The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy

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Granularity and Production Networks in Macroeconomics

Introduction

- 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?
  - Input-output, trade and migration linkages
  - Differences in regional and sectoral TFP, local factors, and geography
- We model and calibrate these mechanisms for all 50 U.S. states and 26 traded and non-traded industries
- Aggregate real GDP elasticity to local productivity changes varies substantially:
  - 1.6 in NY, 1.3 in CA, but only 0.89 in FL and 0.34 in WI

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 changes
    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 uses static, multi-sector, multi-country quantitative models to assess the gains from trade
  - For example, Arkolakis, et al. (2012), Costinot, Donaldson, and Komunjer (2012), Caliendo and Parro (2012) and more
  - Paper relates to studies on internal trade and migration: Redding (2012), Allen and Arkolakis (2014), Fajgelbaum and Redding (2014)
- We adapt a multi-sector version of Eaton and Kortum (2002) 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

$$\begin{aligned} v_n &\equiv \max_{\left\{c_n^j\right\}_{j=1}^J} \prod_{j=1}^J \left(c_n^j\right)^{\alpha^j} \text{ with } \sum_{j=1}^J \alpha^j = 1 \\ s.t. \sum_{j=1}^J P_n^j c_n^j &= w_n + \frac{\sum_i \iota_i r_i H_i}{\sum_i L_i} + (1-\iota_n)\frac{r_n H_n}{L_n} \equiv I_n. \end{aligned}$$

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

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

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 goods in industry 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_{in}^k denote the share of region i's total expenditures on sector k's intermediate goods purchased from region n

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

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

- Trade surplus/deficit in n is given by $L_n \frac{\sum_i \iota_i r_i H_i}{\sum_i L_i} - \iota_n r_n H_n$

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

Changes in real 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

Changes in Welfare

- Welfare changes are given by

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

where $\varpi_n = \frac{(1-\beta_n \iota_n) w_n}{(1-\beta_n \iota_n) w_n + (1-\beta_n)\chi}$

  - Note that if $\iota_n = 0$ for all n, then $\chi = 0$ and $\varpi_n = 1$. In that case

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

- ACR (2012) emphasize the case with one sector, no factor mobility, and no trade deficits 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)
  - System of $2N + 3JN + JN^2 = 69000$ equations and unknowns
- Some issues:
  - We estimate ι_n to match 2007 regional trade imbalances, S_n
    - ⋆ Not exact since $\iota_n \in [0, 1]$ iota iota-map
    - ⋆ So use counterfactual without unexplained deficits
  - No international trade: CFS provides data of expenditures on domestically produced goods

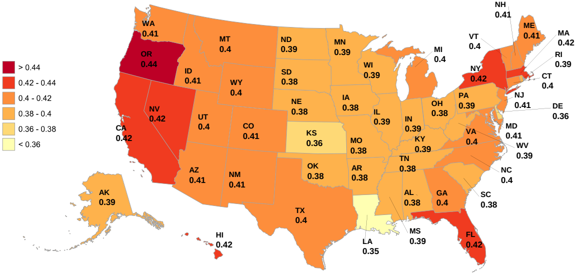
Data

- We need to find data for I_n, L_n^j, S_n, π_{ni}^j as well as values for the parameters $\theta^j, \alpha^j, \beta_n, \iota_n, \gamma_n^{jk}$
  - 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
  - ι_n : From S_n using minimum least squares
  - γ_n^{jk} : Get γ_n^j from BEA value added shares and use national IO table to compute $\gamma_n^{jk} = (1 - \gamma_n^j)\gamma^{jk}$

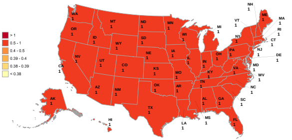
Aggregate and Local or Sectoral Elasticities

- We present all results using elasticities
  - All based on 10% changes ($\hat{T}_n^j = 1.1$)
    - Matters due to non-linearities
  - Aggregate elasticities calculated by dividing by share of state/sector and the size of the shock
    - So benchmark for aggregate TFP elasticity is 1 independent of the size of the state
  - Local/sectoral elasticities adjusted by the size of the shock only
    - So benchmark for local TFP elasticity in the affected state/sector is 1 too

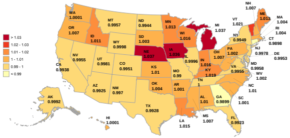
Aggregate TFP elasticity of a local productivity change



NRNS Model



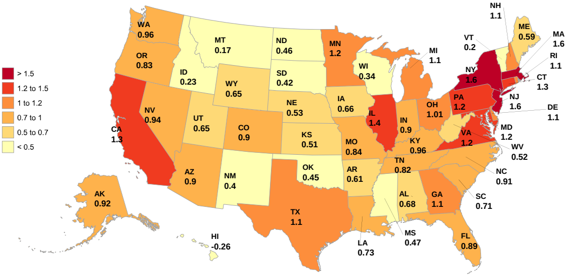
RNS Model



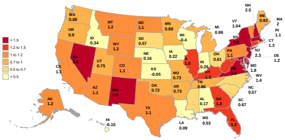
$$\ln \hat{A}_n^j = \ln \frac{\left(\hat{T}_n^j\right)^{\gamma_n^j}}{\left(\hat{\pi}_{nn}^j\right)^{1/\theta^j}}$$

