Clusters, Shocks, and Economic Resilience

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Clusters are Everywhere

A cluster is a **geographical concentration of related industries** connected through various types of linkages and spillovers and supporting institutions

Motion Pictures – LA

Medtronic
smiths medical
3M Boston Scientific

Medical Devices in Minneapolis

taït communications
IBM
EFFECTUS LIMITED
skilitix
Stickmen Studios IMAGINE THIS

ICT in Christchurch NZ

Education & Knowledge in West Sweden

Motivation:
How to Mitigate Economic Crises?

- The Great Recession **destroyed many jobs** and had the **slowest job recovery**
  - **6 millions jobs lost** in 2007-09 (~ 5% of the US economy)
  - **Regions varied in resilience**: Salt Lake City, UT vs. Redding, CA
  - **Clusters varied in resilience**: Medical Devices in Salt Lake City vs. Madison, WI

- There are two opposing hypotheses on how to mitigate shocks and uncertainty:
  - **Industry Diversification vs. Cluster Agglomerations**

- We examine the **role of regional clusters** –groups of related and co-located industries– **in employment growth during the business cycle** (2003-2011):
  1. Do cluster agglomerations affect employment growth during an economic crisis?
  2. Are such cluster effects lower or higher during the crisis vs. the non-crisis periods?
  3. What agglomeration channels are important for resilience?

- We offer implications for policymakers to define regional strategies

- Based on Delgado/Porter (2016) “Clusters and the Great Recession”

Regional Industries Resilience in Employment Growth

- We explore **regional industries resilience in employment growth** to a recession

- **Resilience is defined as higher growth than the same industry in other locations**:
  - during the recession (**lower vulnerability** to the shock), and/or
  - post-recession (**faster recovery**)

- We **focus on "traded" industries** (exclude retail, restaurants, …)

- **Context of the Great Recession: 2007-2009**
  - **Economy-wide demand** shock that resulted in **uncertainty** and reduction in demand for most industries (Bloom et al. 2012)
  - Productivity shock for some industries (Financial services, …)

The Role of Clusters in the Resilience of their Regional Industries

- **Empirical Approach**: If clusters matter for resilience, then regional industries located within 'strong' clusters will grow faster during/after the recession
- Thus, our model specifies a region-industry annual employment growth as a function of the **strength of the cluster that surrounds the focal region-industry** (i.e., specialization in the set of related industries)

Medical Devices Cluster in Salt Lake City, Utah EA, 2003

NAICS Code	Industry Name	Industry Employment	Cluster Specialization (outside industry)
339112	**Surgical & Medical Instrument**	**3760**	**1.8**
339113	Surgical Appliance & Supplies	1389	
339114	Dental Equipment & Supplies	780	
333314	Optical Instrument & Lens	10	
339115	Ophthalmic Goods	350	

Cluster Definition: Delgado/Porter/Stern, 2016.
Cluster Specialization (Location Quotient): LQ>1 means that the cluster is "over-represented" in the region.

Preview of Findings: Cluster Resilience & Industry Specialization Risk

- **Multiple types of agglomerations are at work in clusters during a recession:**
  - The growth of regional industries during the business cycle and, **specially during the crisis**, is facilitated by the strength of their clusters in terms of:

✓ **Employment** in related industries	**Various types of links**
✓ **Number of Businesses** in related industries	**Various types of links**
✓ Employment in **upstream industries**	**Input links**
✓ Employment in **downstream industries**	**Output links**
✓ **Patenting** in related industries	**Knowledge links**

- The benefits of location in a cluster were greater for Supply Chain industries vs. B2C industries: **inter-firm links are important for resilience**
- We find evidence of **industry specialization risk**: Large regional industries located in weak clusters were especially vulnerable to the crisis

Outline

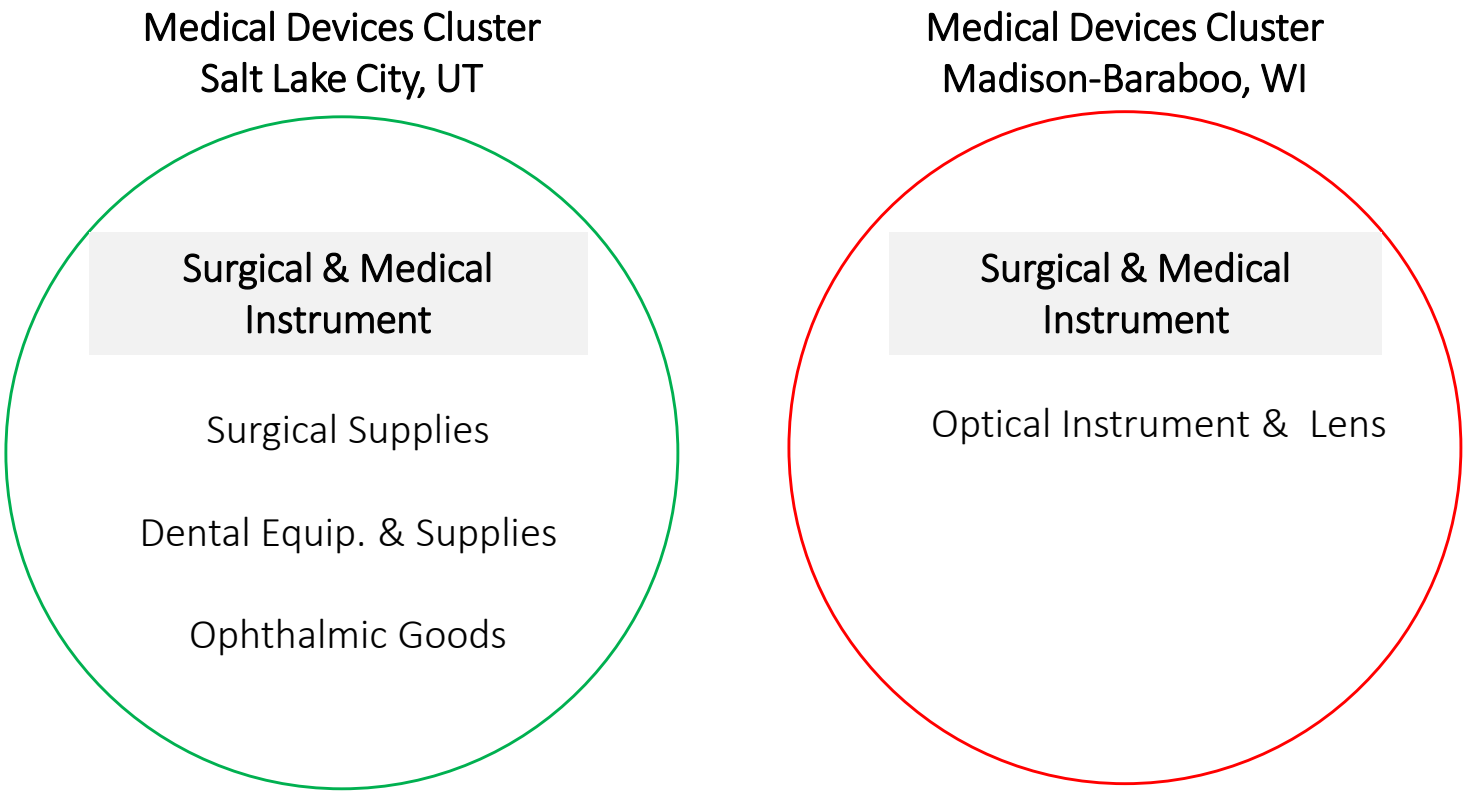
- ✓ Motivation
- **Hypotheses**
- Data and Cluster Definitions
- Econometric Model and Key findings
- Conclusions and Future Directions

Hypothesis: Cluster Resilience

- *After controlling for the size of a regional industry,* ***an industry located in a stronger cluster will be more resilient to an economic recession*** *than the same industry located in a region with a weak cluster*

- ***Stronger cluster****=higher specialization in the set of related industries*

Same Industry in Two Clusters: Which One Will Be More Resilient?



Surgical & Medical Instrument Mfg industry (NAICS-339112) in Medical Devices Cluster

Economic Areas (EAs)	Industry, 2003	
	Employment	Specialization
Salt Lake City, UT	3,760	5.0
Madison-Baraboo, WI	952	2.2

Notes: Specialization variables are measured by Location Quotient.

