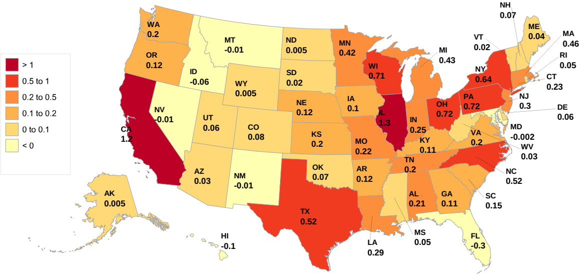
RNS Model



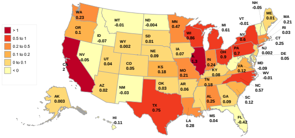
$$\ln \hat{A}_n^j = \ln \frac{\left(\hat{T}_n^j\right)^{\gamma_n^j}}{\left(\hat{\pi}_{nn}^j\right)^{1/\theta^j}}$$

▸ Zoom

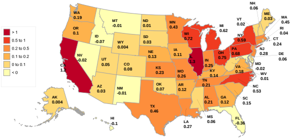
Aggregate impact of 10% local change: Real GDP



NRNS Model



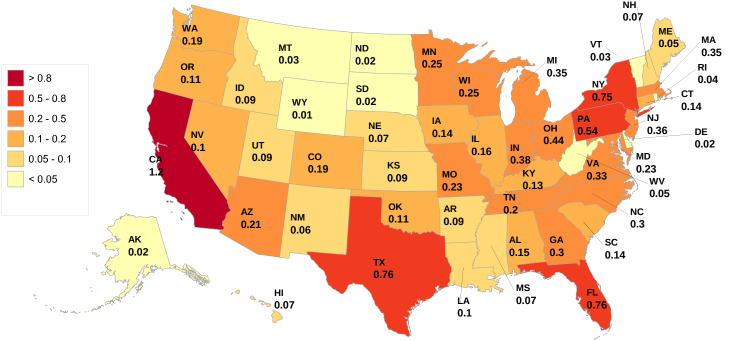
RNS Model



$$\ln \widehat{GDP}_n^j = \ln \hat{A}_n^j + \ln \hat{L}_n^j + \ln\left(\frac{\hat{w}_n}{\hat{x}_n^j}\right)$$

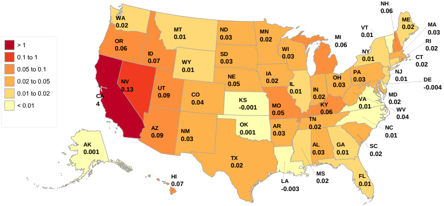
Local Factors Zoom

Aggregate impact of 10% local change: Welfare

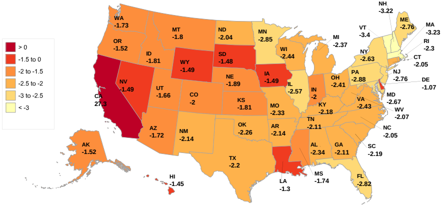


Regional impact of 10% change in California

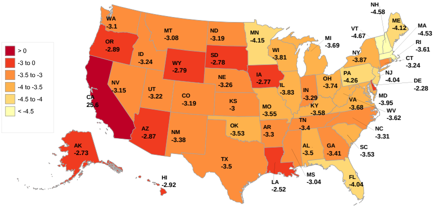
Change in TFP (%)



Change in GDP (%)

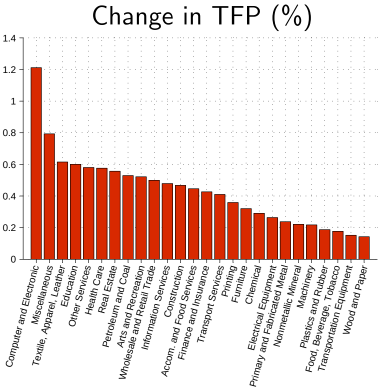


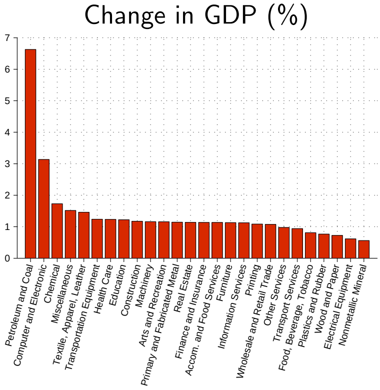
Change in Employment (%)



Zoom

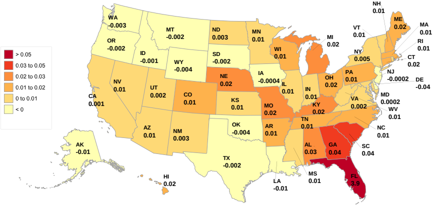
Sectoral impact of 10% change in California



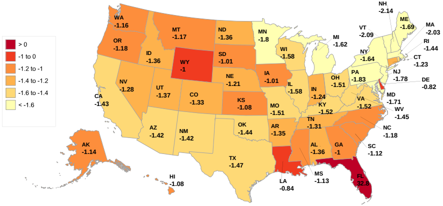


Regional impact of 10% change in Florida

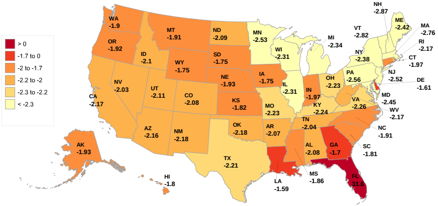
Change in TFP (%)



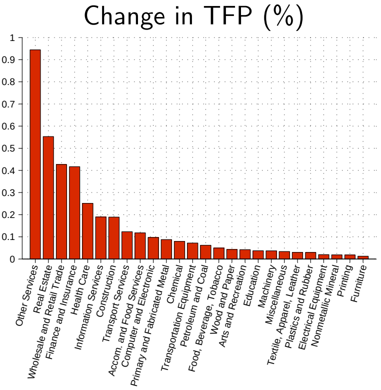
Change in GDP (%)