Zoom

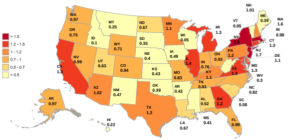
Aggregate GDP elasticity of a local productivity change



NRNS Model



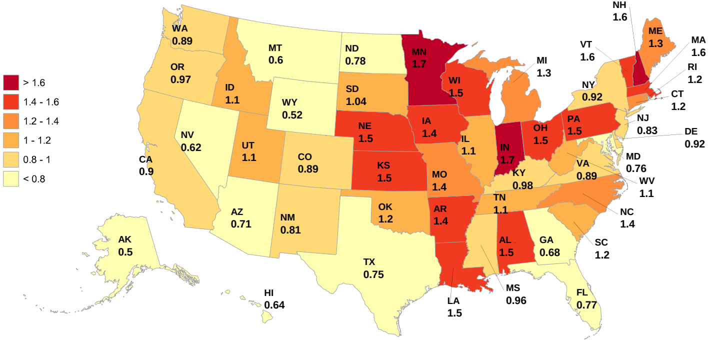
RNS Model



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

Local Factors   Zoom

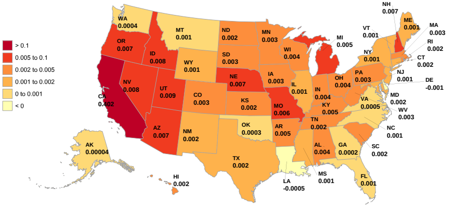
Welfare elasticity of a local productivity change



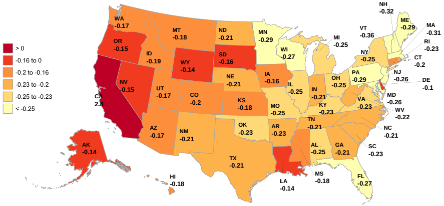
iota-map

Regional elasticity of a productivity change in California

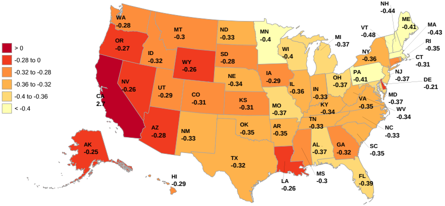
TFP elasticity



GDP elasticity

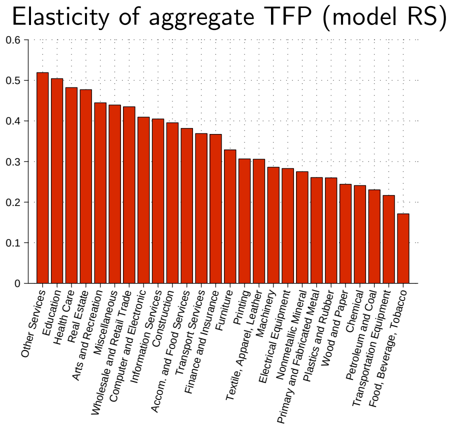


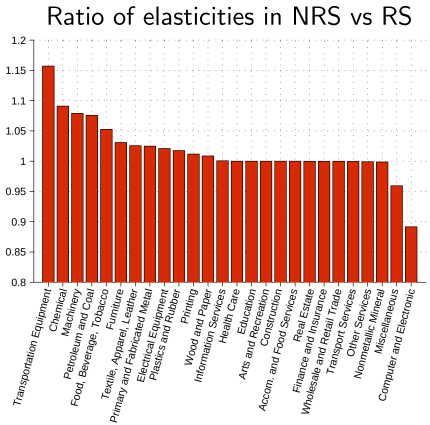
Employment elasticity



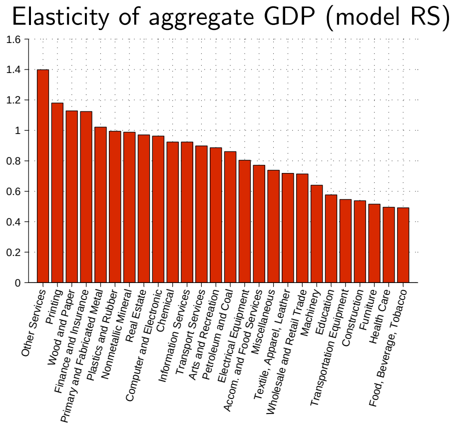
▸ Zoom ▸ Sectoral Comp.