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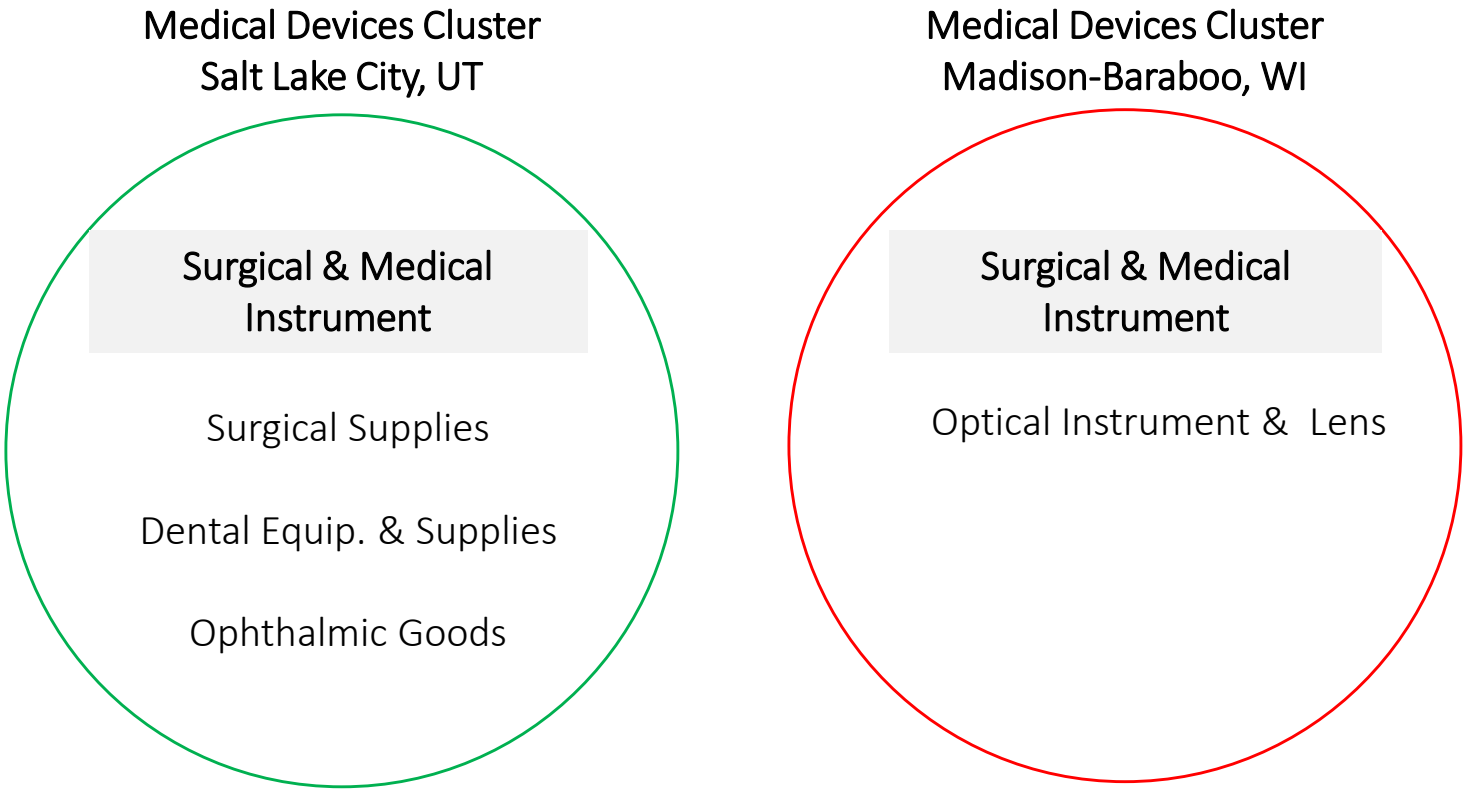

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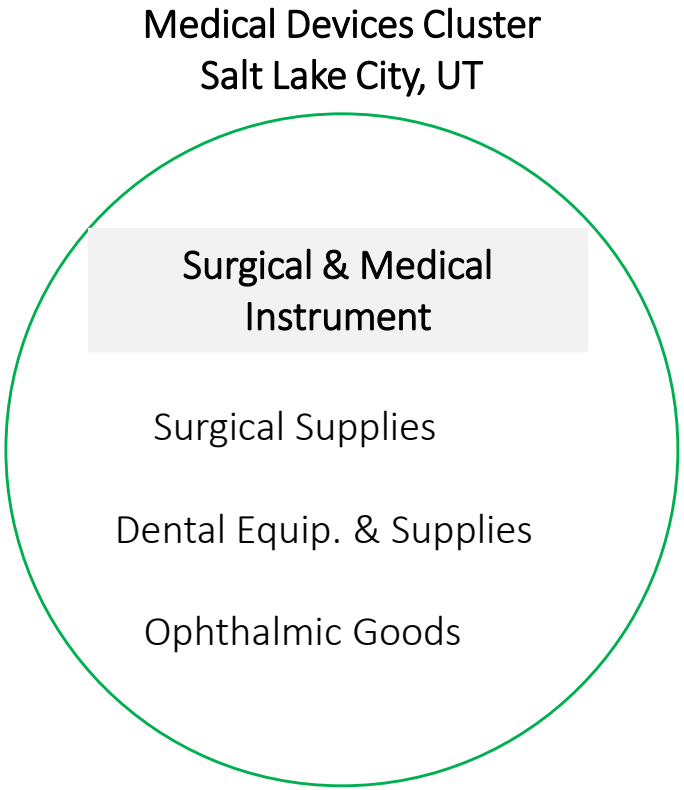
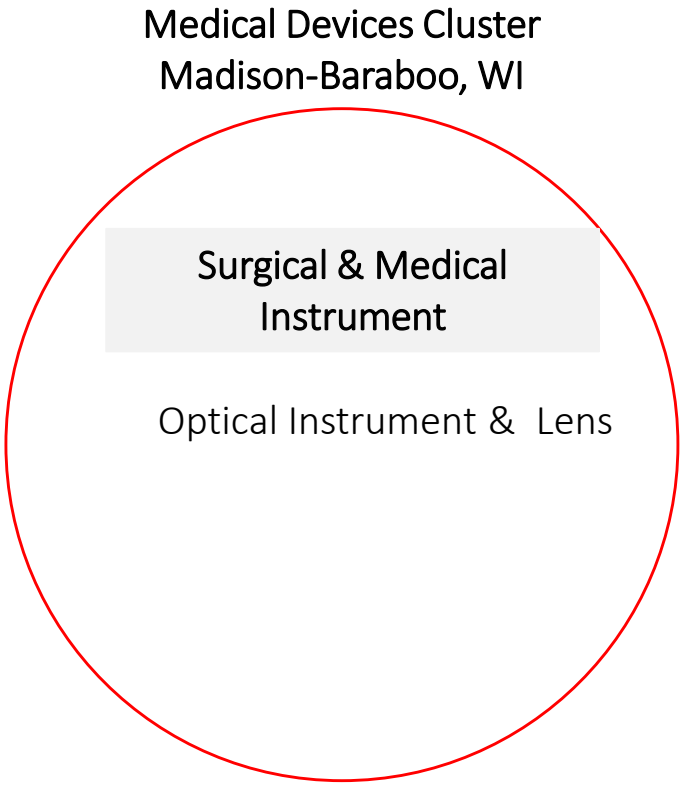




Surgical & Medical Instrument Mfg industry (NAICS-339112) in Medical Devices Cluster

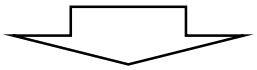
Economic Areas (EAs)	Industry, 2003		Cluster (outside industry), 2003	Annual Industry Employment Growth	
	Employment	Specialization	**Specialization**	2007-09	2009-11
Salt Lake City, UT	3,760	5.0	1.8	5%	6%
Madison-Baraboo, WI	952	2.2	0.4	-31%	-6%
Average Across EAs				-14%	-3%

Notes: Specialization variables are measured by Location Quotient.

