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

Lorenzo Caliendo, Yale University
Fernando Parro, Johns Hopkins
Esteban Rossi-Hansberg, Princeton University
Pierre-Daniel Sarte, Richmond Fed
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
  - ... and sometimes firms: Jovanovic (1987), and Gabaix (2011)
- 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
- 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, $L^j_n$: 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

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

$$s.t. \sum_{j=1}^{J} P^j_n c_n^j = w_n + \sum_{i} \frac{t_i r_i H_i}{L_i} + (1 - \lambda_n) \frac{r_n H_n}{L_n} \equiv I_n.$$ 

- 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 $P_n = \prod_{j=1}^{J} \left( P^j_n / a^j \right)^{a_j}$ 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 \( z_{jn}^j \)
  - Drawn independently across goods, sectors, and regions from a Fréchet distribution with shape parameter \( \theta_j \)
  - Productivity of all firms is also determined by a deterministic productivity level \( T_{jn}^j \)
- The production function of a variety with \( z_{jn}^j \) and \( T_{jn}^j \) is given by
  \[
  q_n^j(z_n^j) = z_n^j \left[ T_n^j h_n^j(z_n^j) \beta_n I_n^j(z_n^j)(1-\beta_n) \right]^{\gamma_n^j} \prod_{k=1}^J M_{nk}^{jk}(z_n^j) \gamma_{jk}^n
  \]
- Importantly, \( T_{jn}^j \) 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

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

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

\[
\frac{x_n^j}{z_n^j} (T_n^j)^{-\gamma_n^j}
\]

and so its price under competition is given by

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

where \(\kappa_{n_i}^j \geq 1\) are “iceberg” bilateral trade cost
Model - Final goods

- The production of final goods is given by

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

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

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

where \( \zeta_n^j \) 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 \( \omega_n \equiv (r_n / \beta_n)^{\beta_n} \left( w_n / (1 - \beta_n) \right)^{(1-\beta_n)} \)
Regional trade

- Total expenditure on goods in industry $j$ in region $n$

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

where $\pi_{in}^k$ 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),

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

- Trade surplus/deficit in $n$ is given by $L_n \frac{\sum_i \tau_i r_i H_i}{\sum_i L_i} - \tau_n r_n H_n$
Changes in measured TFP

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

\[
\frac{Y_{jn}^j}{P_{jn}^j} = \frac{x_{jn}^j}{P_{jn}^j} \left[ (H_{jn}^j)^{\beta_n} (L_{jn}^j)^{1-\beta_n} \right]^{\gamma_n^j} \prod_{k=1}^J (M_{kn}^{jk})^{\gamma_{kn}^{jk}}
\]

- \(Y_{jn}^j / P_{jn}^j = Q_{jn}^j\) when \(j\) is a non-tradable good

- So the change in measured TFP as a result of \(\hat{T}_{jn}^j\) is

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

- 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

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

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

\[
\ln \left( \frac{\hat{w}_n}{\hat{x}_n^j} \right) = \beta_n \ln \left( \frac{\hat{w}_n}{\hat{r}_n} \right) = \beta_n \ln \frac{1}{\hat{L}_n}
\]

... 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

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

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

- Note that if \( \iota_n = 0 \) for all \( n \), then \( \chi = 0 \) and \( \omega_n = 1 \). 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 $\iota_n$ to match 2007 regional trade imbalances, $S_n$
    - Not exact since $\iota_n \in [0, 1]$
    - 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 $I_n, L^j_n, S_n, \pi^j_{ni}$ as well as values for the parameters $\theta^j_i, \alpha^j, \beta_n, \iota_n, \gamma^{jk}_{in}$

  - $L^j_n$: BEA, with aggregate employment across all states summing to 137.3 million in 2007
  - $I_n$: Total value added in each state in 2007
  - $\pi^j_{ni}$ and $S_n$: CFS with total trade equal to 5.2 trillion in 2007
  - $\theta^j_i$: We use the numbers in Caliendo and Parro (2012)
  - $\alpha^j$: Calculated as the aggregate share of consumption
  - $\beta_n$: 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