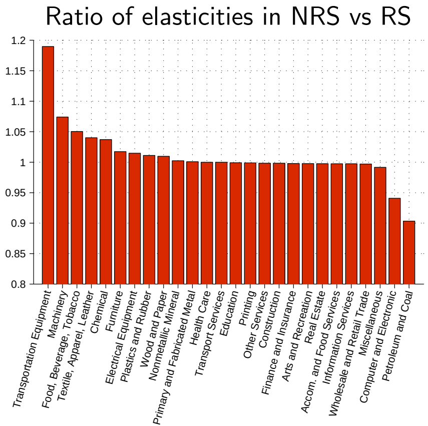
Aggregate TFP elasticities to a sectoral change



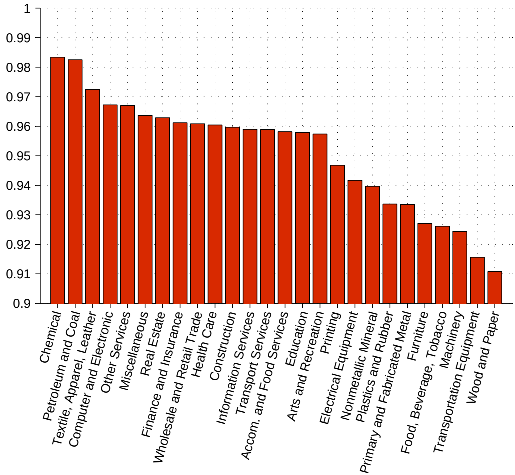


Aggregate GDP elasticities to a sectoral change





Welfare elasticity of a sectoral productivity change



Concentration

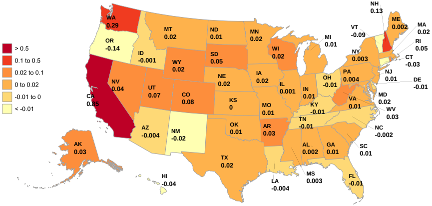
An Application

The Productivity Boom in Computers and Electronics in California

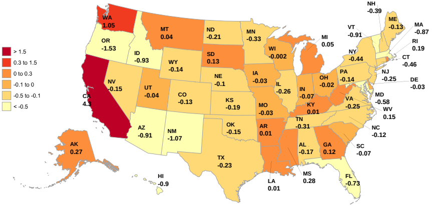
- California, home of prominent information and technology firms
  - Apple, Cisco Systems, Hewlett-Packard, Intel and others
- In 2007, California accounted for 24% of all employment in Computers and Electronics
  - Texas 8%, Massachusetts 6%, other states (37) less than 2%
- From 2002-2007 California experienced a productivity boom in Computers and Electronics
  - An average of 31% annual fundamental TFP increase in that sector, which corresponds to a 14.6% yearly increase in measured TFP
  - The largest across all states and regions in the U.S. during that period
- We evaluate how productivity boom in that sector and state propagated to all other sectors and states of the U.S. economy

Productivity Boom in Comp. & Elec. in California

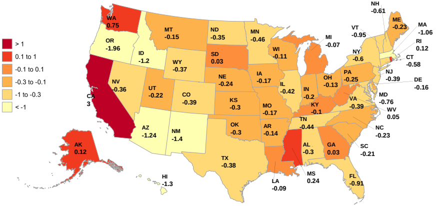
Regional TFP effects (percent)



Regional GDP effects (percent)



Regional Employment effects (percent)



Another Application

The Economic Impact of Hurricane Katrina

- On August 2005, Hurricane Katrina hit at the border of Louisiana and Mississipi. Structural damages were later estimated at 75.3 million, Burton and Hicks (2005).

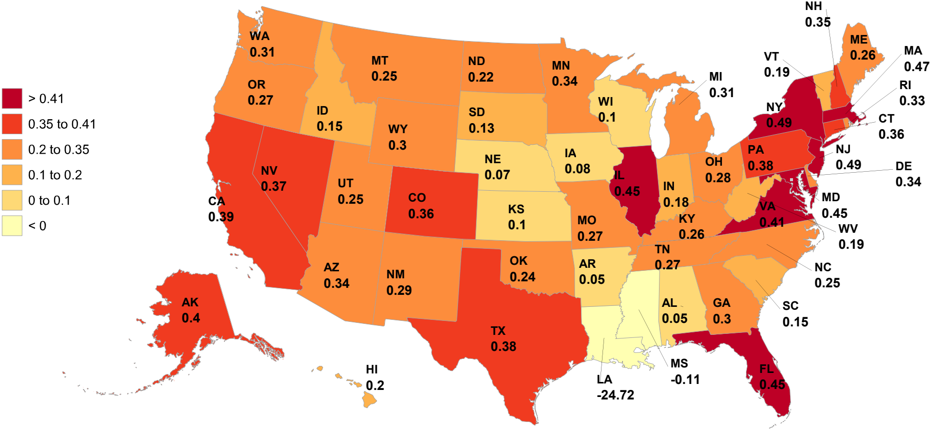
- Structural damage estimates shared across Mississipi, Louisiana, and Alabama. We consider the effects of the destruction of structures in Louisiana, $\widehat{H} = 0.748$.

- We find: Katrina reduced U.S. welfare by 0.24 percent, and GDP by 0.12 percent. Employment in Louisiana fell by 25 percent, or about 490 thousand workers.

- BLS (2008) estimates that Katrina resulted in a loss of population 1.1 million, of which 51 percent had employment status, corresponding to about 574,000 workers.