Mechanism of Cluster Resilience: Agglomeration Economies across Related Industries

- **Economies of agglomeration that arise among related industries** (Marshall, 1920; Porter, 1990; Feldman/Audretsch, 1999; Delgado et al., 2010, 2014)
  - Better access to inputs and demand (input-output links)
  - More efficient labor markets
  - Better access to complementary knowledge and innovation opportunities

- **Supporting institutions in clusters** that can foster socioeconomic links and facilitate economies of agglomeration (Storper, 1995; Sorenson/Audia, 2000)
  - Cluster organizations, trade associations, training, financial

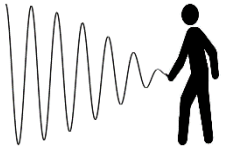


These **agglomeration benefits** can be at work **during an economic recession**

Mechanism of Cluster Resilience: Inter-Firm Links Can be *Especially* Important During a Crisis

- The crisis **increased uncertainty** in most industries (Bloom et al., 2012)
- Firms can **respond better to uncertainty in demand with supplier-buyer collaborations** versus vertical integration (e.g., Kranton/Minehart, 2000)
  - The Silicon Valley model (Saxenian, 1994)
  - Automakers in the US reduced vertical integration in response to competition (Helper, MacDuffie and Sabel, 2000)
- These **supplier-buyer collaborations are more likely in stronger clusters**; and they could be **important during a crisis**:
  - Suppliers can have many buyers, and buyers many suppliers (**diversify risk**)
  - Suppliers and buyers may benefit from repeated interactions (**share the risk**)
- The industry breadth of a cluster may allow a **broader set of collaborations**, and pooling resources during a crisis (Holm/Østergaard, 2015; ICT)

Counterfactual: Cluster Vulnerability



- **Shocks can propagate and amplify among related industries and firms**, and increase the depth/duration of a shock (Acemoglu et al. 2014; Barrot and Sauvagnat, 2014)

- Recent **macroeconomic studies** find that **import shocks** in manufacturing **propagates from downstream national industries to their upstream national industries** (i.e., from buyers to their suppliers), reducing employment growth in the US (Acemoglu et al. 2014)

- Important **differences with the macroeconomic studies of shock propagation**:
  - We focus on **regional industries** operating in clusters **vs. national industries**
  - We consider an economy-wide demand shock vs. industry-specific shocks

Outline

- ✓ Introduction
- ✓ Hypotheses
- **Data and Cluster Definitions**
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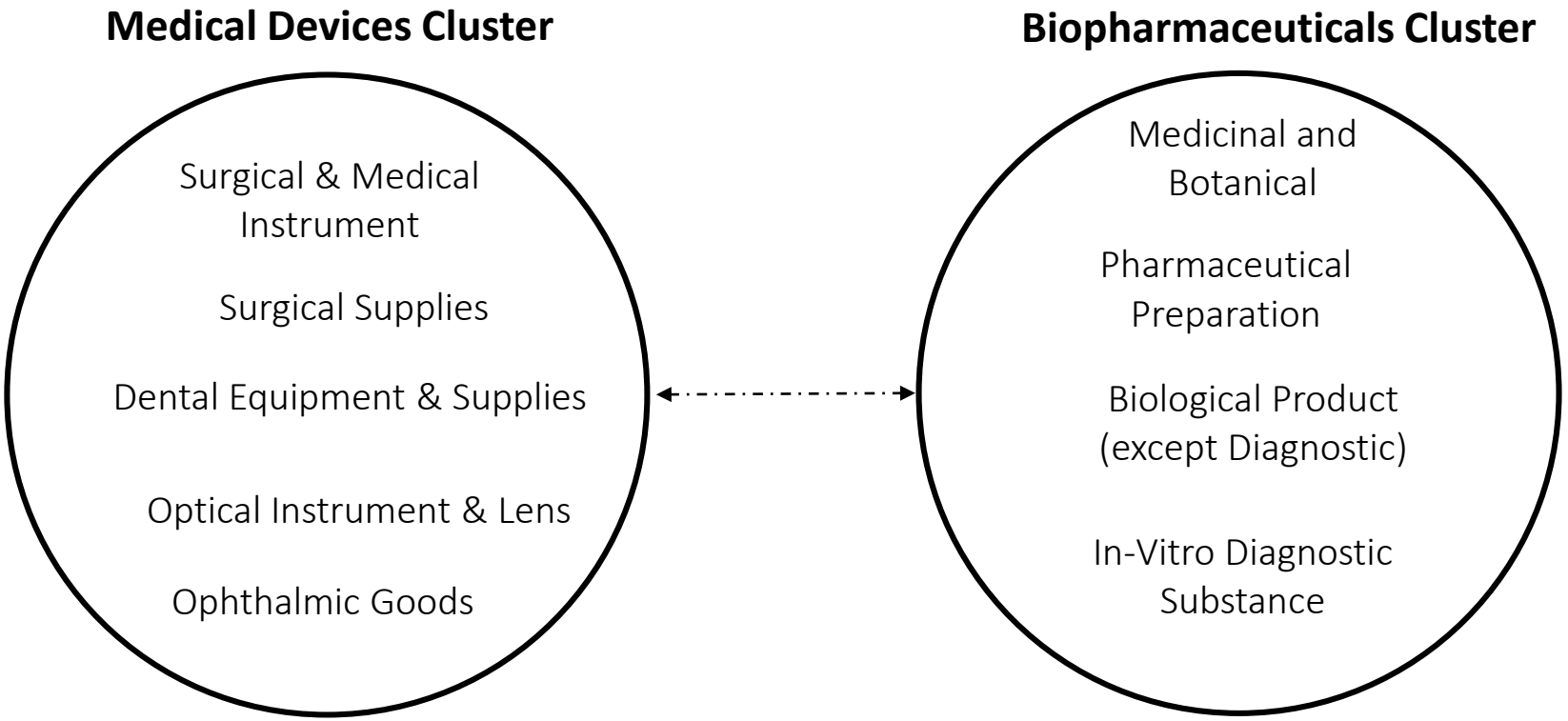
Public Data

- Using County Business Pattern (CBP) data and the US Cluster Mapping Project dataset, we measure employment at the **region-industry and region-cluster level**

  - We focus on a dataset that spans the **years 2003-2011**
  - includes **177** mutually exclusive **Economic Areas** (EAs), and
  - incorporates **778 traded industries** (6-digit NAICS)
    - **Traded**: Manufacturing and service industries that concentrate in particular regions and sell their products across regions/countries
    - **Local** industries **are excluded** (e.g., retail, restaurants)
  - grouped into **51 clusters** of related industries for each EA
    - **U.S. Benchmark Cluster Definitions** developed by Delgado, Porter, and Stern (2016) grouping related industries based on input-output links, shared labor occupations, and co-location patterns

Defining Clusters of Related Industries: Cluster Analysis

- To define clusters, we use **cluster analysis**: numerical methods to classify similar objects (**industries**) into groups (Everitt et al., 2011)
- Creates groups (clusters) in such a way that objects (industries) in the same group are more similar among themselves than to those in other groups



Source: Delgado/Porter/Stern, 2016, "Defining Clusters of Related Industries," *Journal of Economic Geography*