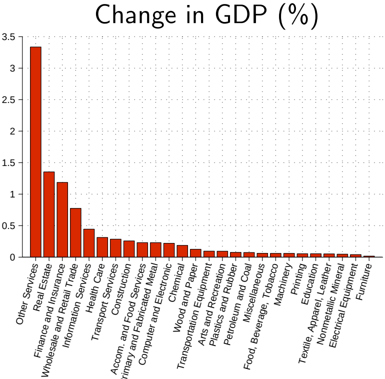


Change in Employment (%)



Aggregate impact of 10% sectoral change

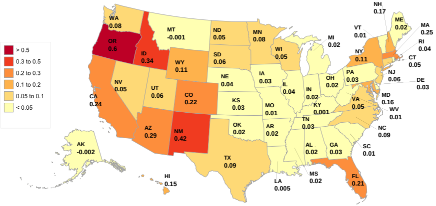




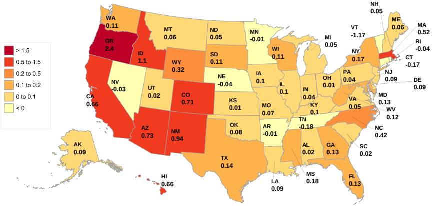
Regional impact of 10% change in Computers & Elec.

- Elasticity of aggregate GDP to change is 0.94

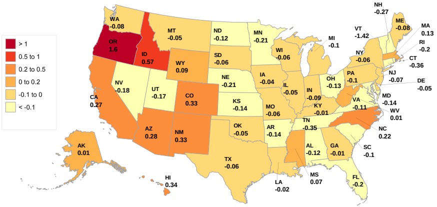
Change in TFP (%)



Change in GDP (%)



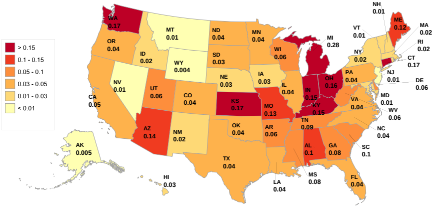
Change in Employment (%)



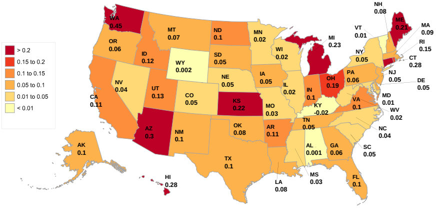
Regional impact of 10% change in Transportation Eq.

- Elasticity of aggregate GDP to change is 0.52

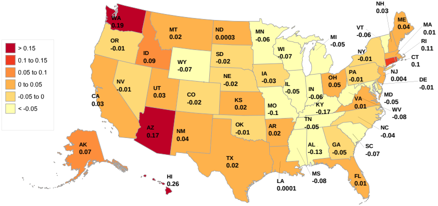
Change in TFP (%)



Change in GDP (%)



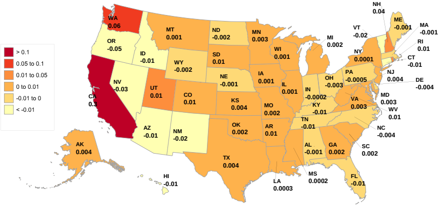
Change in Employment (%)



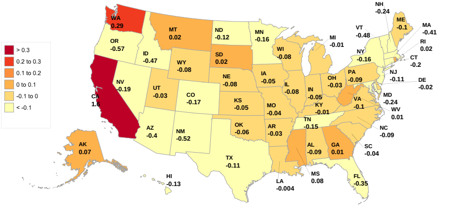
Regional impact of 10% change to C & E in California

- Value added industry share in California is 5.5%

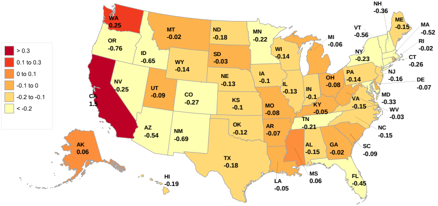
Change in TFP (%)



Change in GDP (%)



Change in Employment (%)



Trade costs

- The exercises above suggest that trade is important in determining the effect of productivity changes
  - But how important are regional trade barriers?
  - What portion of trade barriers is explained by physical distance?
    - ⋆ Compute average miles per shipment for each region from CFS (996 for Indiana but 4154 for Hawaii)
  - What are the gains (TFP, GDP, welfare) from reducing distance versus other trade barriers?
- Following Head and Ries (2001) we can compute

$$\frac{\pi^j_{ni}\pi^j_{in}}{\pi^j_{ii}\pi^j_{nn}} = \left(\kappa^j_{ni}\kappa^j_{in}\right)^{-\theta^j}$$

- So given θ^j, and assuming symmetry, we can identify κ^j_{ni}

Counterfactuals

- Decompose trade barrier using

$$\log \kappa_{ni}^{j} = \delta^{j} \log d_{ni}^{j} / d_{ni}^{j\,\min} + \eta_{n} + \varepsilon_{ni}^{j}$$

- Then calculate counterfactuals:

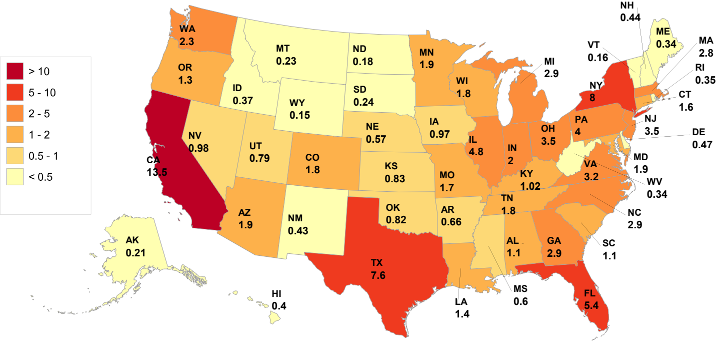
Effects of a reduction in trade cost across U.S. states		
	Distance	Other barriers
Aggregate TFP gains	50.64%	3.64%
Aggregate Welfare gains	59.50%	9.65%
Aggregate GDP gains	124.75%	10.81%

Conclusions

- Study the effects of disaggregated productivity changes in a model that recognizes explicitly the role of geographical factors
  - Calibrate for 50 U.S. states and 26 sectors
  - Ready to implement in other countries or regions
- Disaggregated productivity changes can have dramatically different aggregate quantitative implications
  - Regional productivity increases can lead to declines in aggregate GDP
  - Sectoral productivity increases almost always have positive effects
    - ⋆ But very heterogenous regional impact
- For future work:
  - Identification of productivity changes and decomposition
  - Local factor accumulation
  - Regional trade imbalances

Economic activity in the U.S.