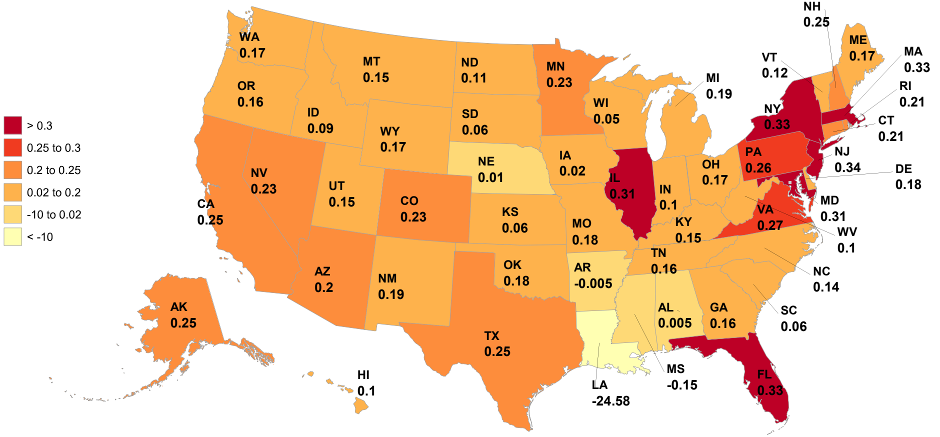
The Economic Impact of Hurricane Katrina

Regional Employment effects (percent)



The Economic Impact of Hurricane Katrina

Regional GDP effects (percent)



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:

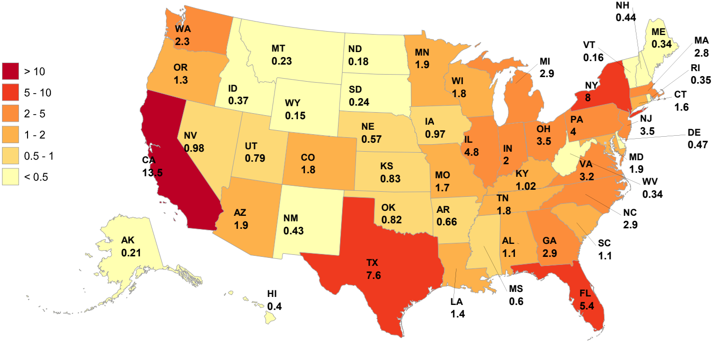
Effects of a reduction in trade cost across U.S. states		
	Distance	Other barriers
Aggregate TFP gains	50.98%	3.62%
Aggregate GDP gains	125.88%	10.54%
Aggregate Welfare gains	58.83%	10.10%

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
  - Elasticity of regional change on welfare varies from 1.7 in MN to 0.75 in TX and 0.5 in AK
  - Elasticity of sectoral productivity increases also varies from .98 in Chemicals to .92 in Transportation Equipment
    - ★ And very heterogenous regional impact
- For future work:
  - Mobility frictions
  - Local factor accumulation

Economic activity in the U.S.

Share of GDP by region (%, 2007)



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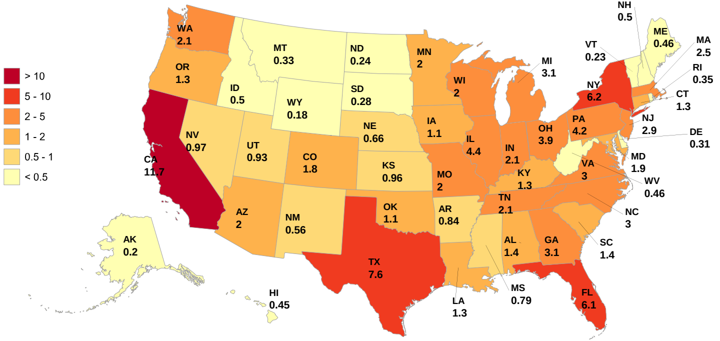
Economic activity in the U.S.

Share of Employment by region (%, 2007)



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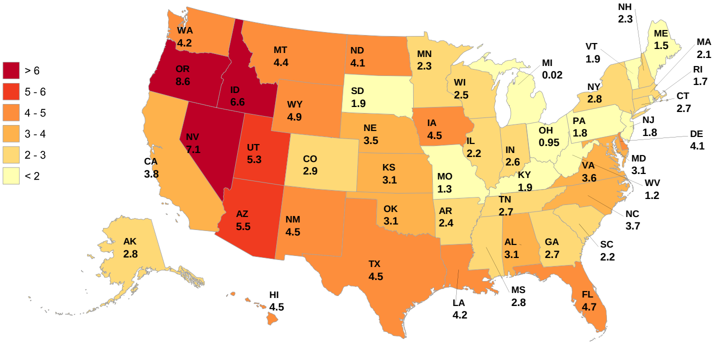
Economic activity in the U.S.

Change in GDP (%, 2002 to 2007)



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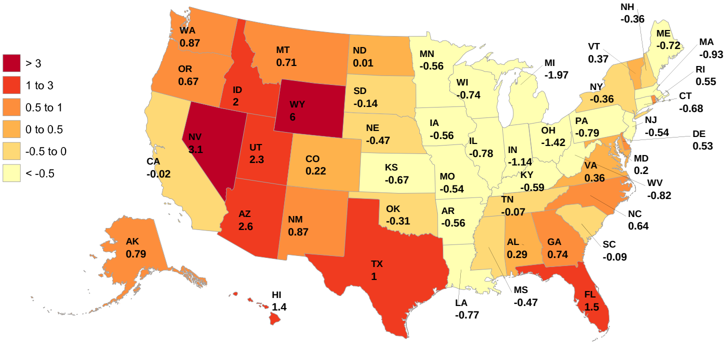
Economic activity in the U.S.