  - $\iota_n$: From $S_n$ using minimum least squares
  - $\gamma^{jk}_{in}$: Get $\gamma^j_i$ from BEA value added shares and use national IO table to compute $\gamma^{jk}_{in} = (1 - \gamma^j_i) \gamma^{jk}$
Aggregate and Local or Sectoral Elasticities

- We present all results using elasticities
  - All based on 10% changes ($\hat{T}_n = 1.1$)
    - 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

\[
\ln A'_n = \ln \left( \frac{\hat{T}^j_n}{\hat{\pi}^j_{nn}} \right)^{1/\theta^j}
\]
Aggregate GDP elasticity of a local productivity change

\[ \ln \hat{GDP}_n^j = \ln \hat{A}_n^j + \ln \hat{L}_n^j + \ln \left( \frac{\hat{w}_n}{\hat{\chi}_n^j} \right) \]

Local Factors
Welfare elasticity of a local productivity change

iota-map
Regional elasticity of a productivity change in California

**TFP elasticity**

**GDP elasticity**

**Employment elasticity**
Aggregate TFP elasticities to a sectoral change

Elasticity of aggregate TFP (model RS)

Ratio of elasticities in NRS vs RS
Aggregate GDP elasticities to a sectoral change

Elasticity of aggregate GDP (model RS)

Ratio of elasticities in NRS vs RS

Caliendo, Parro, Rossi-Hansberg, Sarte
Regions, Sectors Trade and Productivity
Welfare elasticity of a sectoral productivity change
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
Caliendo, Parro, Rossi-Hansberg, Sarte

Regions, Sectors Trade and Productivity

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 Mississippi. Structural damages were later estimated at 75.3 million, Burton and Hicks (2005).

- Structural damage estimates shared across Mississippi, Louisiana, and Alabama. We consider the effects of the destruction of structures in Louisiana, \( \hat{H} = 0.748 \).

- 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)

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The Economic Impact of Hurricane Katrina

Regional GDP effects (percent)

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Regions, Sectors Trade and Productivity
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 \( \theta^j \), and assuming symmetry, we can identify \( \kappa^j_{ni} \)
Counterfactuals

- Decompose trade barrier using

\[ \log \kappa_{ni}^j = \delta^j \log \frac{d_{ni}^j}{d_{ni}^{j \min}} + \eta_n + \epsilon_{ni}^j \]

- Then calculate counterfactuals:

<table>
<thead>
<tr>
<th>Effects of a reduction in trade cost across U.S. states</th>
<th>Distance</th>
<th>Other barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate TFP gains</td>
<td>50.98%</td>
<td>3.62%</td>
</tr>
<tr>
<td>Aggregate GDP gains</td>
<td>125.88%</td>
<td>10.54%</td>
</tr>
<tr>
<td>Aggregate Welfare gains</td>
<td>58.83%</td>
<td>10.10%</td>
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</tbody>
</table>

Caliendo, Parro, Rossi-Hansberg, Sarte
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)
Economic activity in the U.S.

Share of Employment by region (%, 2007)

[Map of the United States with state economic activity percentages indicated by color.]
Economic activity in the U.S.
Change in GDP (%, 2002 to 2007)
### Economic activity in the U.S.