Share of GDP by region (%, 2007)



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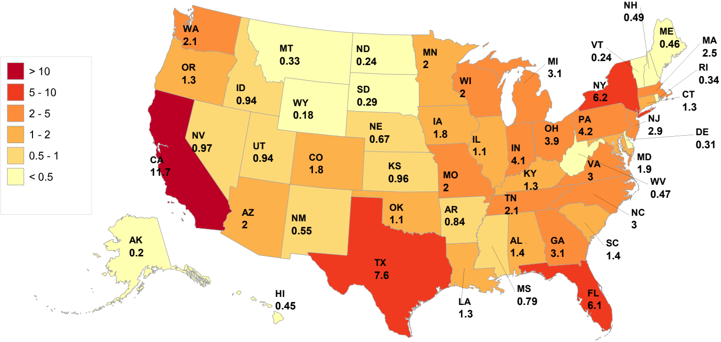
Economic activity in the U.S.

Share of Employment by region (%, 2007)



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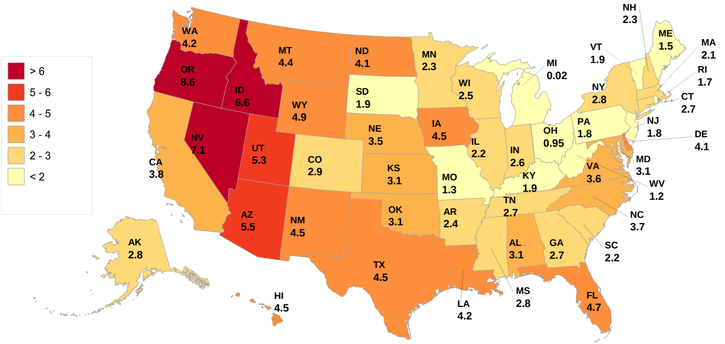
Economic activity in the U.S.

Change in GDP (%, 2002 to 2007)



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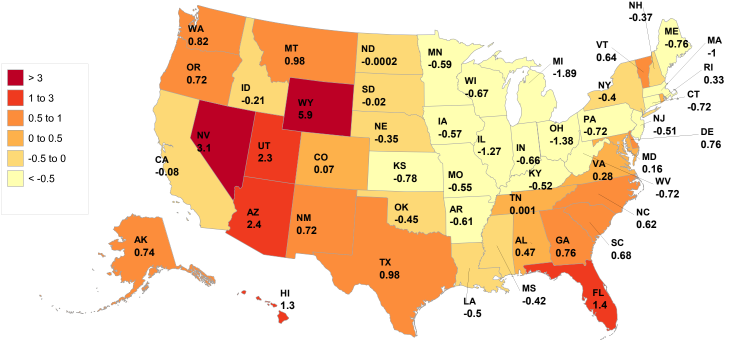
Economic activity in the U.S.

Change in Employment (%, 2002 to 2007)



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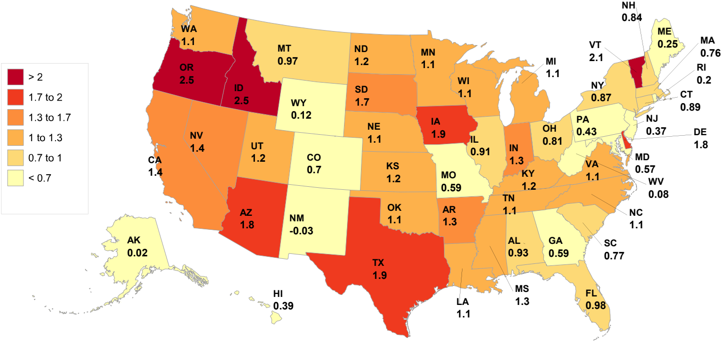
Change in measured TFP by region

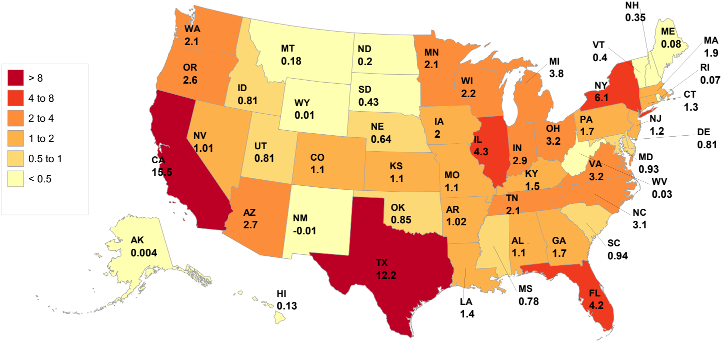
Annualized rate (2002-2007, %)



▸ Back Intro

Regional contribution

Regional contribution to the change in aggregate measured TFP (%)



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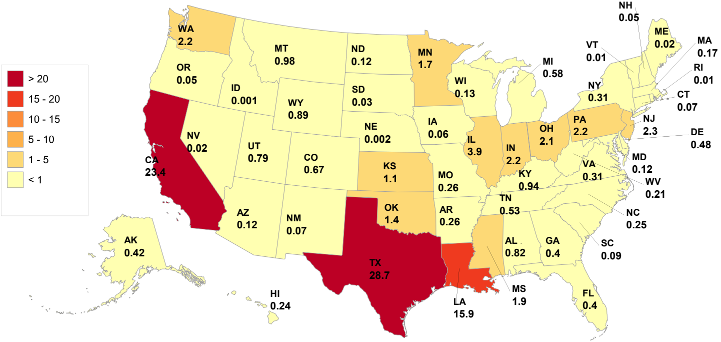
Economic activity in the U.S.