Change in Employment (%, 2002 to 2007)



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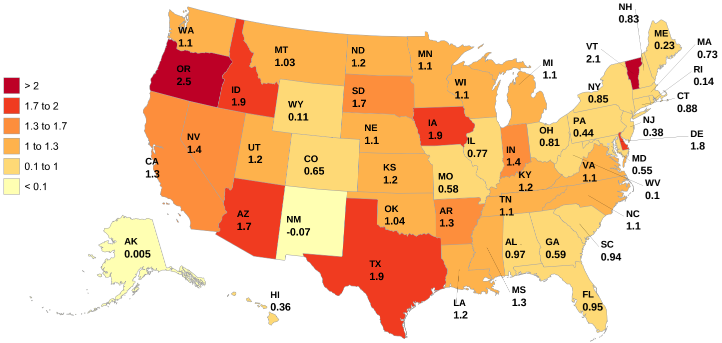
Change in measured TFP by region

Annualized rate (2002-2007, %)



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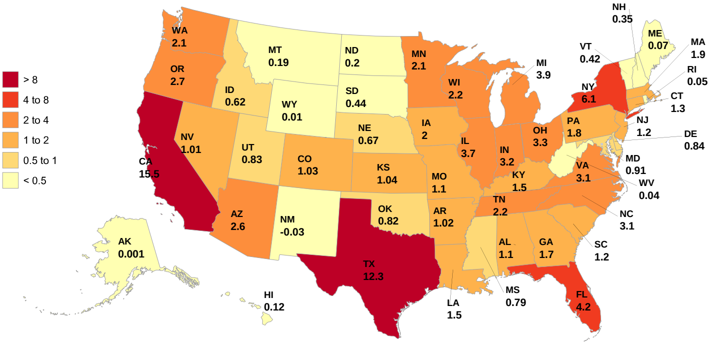
Regional contribution

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



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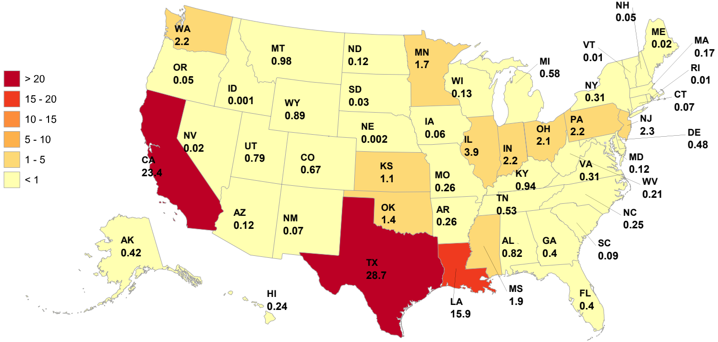
Economic activity in the U.S.

Petroleum and Coal concentration across regions (%, 2007)



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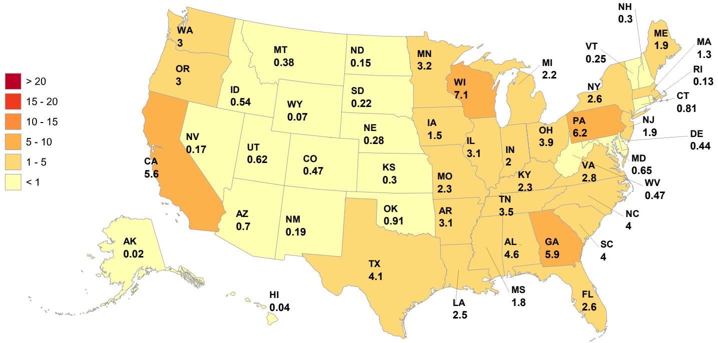
Economic activity in the U.S.

Wood and Paper concentration across regions (%, 2007)



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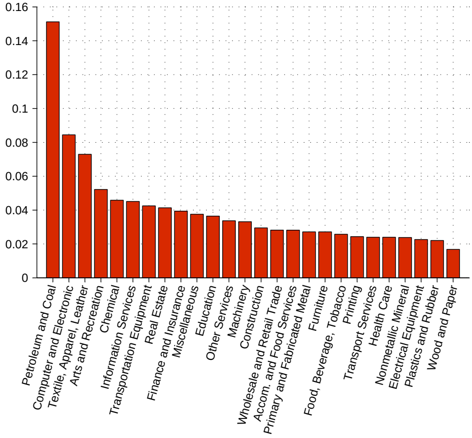
Regional concentration of economic activity across sectors