Benchmark Cluster: Medical Devices

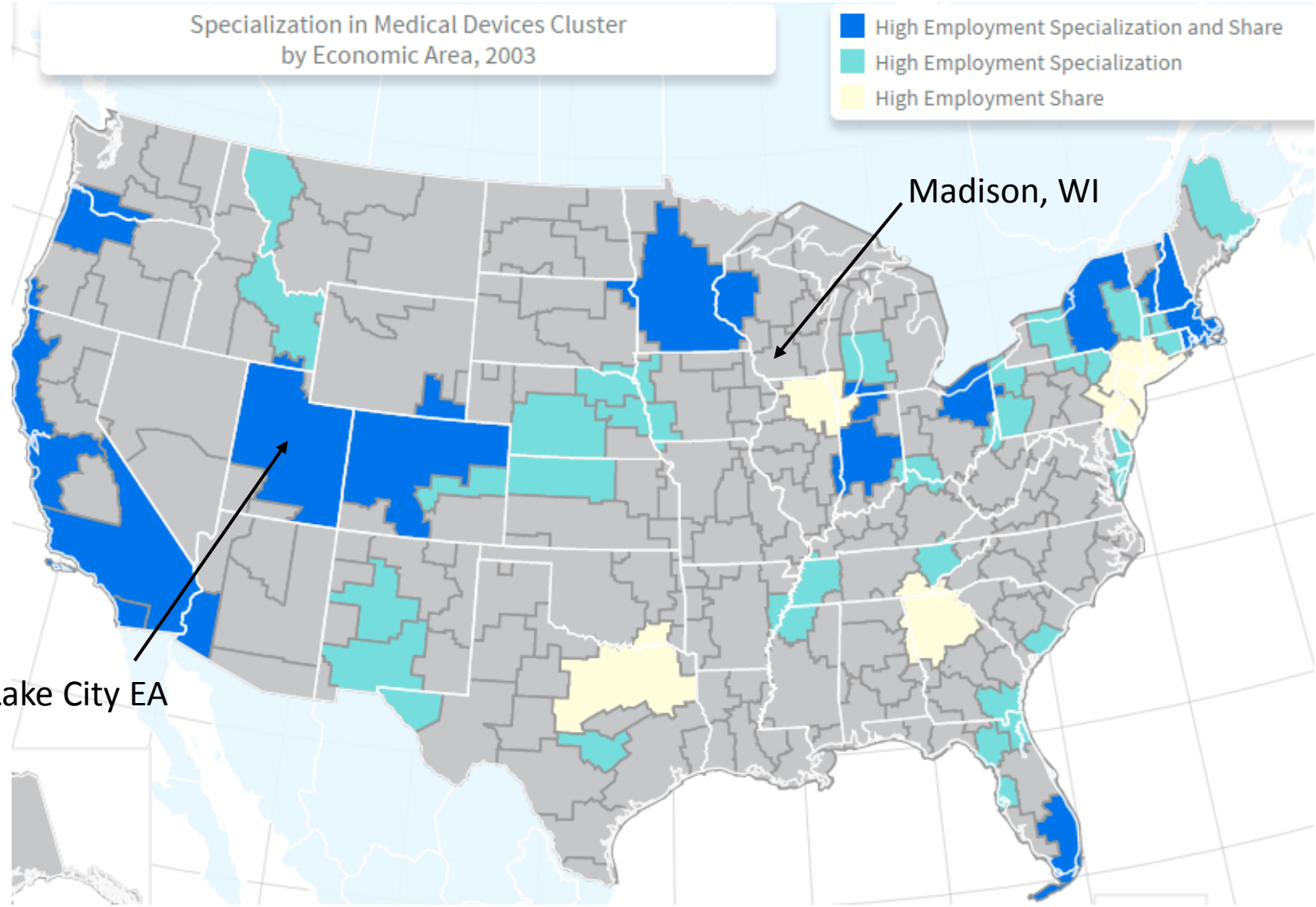
Description: Establishments in this cluster primarily manufacture surgical, medical, dental, optical, ophthalmic, and veterinary instruments and supplies.

NAICS 5 Industries	Industry Name	Within Cluster Relatedness$_{ic}$ Rank (1=best, 51=worst)	Score
333314	Optical Instrument and Lens	1	1.97
339115	Ophthalmic Goods	1	2.48
339112	Surgical and Medical Instrument	1	2.18
339113	Surgical Appliance and Supplies	1	2.34
339114	Dental Equipment and Supplies	1	1.61

Within Cluster Relatedness: industries ranked best in this group than in any other group

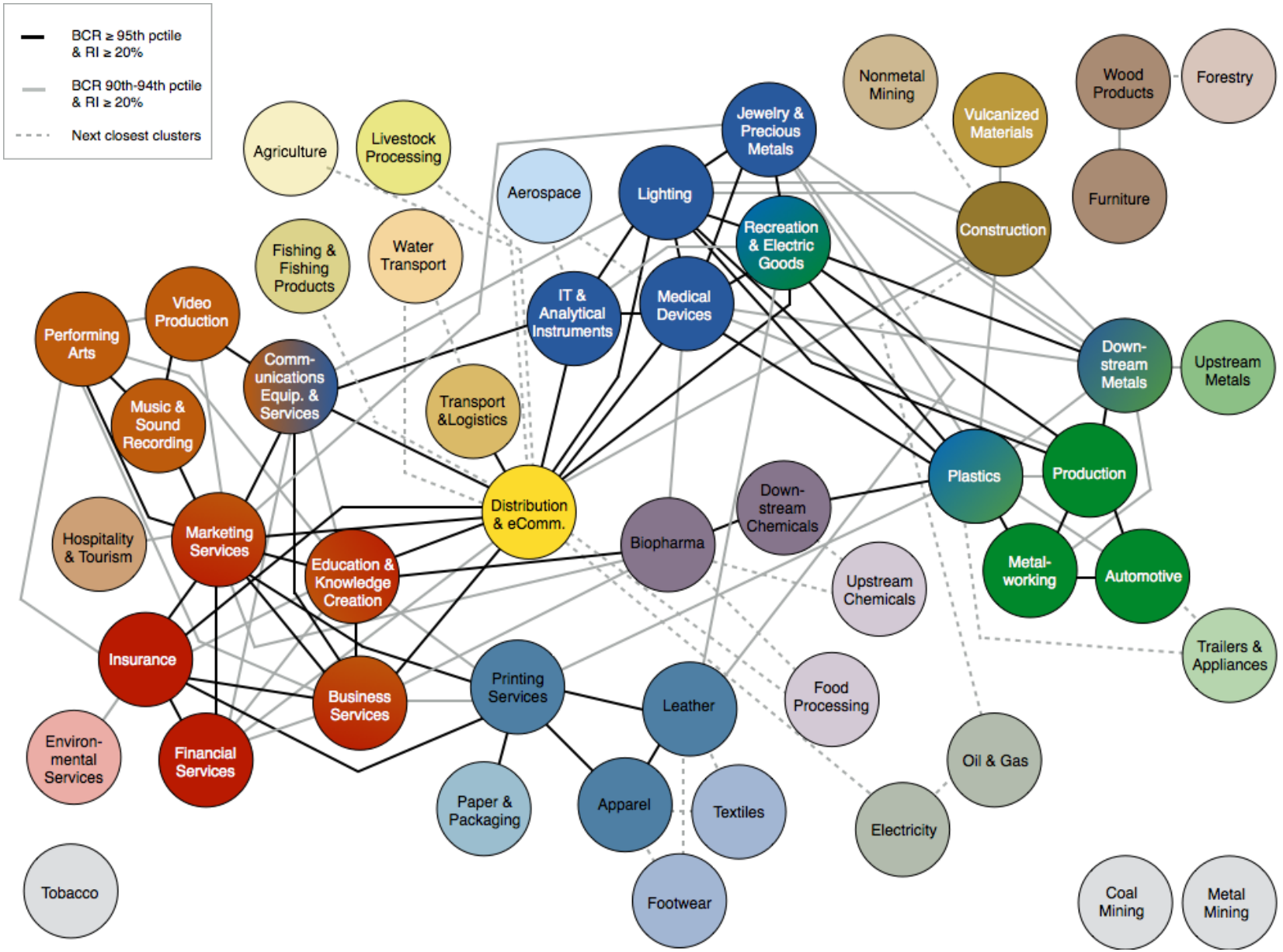
Source: Delgado/Porter/Stern (2016)

Mapping Strongest Medical Device Clusters, 2003



Source UCMP. Interactive map at: http://www.clustermapping.us/cluster/medical_devices.