Petroleum and Coal concentration across regions (%, 2007)



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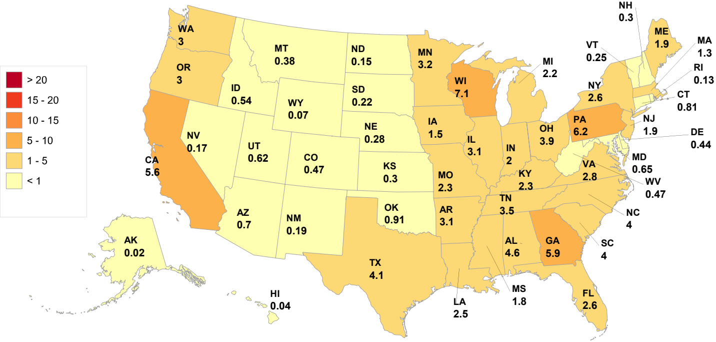
Economic activity in the U.S.

Wood and Paper concentration across regions (%, 2007)



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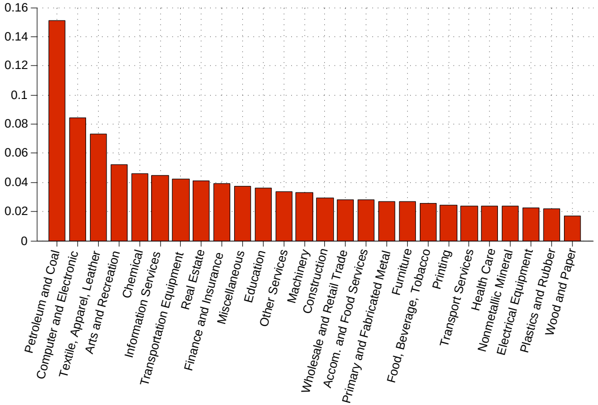
Regional concentration of economic activity across sectors

Herfindahl Index, 2007



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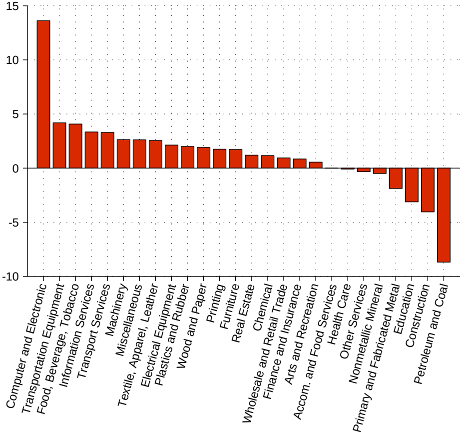
Change in sectoral measured TFP

Annualized rate (2002-2007, %)



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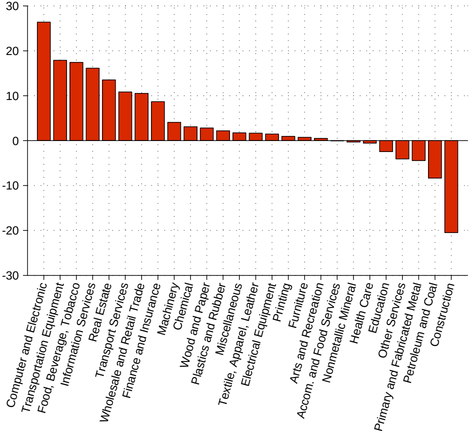
Sectoral contribution

Sectoral contribution to the change in aggregate measured TFP (%)



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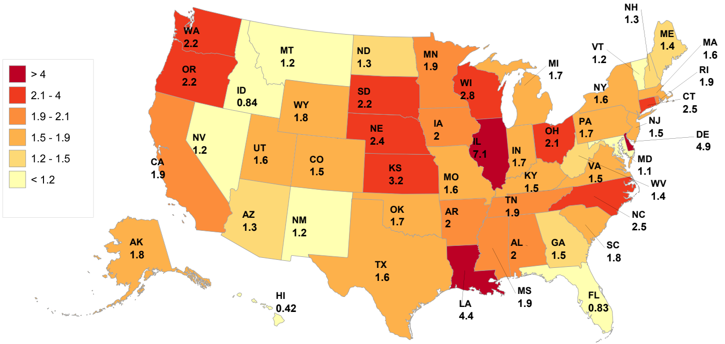
Per capita income from local factors

- Use $I_n = r_n H_n + w_n L_n$



Back Intro | Counterfactuals GDP

Regional Trade

- Regional trade much more important than international trade

U.S. trade as a share of GDP (%, 2007)			
	Exports	Imports	Total
International trade	11.9	17.0	28.9
Inter-regional trade	33.4	33.4	66.8

Source: World Development indicators and CFS

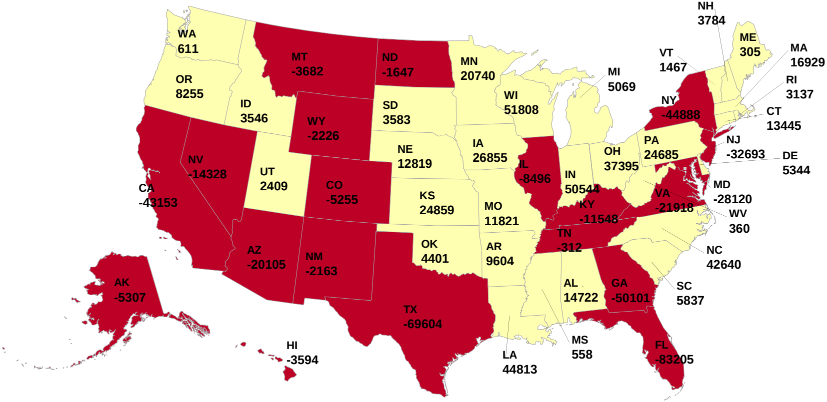
▸ Regional trade

- Still, calibrated trade costs are such that eliminating distance increases GDP by 125% and measured TFP by 50%
  - So geography of production determines prices and trade flows

▸ Back

Economic activity by regions

Net exports (exports - imports) across U.S. states (2007)