Herfindahl Index, 2007



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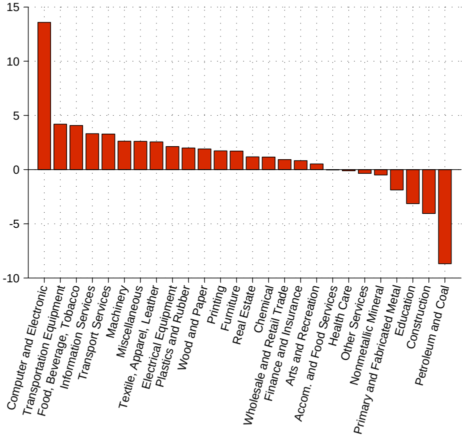
Change in sectoral measured TFP

Annualized rate (2002-2007, %)



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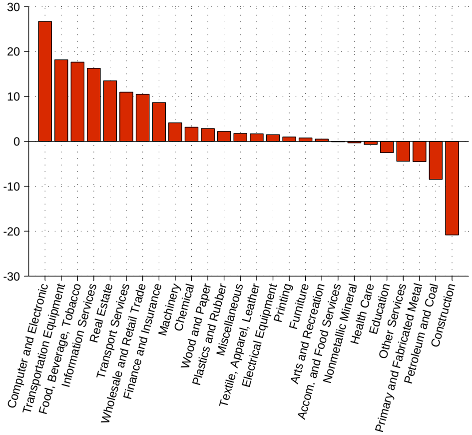
Sectoral contribution

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



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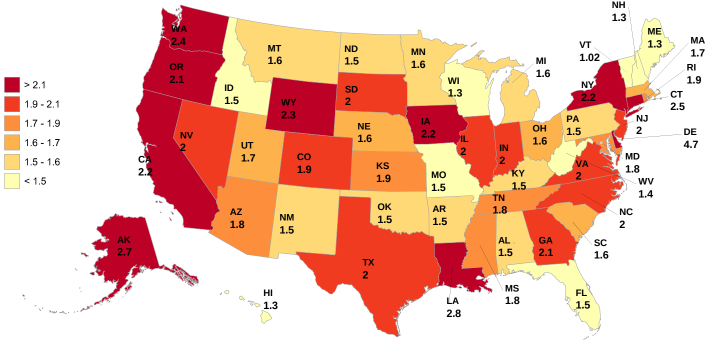
Per capita returns from local factors

- Depicts $\frac{r_n H_n}{L_n}$ calculated using $GDP_n = w_n L_n + r_n H_n$



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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

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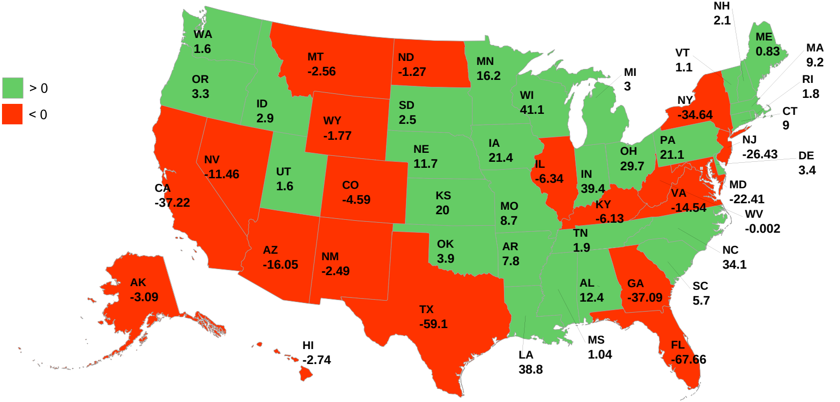
Economic activity by regions

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



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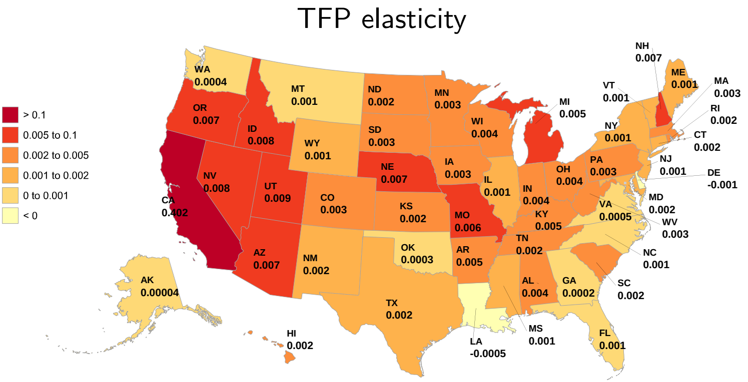
Regional elasticity of a productivity change in California



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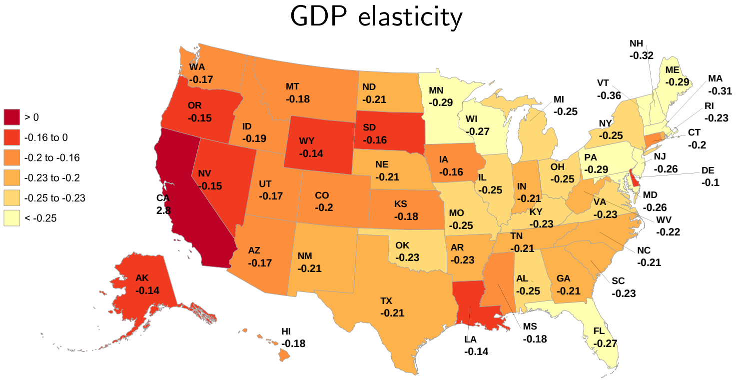
Regional elasticity of a productivity change in California