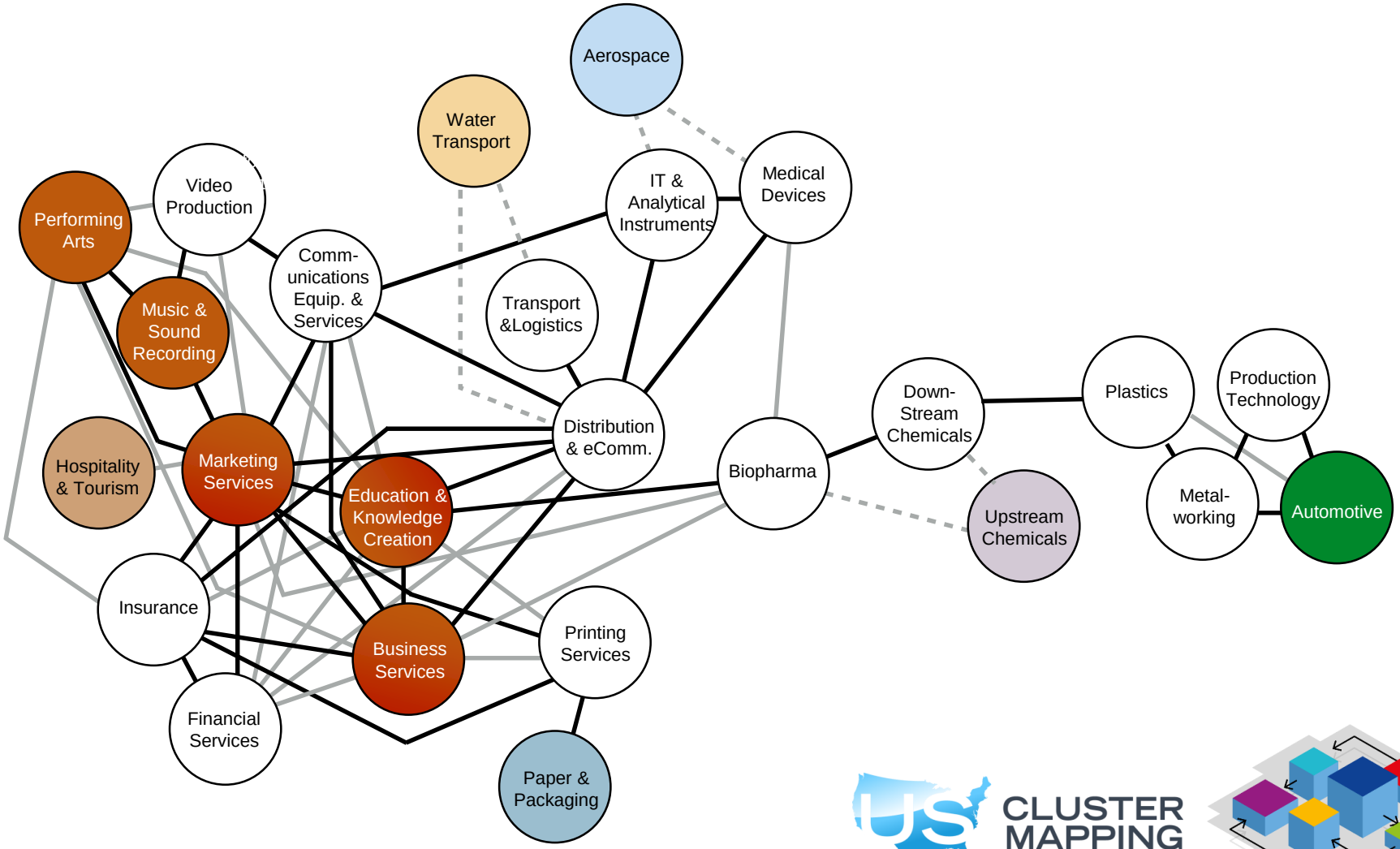
Portfolio of 51 Traded Clusters and their Connections



Source: Delgado, Porter, and Stern (2016). BCR (Between Cluster Relatedness Score).

Regions Have Comparative Advantages Manifested in their Clusters

Cluster Composition of West Sweden NUTS2, 2014



CLUSTER MAPPING

EU Cluster Portal

Delgado, Porter, Stern (2016).

West Sweden NUTS2 Region: Strong clusters (+75 percentile specialization; colored) and their connected clusters.

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- **Econometric Model**
- Key findings
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Econometric Model: Region-Industry Annual Employment Growth

$$\ln\left(\frac{\text{Industry Employment}_{icr,t}}{\text{Industry Employment}_{icr,t-1}}\right) = \alpha_0 + \delta_t \text{Year}_t * \ln(\text{Industry Employment}_{icr,t-1}) +$$

$$\beta_t \text{Year}_t * \ln(\text{Cluster Specialization}^{\text{outside i}}_{\text{Employ, icr,2003}}) + \alpha_{it} + \alpha_{rt} + \varepsilon_{icrt}$$

- **Dep. Variable:** Annual employment growth of industry *i* at region (EA) *r* during 2003-2011
- **The explanatory variables** (in logs) **are**
  - Employment level of the region-industry at *t-1*
  - Employment specialization of the region-cluster (outside the industry) in 2003
- **The estimated coef. (δ_t β_t) vary by year** to examine the effect during the business cycle
- **Controls**: Identification Strategy
  - **Industry-Year FEs** and **Region-Year FEs**
  - Some specifications include **the region-industry pre-recession trends** to account for unobserved factors (e.g., region-industry policies like subsidies, firm composition)
  - Some specifications allow the **coef. to vary by cluster (δ_{ct} β_{ct}) and by region (δ_{rt} β_{rt})**

- **Estimate OLS model with standard errors clustered by region-cluster**
- **Placebo:** Estimate using **random clusters of unrelated Industries**

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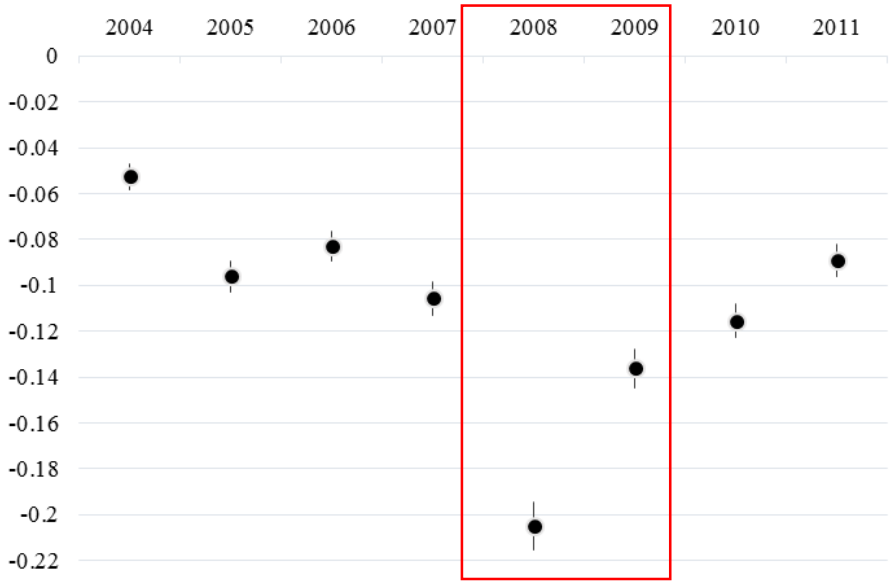
Findings: Industry Specialization Risk and Cluster Resilience

	Y=EA-Industry Annual Employment Growth 2003-11
$Year_{2004}$*Ln(Industry Employment) $_{irt-1}$	-0.053**
$Year_{2005}$*Ln(Industry Employment) $_{irt-1}$	-0.096**
$Year_{2006}$*Ln(Industry Employment) $_{irt-1}$	-0.083**
$Year_{2007}$*Ln(Industry Employment) $_{irt-1}$	-0.106**
$Year_{2008}$*Ln(Industry Employment) $_{irt-1}$	-0.205**
$Year_{2009}$*Ln(Industry Employment) $_{irt-1}$	-0.136**
$Year_{2010}$*Ln(Industry Employment) $_{irt-1}$	-0.115**
$Year_{2011}$*Ln(Industry Employment) $_{irt-1}$	-0.089**
$Year_{2004}$*Ln(Cluster Specialization $_{Emp}$)$_{icr2003}$	0.049**
$Year_{2005}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.057**
$Year_{2006}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.045**
$Year_{2007}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.055**
$Year_{2008}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.096**
$Year_{2009}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.055**
$Year_{2010}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.048**
$Year_{2011}$*Ln(Cluster Specialization $_{Emp}$) $_{icr2003}$	0.039**
Industry Pre-recession Employ Growth$_{ir2003-07}$	
EA-Year Fixed Effects (1,408 dummies)	Yes
Industry-Year Fixed Effects (6,207 dummies)	Yes
R-squared	0.091
Obs.	497,236