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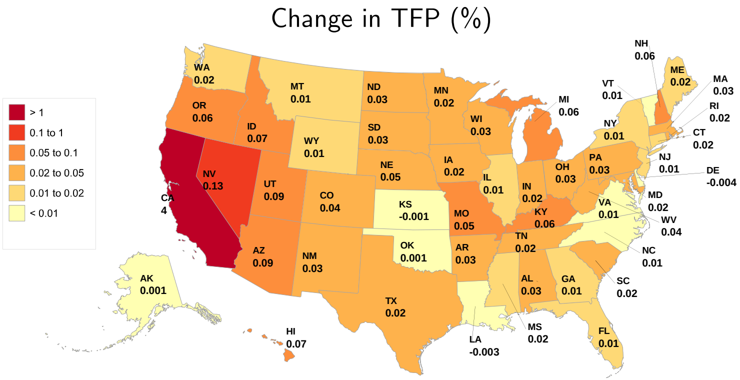
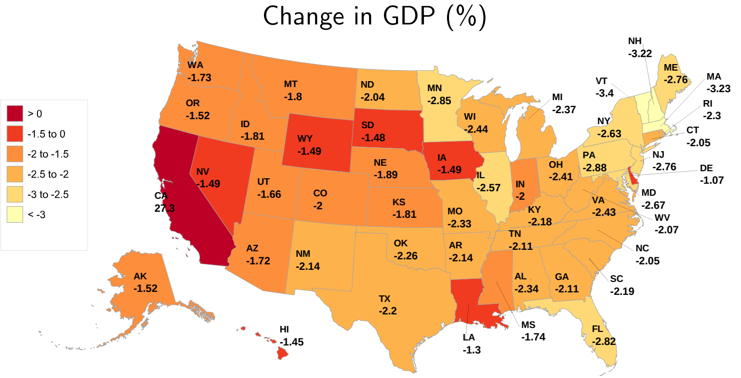
Regional impact of 10% change in California

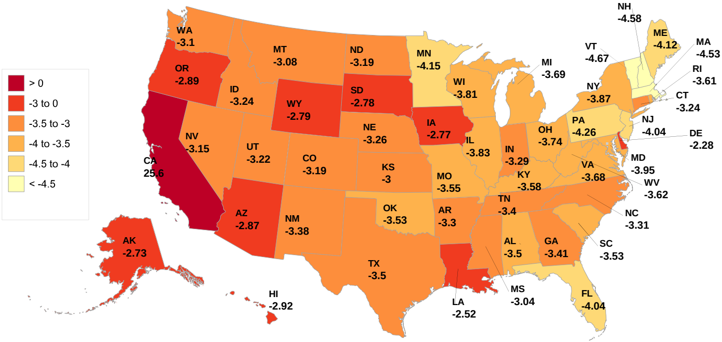


Regional impact of 10% change in California



Regional impact of 10% change in California

Change in Employment (%)



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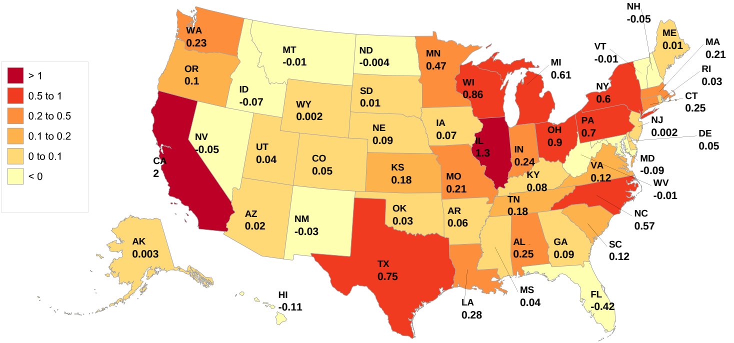
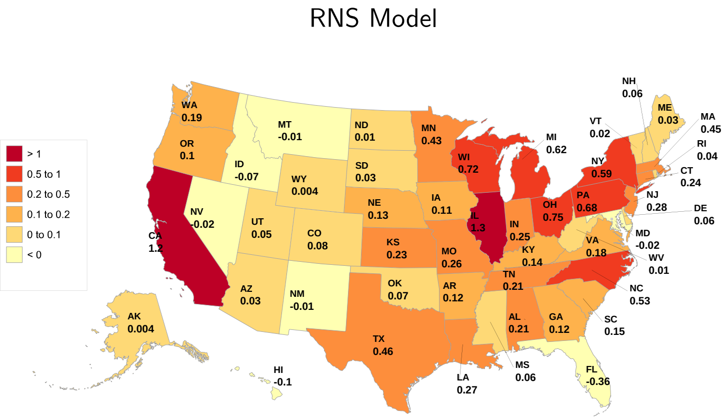
Aggregate impact of 10% local change: Real GDP

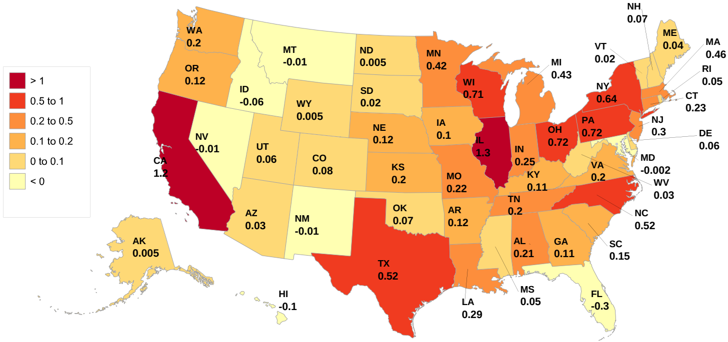
NRNS Model



Aggregate impact of 10% local change: Real GDP



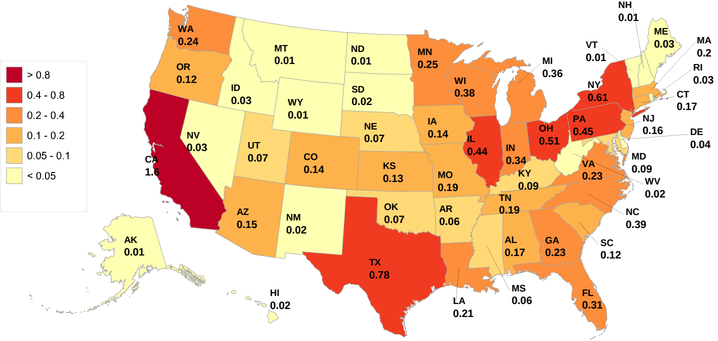
Aggregate impact of 10% local change: Real GDP