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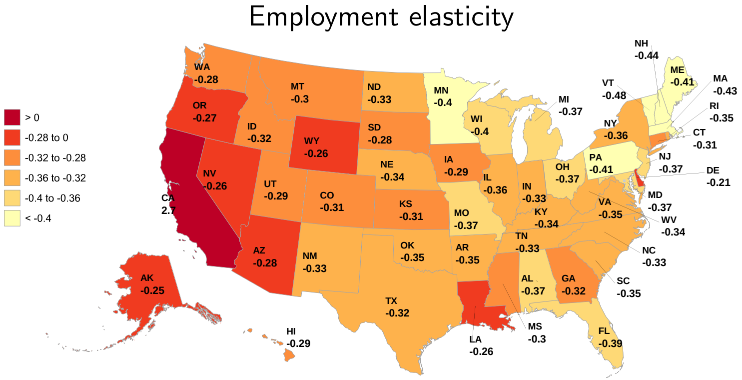
Regional elasticity of a productivity change in California



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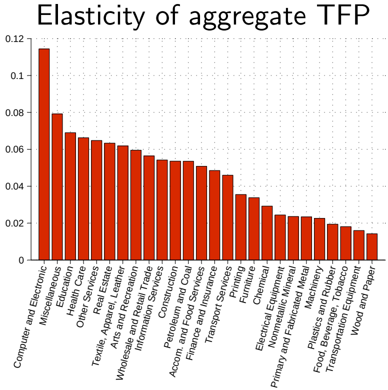
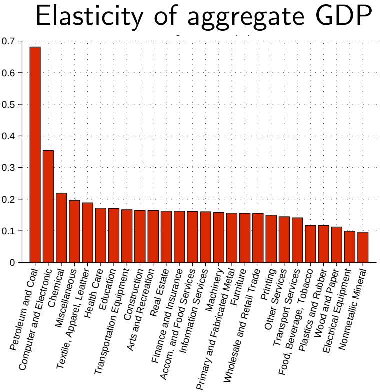
Sectoral elasticity of a productivity change in California





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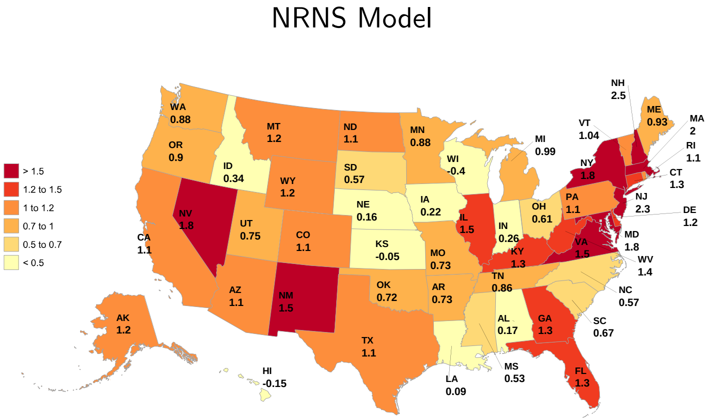
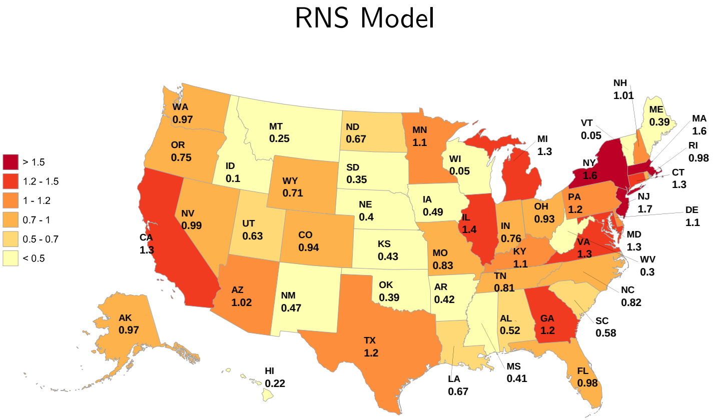
Aggregate elasticity of a local change: Real GDP