Estimated Coefficients: Industry Specialization Risk and Cluster Resilience

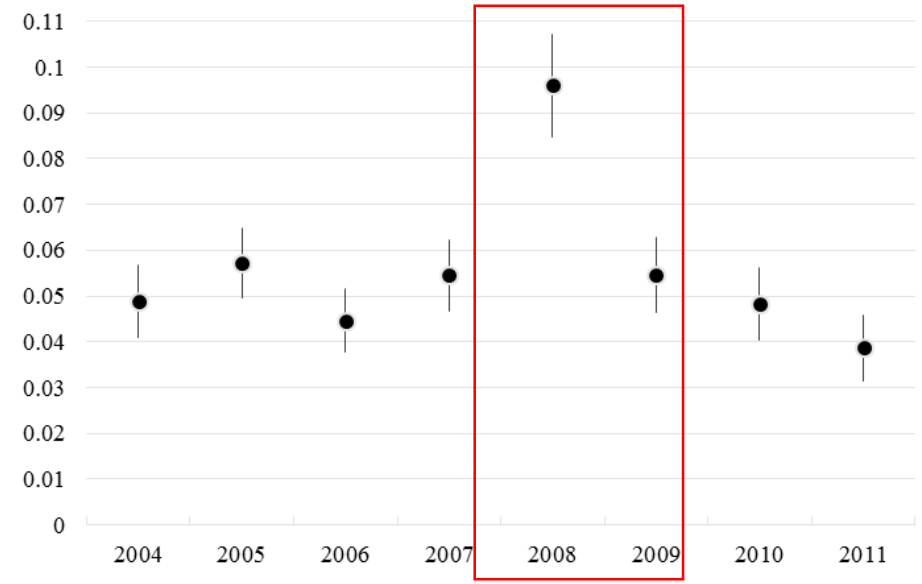
δ_t **Ln Industry Employment** (95% Confidence Intervals; Model 1)

- Convergence effect is larger during the crisis (07-09)



β_t **Ln Cluster Specialization**$_{\mathbf{Emp}}$ (95% Confidence Intervals; Model 1)

- Cluster effect is larger during the crisis (07-09)
- Post-recession effects are slightly lower than Pre-crisis



Unrelated Industries Do Not Mitigate Economic Crises

- While most policy prescriptions call for industry diversity to mitigate shocks, random clusters of **unrelated industries do not improve resilience**
- Instead, **pooling resources among related industries mitigate shocks**

Estimated Coef. of Cluster Specialization (β_t) on
Region-Industry Annual Employment Growth, 2003-2011

Fig 1: BCD Clusters of Related Industries

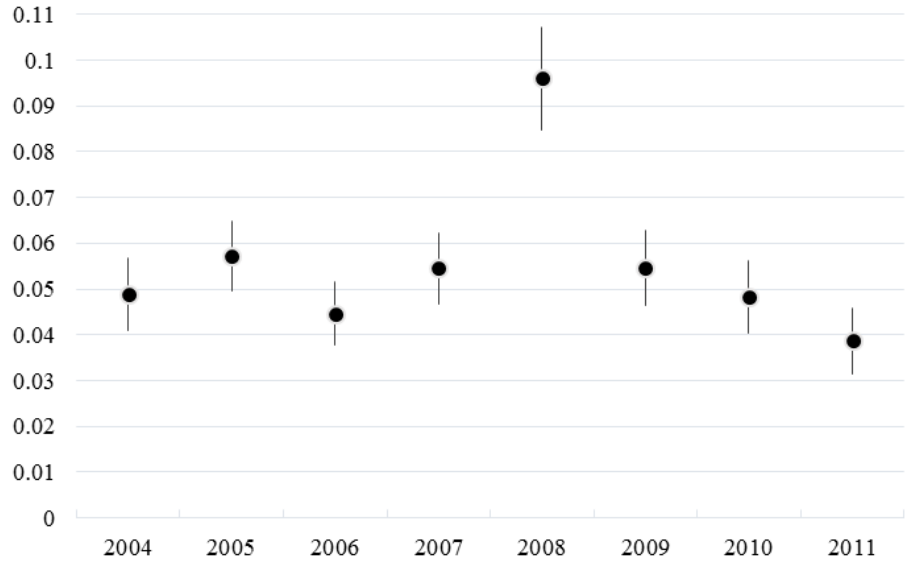


Fig 2: Random Clusters of Unrelated Industries

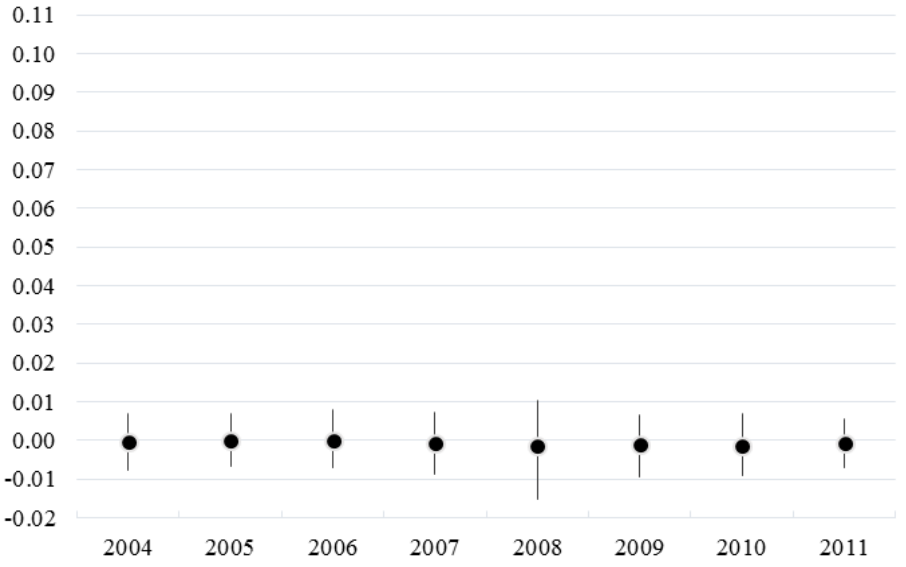


Fig.2: 10% bootstrap confidence intervals (200 random sets of clusters)

Findings: Various Agglomeration Channels during a Recession

Number of businesses, Buyers, Suppliers, & Patenting

Cluster Resilience: Various Types of Agglomeration Channels

Magnitude of the Estimated Cluster Effects

% Increase in EA-Industry Annual Employment Growth by 1-Std Dev Increase above the Mean in X

	Cluster Spec Emp	Cluster Breadth	Cluster Spec Emp-Suppliers	Cluster Spec Emp-Buyers	Cluster Spec Establishments	Cluster Spec Patents
Pre-crisis 2003-07	5.1	4.6	4.6	4.2	**7.7**	1.1
Crisis 2007-09	7.5	7.2	6.7	6.2	**12.3**	2.1
Post-crisis 2009-11	4.3	4.1	3.8	3.5	**7.0**	1.1

All effects are significant at 1% level.