▸ Counterfactuals GDP

Aggregate impact of 10% local change: TFP

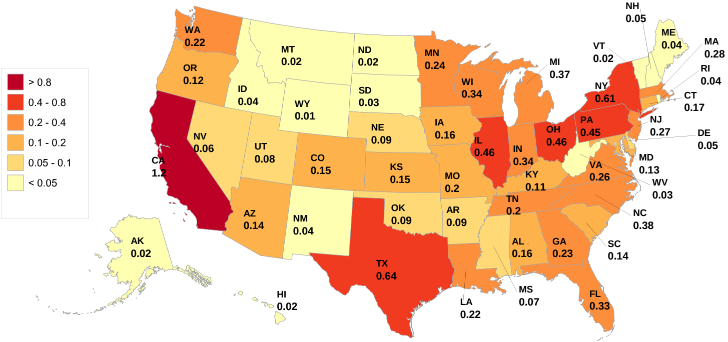
Model with no inter-regional trade and no inter-sectoral trade, NRNS
Then $\ln \hat{A}_n^j = \ln \hat{T}_n^j$



Aggregate impact of 10% local change: TFP

Model with inter-regional trade and no inter-sectoral trade, RNS

Then $\ln \hat{A}_n^j = \dfrac{\hat{T}_n^j}{\left(\hat{\pi}_{nn}^j\right)^{1/\theta^j}}$



Back

Desmet and R-H (2014)

- Economic growth and development vary widely across space.
- But no *dynamic spatial theory* has emerged: Why?
  - Dimensionality makes the problem intractable
  - Some attempts with 2 or 3 locations or without space: hard to link to data
- We construct a two-sector growth model with spatial micro-foundations. Model captures main
  - Macro stylized facts: structural transformation, aggregate growth,...
  - Spatial stylized facts: co-location, increased dispersion in land rents, increased concentration of services,...

Main Components

1. Firms in a continuum of locations can produce in two industries, manufacturing and services, using land and labor
   - CRS technology, so given land, firm faces decreasing returns: *congestion force*
2. Costly trade in goods and services and free labor mobility: *specialization and agglomeration*
   - National labor, goods and services markets, but wages and relative goods prices depend on location
3. Firms invest in innovation: *endogenous growth*
   - Firms buy probability to improve their technology
   - Leads to *local scale effect* in innovation
4. Technology diffuses spatially: *agglomeration and growth*

The Literature

- Endogenous growth with two or more countries: Grossman and Helpman (1991), Young (1991) and Eaton and Kortum (1999)
  - Locations not ordered in space
- A few papers in the "New Economic Geography" tradition, but few general insights and no space
- Quah (2002), Boucekkine et. al. (2009), and Brock and Xepapadeas (2008a) study general spatial dynamic problems
  - Includes either diffusion or capital mobility with immobile but fully forward looking agents
  - 'Ill-posed' problems so cannot be fully analyzed apart from special cases
- Endogenize innovation, and growth, relative to Desmet and Rossi-Hansberg (2009)
  - Endogenous start of technology innovations in a sector: structural transformation

The Model

- The economy consists of land and people located in the closed interval $[0, 1]$
- Density of land at each location ℓ equal to one
- Population size is $\overline{L}$
- Each agent is endowed with one unit of time each period
- Each agent owns a diversified portfolio of land and firms
- Agents are infinitely lived and have rational expectations

Preferences and Consumer's Problem

- Agents live where they work and they derive utility from the consumption of two goods: manufactures and services
- Labor is freely mobile so all agents obtain utility $\bar{u}_t$ each period
- Agents supply their unit of time inelastically in the labor market
- The problem of an agent at a particular location ℓ is given by

$$\max_{\{c_i(\ell,t)\}_0^\infty} E \sum_{t=0}^{\infty} \beta U(c_M(\ell,t), c_S(\ell,t)) \qquad \text{s.t.}$$

$$w(\ell,t) + \frac{\bar{R}(t) + \Pi(t)}{\bar{L}} = p_M(\ell,t)\, c_M(\ell,t) + p_S(\ell,t)\, c_S(\ell,t)$$

- Numerical examples in the next section use CES

$$U(c_M, c_S) = (h_M c_M^\alpha + h_S c_S^\alpha)^{1/\alpha} \text{ with } 1/(1-\alpha) < 1$$

Technology

- Firms specialize in one sector and use labor and one unit of land
- Production of a firm is given by

$$M\left(L_M\left(\ell,t\right)\right) = Z_M^{+}\left(\ell,t\right)L_M\left(\ell,t\right)^{\mu}$$

$$S\left(L_S\left(\ell,t\right)\right) = Z_S^{+}\left(\ell,t\right)L_S\left(\ell,t\right)^{\sigma}$$

Diffusion

- Technology diffuses locally between time periods
- If $Z_i^+(r, t-1)$ was used at r in $t-1$, next period t location ℓ has access to

$$e^{-\delta|\ell-r|} Z_i^+(r, t-1)$$

- Hence, before the innovation decision, location ℓ's technology is

$$Z_i^-(\ell, t) = \max_{r \in [0,1]} e^{-\delta|\ell-r|} Z_i^+(r, t-1)$$

which of course includes its own technology

Idea Generation

- A firm can decide to buy a probability $\phi \leq 1$ of innovating at cost $\psi(\phi)$ in a particular industry i
- An innovation is a draw of a technology multiplier z_i from

$$\Pr\left[z < z_i\right] = \left(\frac{1}{z}\right)^a$$

- Conditional on innovation and technology Z_i, the expected technology is

$$E\left(Z_i^+(\ell, t) \,|Z_i^-, Innovation\right) = \frac{a}{a-1} Z_i^- \text{ for } a > 1$$