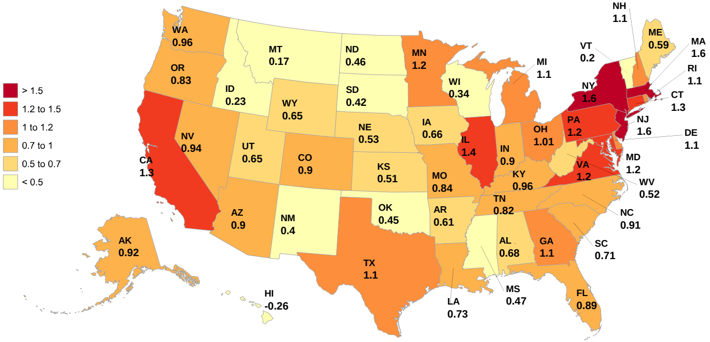


Aggregate elasticity of a local change: Real GDP



Aggregate elasticity of a local change: Real GDP

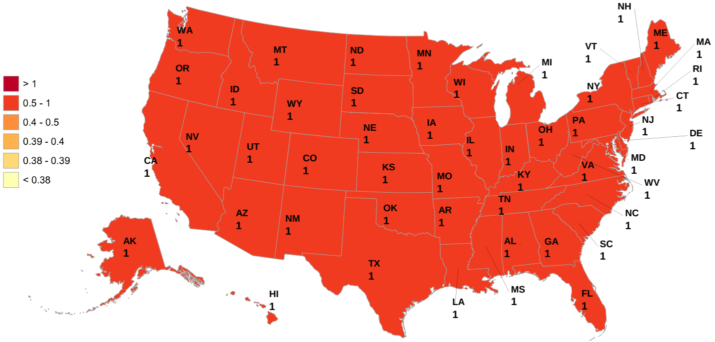
RS Model



▸ Counterfactuals GDP

Aggregate elasticity of a local change: TFP

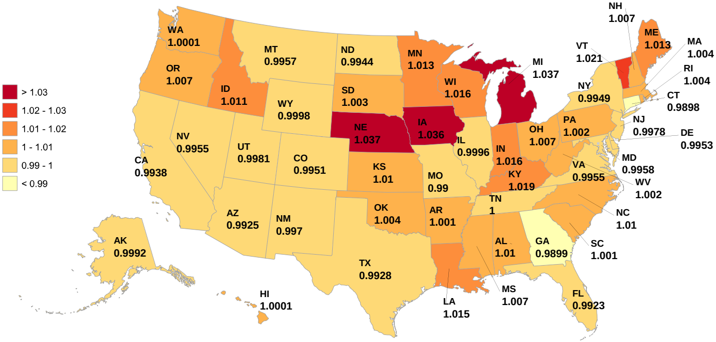
Model with no inter-regional trade and no inter-sectoral trade, NRNS
Then $\ln \hat{A}_n^j = \ln \hat{T}_n^j$



Aggregate elasticity of a local change: TFP

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

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



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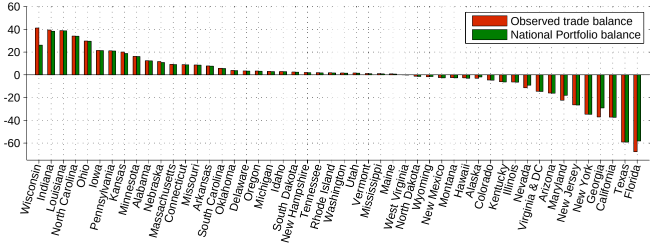
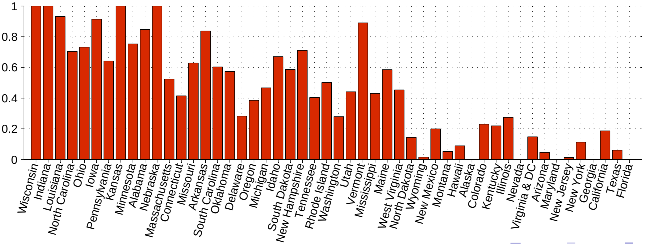
Trade balances and contributions to the National Portfolio

Trade Balance: Model and data (2007 U.S. dollars, billions)



Local rents on structures contributed to the National Portfolio (ι_n)



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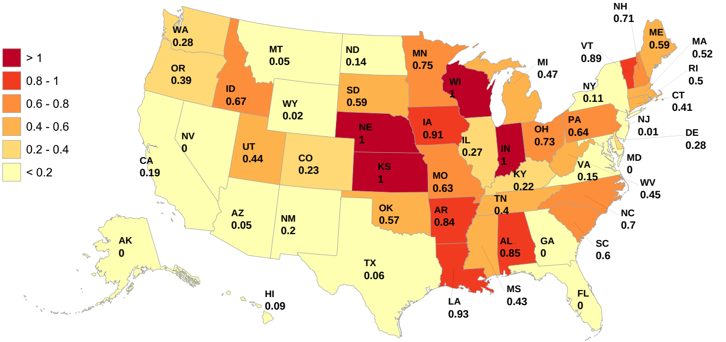
Contributions to the National Portfolio

Local rents on structures contributed to the National Portfolio (ι_n)



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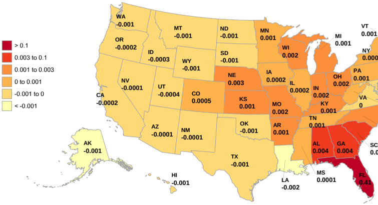
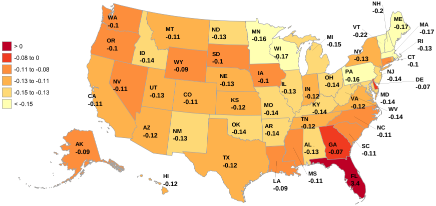
Regional elasticity of a productivity change in Florida

TFP elasticity



GDP elasticity



Employment elasticity