- **Various types of agglomerations seem to be at work** during the crisis
  - The estimated **cluster effect is positive and higher during the crisis**
  - The cluster effect is greater with ***Cluster Spec*** **based on number of establishments**. This suggests that clusters with more businesses (i.e., more potential **inter-firm collaboration**) are more resilient (Saxenian, 1994)
- The estimated effect is **lower post-crisis**: cluster environment has deteriorated

Findings: Supply Chain vs. Business-to-Consumer Industries

Assess the importance of inter-firm links for resilience

Supply Chain vs. B2C Industries

- Supply Chain (SC) industries sell primarily to other businesses: e.g., semiconductors, engineering services, cloud computing, ….
- B2C industries sell primarily to personal consumers: e.g., food, apparel, …
- **Firms in SC industries have more inter-firm links** (they produce inputs)

All Traded Industries, 2012	
Average Wage	$65,900
Employment, mill	42
STEM Intensity	12.9%

Supply Chain Traded	
Average Wage	$72,800
Employment, mill	26
STEM Intensity	17.0%

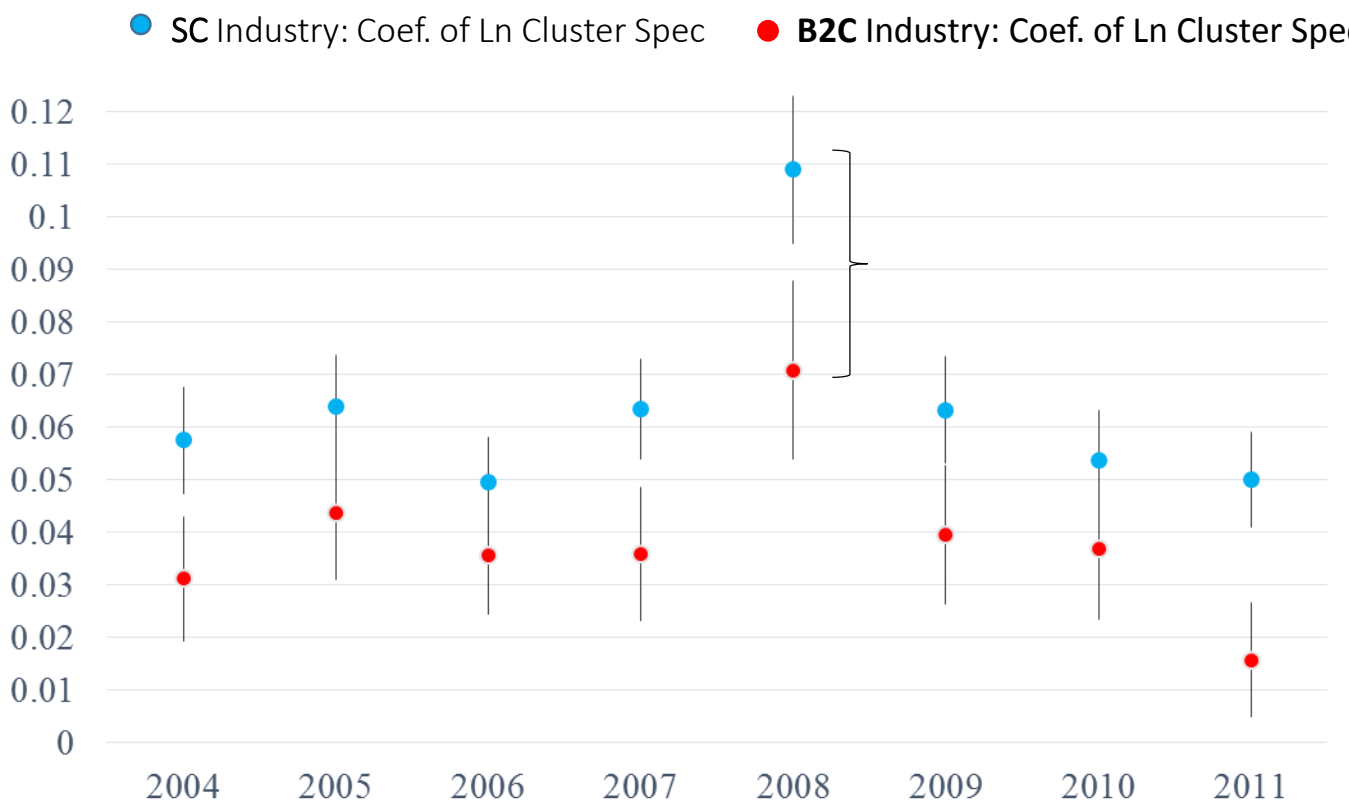
Business-to-Consumer Traded	
Average Wage	$54,500
Employment, mill	16
STEM Intensity	5.9%

Delgado and Mills (2016)

Supply Chain Industries are More Resilient In Clusters

- SC industries experienced greater cluster effects than B2C during the whole business cycle and, especially, during the recession
- **This suggests that inter-firm links matter *especially* for resilience**

Estimated Effect of Cluster Specialization on EA-Industry Annual Employment Growth, 2003-11

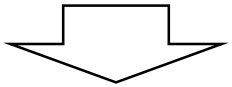


How to Improve Employment Resilience to Economic Crises?

Invest in Your Comparative Advantage

- **Strong clusters improve the resilience of their industries in employment and business creation** (investment)

- **Why?**
  - Pooling resources (skills, knowledge) among related & co-located industries
  - Collaboration between proximate firms (supplier-buyers)
  - Presence of many firms that compete in related but distinct markets
  - These cluster benefits can be specially important when industries are experiencing **high uncertainty**



- **Regions should improve the breadth of emerging & established clusters:**
  - **Specialization in a set of related industries**
  - Instead of specialization in one narrowly defined industry or industry diversity

Extensions to Better Inform Policy

- **What cluster attributes improve employment resilience?**
  - **Presence of related clusters** in the region and nearby regions (e.g., Bio, IT, Medical Devices, Knowledge Creation in Salt Lake City, UT)
  - **Firm composition** of the regional cluster: **What types of firms foster resilience?**
    - ✓ **Many Suppliers and Buyers**
    - **Large** firms?
    - **Geographically diversified** firms?
    - **Low-Leverage** firms (Giroud and Mueller, 2015)?
    - **Startups** (Holm and Østergaard, 2015)?

- **Other performance dimensions**: Resilience in e-ship, innovation, wages, …

- **Longer-term effects**: Cluster evolution in response to the crisis
  - Clusters that lost many firms in core industries may need to **re-invent themselves**
  - **The micro geography of a cluster can change**. Some parts of a region could become disconnected from the clusters, creating **inner cities problems**: pockets with concentrated poverty (Delgado and Kim, 2016)

Extensions to Inform Managers

- Resilience of regional clusters does not mean resilience of all firms

- What **types of firms** will **benefit most** from the cluster during a crisis?
  - Startups vs. Incumbent
  - Specialized vs. Diversified

- **Why?** What **management & operation practices** matter?
  - The **Spatial Organization** of the firm (Alcacer and Delgado, 2016): internal/external agglomerations
  - **Firm Decentralization** of decision making (Aghion et al., 2015)
  - **Relational Contracts** with suppliers (Helper and Henderson, 2014)
  - **Management of Debt** (Giroud and Mueller, 2015)

Thank You!

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Resilience of Regional Industries Located Within Strong Clusters

- We want to examine whether regional industries located within a **'strong' cluster** (i.e., one with high relative presence of related industries) are more resilient (grow faster during/after the crisis)
- Thus, our model specifies region-industry annual employment growth during the business cycle as a function of the
  - Employment size of the focal region-industry
  - **strength of the cluster that surrounds the focal region-industry** (i.e., specialization in the set of related industries)

Medical Devices Cluster in Salt Lake City, Utah EA, 2003

NAICS Code	Industry Name	Industry Employment	Cluster Specialization (outside industry)
339112	**Surgical & Medical Instrument**	**3760**	**1.8**
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Cluster Definition: Delgado/Porter/Stern, 2016.
Cluster Specialization (Location Quotient): LQ>1 means that the cluster is "over-represented" in the region.