- Expected technology for a given ϕ, not conditional on innovating, is

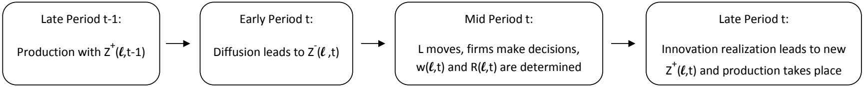
$$E\left(Z_i^+(\ell, t) \,|Z_i^-\right) = \left(\frac{\phi + a - 1}{a-1}\right) Z_i^-$$

Spatial Correlation

- The innovation draws are i.i.d. across time, but not across space
- Conditional on an innovation, let $s(\ell, \ell')$ denotes the correlation in the realizations of $z_i(\ell)$ and $z_i(\ell')$
- We assume that $s(\ell, \ell')$ is non-negative, continuous, symmetric, and

$$\lim_{\ell \downarrow \ell'} s\left(\ell, \ell'\right) = 1 \text{ and/or } \lim_{\ell \uparrow \ell'} s\left(\ell, \ell'\right) = 1$$

Timing


Late Period t-1:
Production with Z+(ℓ,t-1)
Early Period t:
Diffusion leads to Z-(ℓ ,t)
Mid Period t:
L moves, firms make decisions, w(ℓ,t) and R(ℓ,t) are determined
Late Period t:
Innovation realization leads to new Z+(ℓ,t) and production takes place

Firm's Problem

- Firms maximize the expected present value of profits:

$$\max_{\{\phi_i(\ell,t),L_i(\ell,t)\}_{t_0}^{\infty}} E_{t_0}\left[\sum_{t=t_0}^{\infty}\beta^{t-t_0}\left(\begin{array}{c} p_i(\ell,t)\left(\left(\frac{\phi_i(\ell,t)}{a-1}+1\right)Z_i^-(\ell,t)\right)^{\gamma}L_i(\ell,t)^{\mu_i} \\ -w(\ell,t)\,L_i(\ell,t)-R(\ell,t)-\psi(\phi_i(\ell,t)) \end{array}\right)\right]$$

- Free mobility, competition and diffusion imply that the problem of choosing L and R is static
- Hence, the number of workers and land rents solve

$$R_i(\ell,t)=p_i(\ell,t)\left(\frac{\hat{\phi}_i(\ell,t)}{a-1}+1\right)^{\gamma}Z_i^-(\ell,t)^{\gamma}\,\hat{L}_i(\ell,t)^{\mu_i}$$
$$-w(\ell,t)\,\hat{L}_i(\ell,t)-\psi\left(\hat{\phi}_i(\ell,t)\right)$$

so ex-ante one-period profits are zero.

Innovation

Proposition 1:

A firm's optimal dynamic innovation decisions maximize current period profits

- Keys to Proof:
  - Ex-ante profits are zero every period after paying for optimal innovation
  - Diffusion of technology and spatial correlation imply continuous innovation decisions
- So firms solve

$$\max_{\phi_i} p_i(\ell,t)\left(\frac{\phi_i + a - 1}{a-1} Z_i^-(\ell,t)\right)^{\gamma} \hat{L}_i(\ell,t)^{\mu_i} - w(\ell,t)\,\hat{L}_i(\ell,t) - R(\ell,t) - \psi(\phi_i)$$

Innovation

- Note the scale effect in the innovation decision
  - Benefits of innovation depend on actual scale of production
- Firms innovate in a competitive framework with zero profits since:
  - No fixed costs of innovation
  - Land is a factor in fixed supply at each location
- In the numerical exercise we let $\psi\left(\phi; w(\ell, t)\right) = w(\ell, t)\left(\psi_1 + \psi_2 \frac{1}{1-\phi}\right)$ where ψ_1 and ψ_2 are proportional to wages

Transport costs and Land Markets

- Goods are costly to transport.
- Iceberg transport costs: If one unit of any of the goods is transported from ℓ to r, only $e^{-\kappa|\ell-r|}$ units of the good arrive in r
  - The equilibrium depends only on the sum of transport costs
- The price of good i produced in ℓ and consumed in r has to satisfy

$$p_i(r,t) = e^{\kappa|\ell-r|} p_i(\ell,t)$$

- Land is assigned to its highest value. Hence, land rents are such that

$$R(\ell,t) = \max\{R_M(\ell,t), R_S(\ell,t)\}$$

- Denote by $\theta_i(\ell) \in \{0,1\}$ the fraction of land at location ℓ used in the production of good i

Goods and Services Markets

- To write the equilibrium condition in product markets, we need to consider transport costs
- Let $H_i(\ell, t)$ denote the stock of excess supply of product i between locations 0 and ℓ
- Define $H_i(\ell, t)$ by $H_i(0, t) = 0$ and by the differential equation

$$\frac{\partial H_i(\ell, t)}{\partial \ell} = \theta_i(\ell, t)\, x_i(\ell, t) - \hat{c}_i(\ell, t) \sum_i \theta_i(\ell, t)\, \hat{L}_i(\ell, t) - \kappa \left| H_i(\ell, t) \right|$$

  where $x_i(\ell, t)$ denotes production in industry i per unit of land net of real investment costs
- Equilibrium in products markets is guaranteed by $H_i(1, t) = 0$ for all i

Labor Markets

- There is a national labor market and no mobility costs so

$$\int_0^1 \sum_i \theta_i(\ell, t)\, \hat{L}_i(\ell, t)\, d\ell = \overline{L} \text{ all } t$$

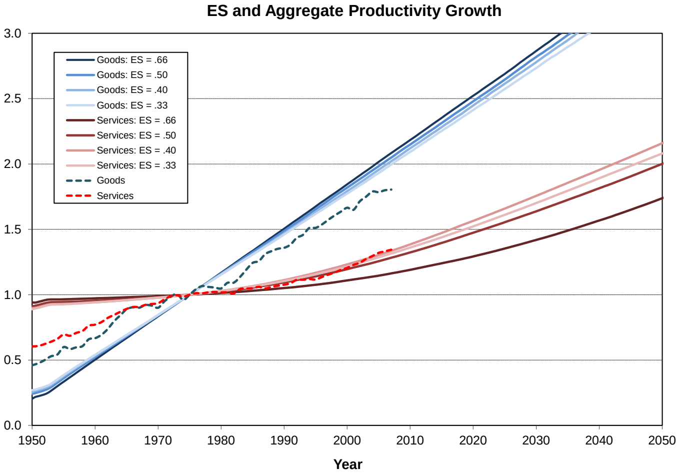
- An equilibrium in this economy is a set of real functions $(\hat{c}_i, \hat{L}_i, \theta_i, H_i, p_i, R_i, w, Z_i^-, Z_i^+, \phi_i)$ of locations $\ell \in [0, 1]$ and time $t = 1, ...,$ for $i \in \{M, S\}$