#### Change in Employment (%, 2002 to 2007)

<table>
<thead>
<tr>
<th>State</th>
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Change in measured TFP by region
Annualized rate (2002-2007, %)
# Regional contribution

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

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Map showing regional contributions with colors indicating the contribution levels from > 8 to < 0.5.
Economic activity in the U.S.
Petroleum and Coal concentration across regions (%, 2007)
Economic activity in the U.S.
Wood and Paper concentration across regions (%, 2007)
Regional concentration of economic activity across sectors
Herfindahl Index, 2007
Change in sectoral measured TFP

Annualized rate (2002-2007, %)
Sectoral contribution

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

[Bar chart showing sectoral contributions to TFP change]
Per capita returns from local factors

• Depicts $\frac{r_nH_n}{L_n}$ calculated using $GDP_n = w_nL_n + r_nH_n$
Regional Trade

- Regional trade much more important than international trade

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Source: World Development indicators and CFS

- 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
Economic activity by regions

Regional elasticity of a productivity change in California

TFP elasticity
Regional elasticity of a productivity change in California

GDP elasticity

- AL: -0.25
- AK: -0.14
- AZ: -0.17
- CA: 2.8
- CO: -0.2
- CT: -0.2
- DE: -0.1
- FL: -0.27
- GA: -0.21
- HI: 0.18
- IA: -0.16
- ID: -0.19
- IL: -0.25
- IN: -0.25
- KS: -0.18
- KY: -0.23
- LA: -0.14
- ME: -0.29
- MD: -0.26
- MA: -0.31
- MI: -0.25
- MN: -0.29
- MS: -0.18
- MO: -0.25
- MT: -0.18
- NE: -0.21
- NV: -0.15
- NH: -0.32
- NJ: -0.26
- NM: -0.21
- NY: -0.25
- OH: -0.25
- OK: -0.23
- OR: -0.15
- PA: -0.29
- RI: -0.23
- SC: -0.21
- SD: -0.16
- TN: -0.21
- TX: -0.21
- UT: -0.17
- VA: -0.23
- VT: -0.36
- WA: -0.17
- WI: -0.27
- WV: -0.22
- WY: -0.14
- WZ: -0.17
- WZ: -0.17
- WZ: -0.17
Regional elasticity of a productivity change in California

Employment elasticity

AL: -0.37
AK: -0.25
AZ: -0.28
AR: -0.35
CA: 2.7
CO: -0.31
CT: -0.31
DE: -0.21
FL: -0.39
GA: -0.32
HI: -0.29
ID: -0.32
IL: -0.36
IN: -0.34
IA: -0.29
KS: -0.31
KY: -0.34
LA: -0.26
ME: -0.41
MA: -0.43
MI: -0.37
MN: -0.40
MS: -0.3
MO: -0.37
MT: -0.3
NE: 0.28
NV: -0.26
OH: -0.37
OK: -0.35
OR: -0.27
PA: -0.41
RI: -0.37
SC: -0.35
SD: -0.28
TN: -0.33
TX: -0.32
UT: -0.29
VT: -0.48
VA: -0.35
WA: -0.28
WV: -0.34
WI: -0.40
WY: -0.26
Sectoral elasticity of a productivity change in California

Elasticity of aggregate TFP

Elasticity of aggregate GDP

Caliendo, Parro, Rossi-Hansberg, Sarte
Regions, Sectors Trade and Productivity
Aggregate elasticity of a local change: Real GDP

NRNS Model

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RNS Model

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RS Model

Counterfactuals GDP

Caliendo, Parro, Rossi-Hansberg, Sarte
Regions, Sectors Trade and Productivity
Aggregate elasticity of a local change: TFP

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

Then \( \ln \hat{A}_{jn} = \ln \hat{T}_{jn} \)
Aggregate elasticity of a local change: TFP

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

Then \( \ln \hat{A}_n^j = \frac{\hat{T}_j}{(\hat{\pi}_n^n)^{1/\theta_j}} \)
Trade balances and contributions to the National Portfolio

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

Observed trade balance
National Portfolio balance

Local rents on structures contributed to the National Portfolio ($\ell_n$)
Contributions to the National Portfolio

Local rents on structures contributed to the National Portfolio ($\ell_n$)
Regional elasticity of a productivity change in Florida

TFP elasticity

GDP elasticity

Employment elasticity

Caliendo, Parro, Rossi-Hansberg, Sarte

Regions, Sectors Trade and Productivity