- Next step, use the model to understand the evolution of the US economy over the last few decades

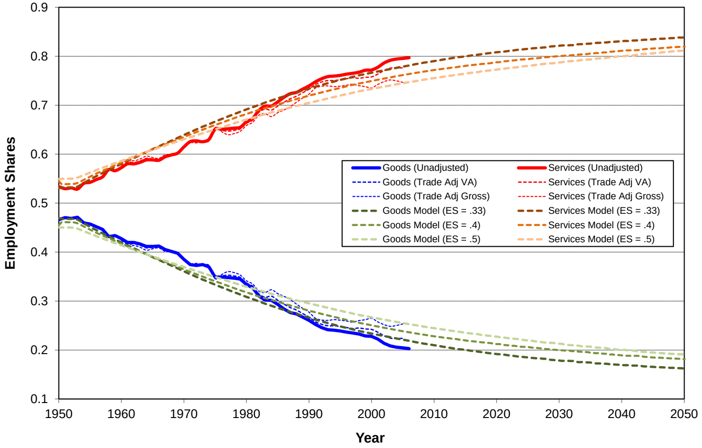
Calibration

- Need initial productivity functions: $Z_S(\ell, 0) = 1$ and $Z_M(\ell, 0) = 0.8 + 0.4\ell$
- Important to use elasticity of substitution smaller than 1
  - Following Stockman and Tesar (1995) we use $\alpha = -1.5$ so $ES = 1/\left(1 - \alpha\right) = 0.4$
  - Similar to Ngai and Pissarides (2007) before service productivity growth begins
- Follow Herrendorf and Valentiniyi (2008) and let $\mu = \sigma = 0.6$
- To capture the initially larger share of employment in services, we let $h_S = 1.4 > h_M = .6$
- To capture the change in employment shares we set the diffusion parameter $\delta = 25$
- We set transport $\kappa = 0.08$ from Ramondo and Rodríguez-Clare (2013)
- Choose ψ_2 and ψ_1 and a to match productivity growth in both industries

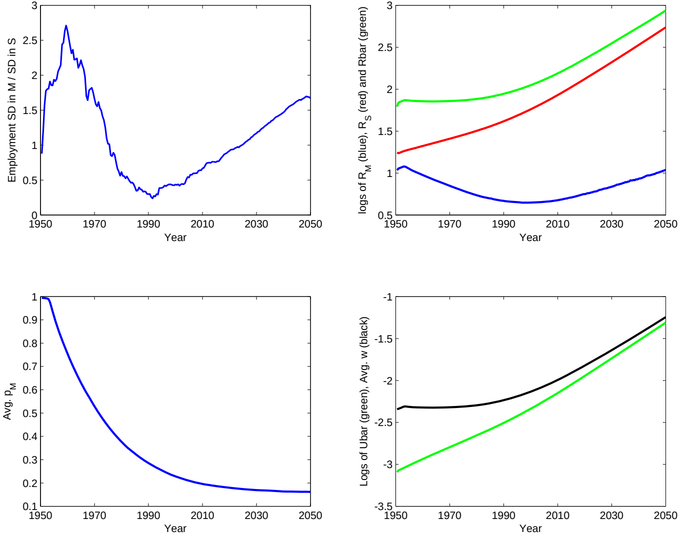
Aggregate Productivity



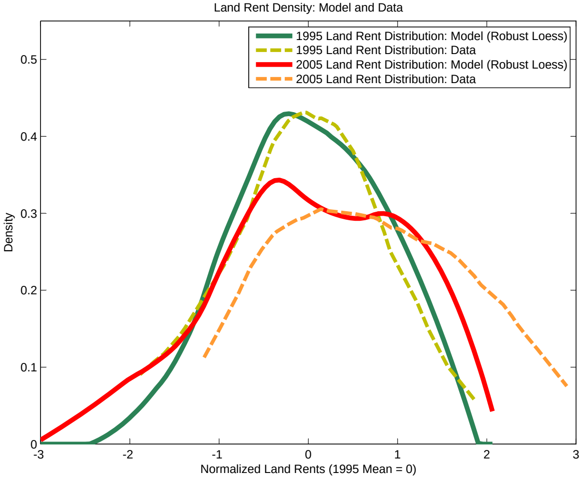
Employment Shares



Other Outcomes

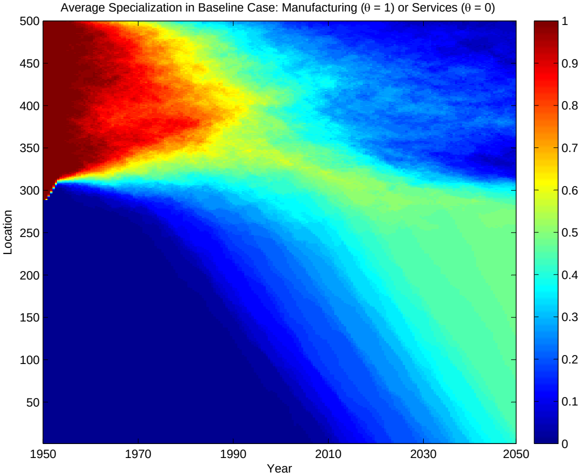


Land Rents



Land Rent Density: Model and Data
1995 Land Rent Distribution: Model (Robust Loess)
1995 Land Rent Distribution: Data
2005 Land Rent Distribution: Model (Robust Loess)
2005 Land Rent Distribution: Data
Density
0
0.1
0.2
0.3
0.4
0.5
-3
-2
-1
0
1
2
3
Normalized Land Rents (1995 Mean = 0)

Sectoral Specialization



Productivity over Time and Space