Example of Industries: SC vs. B2C

	Traded Mfg		Traded Services	
	SC	**B2C**	**SC**	**B2C**
Industry Name	Biological Products	Pharmaceutical Preparation	Engineering Services	Computer Training
NAICS Code (2012)	325414	325412	541330	611420
% sold to Personal Consumption Expenditure (PCE)	0%	71%	0%	91%

Hypothesis: Industry Specialization Risk

Large regional industries located in a weak cluster will be the most vulnerable to an economic crisis:

- At the region-industry level, convergence effects may be at work in employment growth: i.e. region-industry employment growth will be declining in the initial level of employment due to mean reversion or diseconomies of agglomeration (Delgado, Porter, and Stern, 2014)
- **During an economy-wide demand shock, convergence forces in employment growth could become larger because the industry has excess capacity**, which could induce cost-based competition and reduce business expansions
- Thus, large regional industries located in weak clusters won't be able to mitigate the convergence forces and will face industry specialization risk

Example of Industry Specialization Risk

E.g.: Wood Kitchen Cabinet Mfg Industry in Kansas City EA

- Consider the Wood Kitchen Cabinet Industry in Kansas City, MO that has a large presence in the region but is located in a weak Furniture cluster
- We expect **Industry Specialization Risk**: the employment growth of the regional industry during/after the recession will be lower than the same industry in the US

Industry Located in a Weak Cluster: Wood Kitchen Cabinet Mfg Industry (NAICS-337110) in Furniture Cluster

	Industry, 2003		Cluster (outside *i*), 2003		Annual Industry Employment Growth		
	Employment	Specialization	Employment	Specialization	2003-07	2007-09	2009-11
Kansas City-Overland Park-Kansas City, MO-KS	1699	1.3	1806	0.4	1%	-27%	-10%
Average Across EAs					2%	-15%	-8%

Cluster Resilience: Agglomeration Channels

Resilience is facilitated by the presence of **suppliers, buyers, no. of businesses, patenting in the cluster**

Y=EA-Industry Annual Employment Growth, 2003-11 (N=497,236)

	Cluster Spec **Suppliers**	Cluster Spec **Buyers**	Cluster Spec **Establishments**	Cluster Spec **Patents**
$Year_{2004}$*Ln(Industry Employment) $_{irt-1}$	-0.050**	-0.049**	-0.057**	-0.043**
$Year_{2005}$*Ln(Industry Employment) $_{irt-1}$	-0.095**	-0.092**	-0.099**	-0.086**
$Year_{2006}$*Ln(Industry Employment) $_{irt-1}$	-0.081**	-0.080**	-0.087**	-0.074**
$Year_{2007}$*Ln(Industry Employment) $_{irt-1}$	-0.103**	-0.102**	-0.109**	-0.096**
$Year_{2008}$*Ln(Industry Employment) $_{irt-1}$	**-0.201****	**-0.198****	**-0.215****	**-0.189****
$Year_{2009}$*Ln(Industry Employment) $_{irt-1}$	-0.134**	-0.133**	-0.141**	-0.128**
$Year_{2010}$*Ln(Industry Employment) $_{irt-1}$	-0.113**	-0.112**	-0.120**	-0.107**
$Year_{2011}$*Ln(Industry Employment) $_{irt-1}$	-0.088**	-0.087**	-0.093**	-0.083**
$Year_{2004}$*Ln(Cluster Specialization) $_{icr2003}$	0.033**	0.035**	0.095**	0.022**
$Year_{2005}$*Ln(Cluster Specialization) $_{icr2003}$	0.047**	0.041**	0.100**	0.022**
$Year_{2006}$*Ln(Cluster Specialization) $_{icr2003}$	0.033**	0.028**	0.093**	0.010**
$Year_{2007}$*Ln(Cluster Specialization) $_{icr2003}$	0.041**	0.037**	0.102*	0.029**
$Year_{2008}$*Ln(Cluster Specialization) $_{icr2003}$	**0.070****	**0.066****	**0.205****	**0.037****
$Year_{2009}$*Ln(Cluster Specialization) $_{icr2003}$	0.042**	0.039**	0.107**	0.028**
$Year_{2010}$*Ln(Cluster Specialization) $_{icr2003}$	0.035**	0.030**	0.095**	0.019**
$Year_{2011}$*Ln(Cluster Specialization) $_{icr2003}$	0.029**	0.029**	0.082**	0.021**
EA-Year FEs (1,408 dummies)	Yes	Yes	Yes	Yes
Industry-Year FEs (6,207 dummies)	Yes	Yes	Yes	Yes

High Vulnerability U.S. Clusters: Low Employment Growth 2007-09

Cluster Name	Annual Employment Growth Avg 2007-2009	Employment $_{2006}$ (in 1,000)	Employment $_{2006}$ %	Employment Recovery $Employ_{2011}/Employ_{2006}$
Traded Employment	**-0.03**	**43425.0**	**100**	**0.93**
Trailers, Motor Homes, and Appliances	-0.24	180.3	0.4	0.59
Apparel	-0.17	225.4	0.5	0.59
Furniture	-0.17	536.1	1.2	0.58
Textile Manufacturing	-0.16	324.4	0.7	0.61
Wood Products	-0.15	527.1	1.2	0.62
Jewelry and Precious Metals	-0.15	39.7	0.1	0.65
Automotive	-0.15	1114.3	2.6	0.69
Footwear	-0.13	22.4	0.1	0.69
Recreational and Small Electric Goods	-0.12	253.7	0.6	0.69
Nonmetal Mining	-0.12	104.4	0.2	0.78
Leather and Related Products	-0.11	42.8	0.1	0.76
Forestry	-0.10	79.8	0.2	0.80
Plastics	-0.10	827.8	1.9	0.78
Vulcanized and Fired Materials	-0.09	308.7	0.7	0.75
Tobacco	-0.08	20.9	0.0	0.72
Financial Services	-0.07	2388.6	5.5	0.79
Upstream Metal Manufacturing	-0.07	450.4	1.0	0.84

51 national clusters vary in their vulnerability to the crisis and their recovery (Post-/Pre-recession Employment)

What Makes a Good Cluster?

- A **set of related industries** versus specialization in one narrow industry
- Industries and firms related by **various types of links**
  - Input
  - Output
  - Labor occupations and skills
  - Knowledge/technology
- Many clustered **firms that compete and cooperate**
  - Small and Large
  - Startup and Incumbent
- **Support Institutions**: Finance, universities, chamber of commerce, …
- E.g., Biopharmaceuticals and Medical Devices clusters in Boston

Explanatory Variables:

For each focal region-industry *i at year t*, we measure

- **Industry Employment** at *t-1*
- **Cluster Specialization based on employment** (excluding focal industry *i*) in 2003:

$$\frac{\sum_{j \in c, j \neq i} emp_{j,r}}{\sum_{j \in c, j \neq i} emp_{j,US}} \Big/ \frac{emp_r}{emp_{US}}$$

Surgical & Medical Instrument industry (NAICS-339112) in Medical Devices cluster in Salt Lake City, in 2003	
Industry Employment 2003	Cluster Specialization Employment (outside industry), 2003
3,760	**1.8**

- To Identify particular **agglomeration channels:**
- We also measure **Cluster Specialization based on No. of businesses**, **Employment in Upstream industries** and in **Downstream industries, and Patenting** (using the same cluster definition *c*)
- B2B vs B2C

Cluster Resilience: Various Types of Agglomeration Channels

Resilience is facilitated by the presence of **suppliers, buyers, businesses, patenting in the cluster**

Fig 2a. Coef. *Ln* ***Cluster Specialization Suppliers***

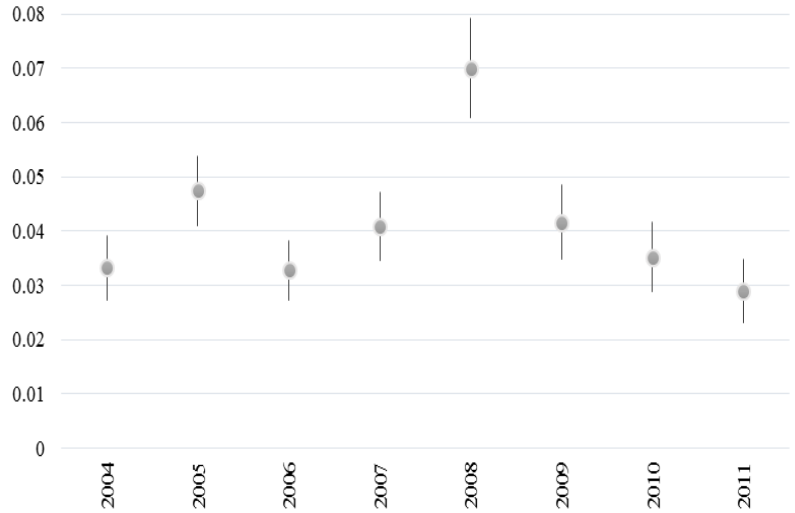


Fig 2b. Coef. *Ln Cluster Specialization* ***Buyers***

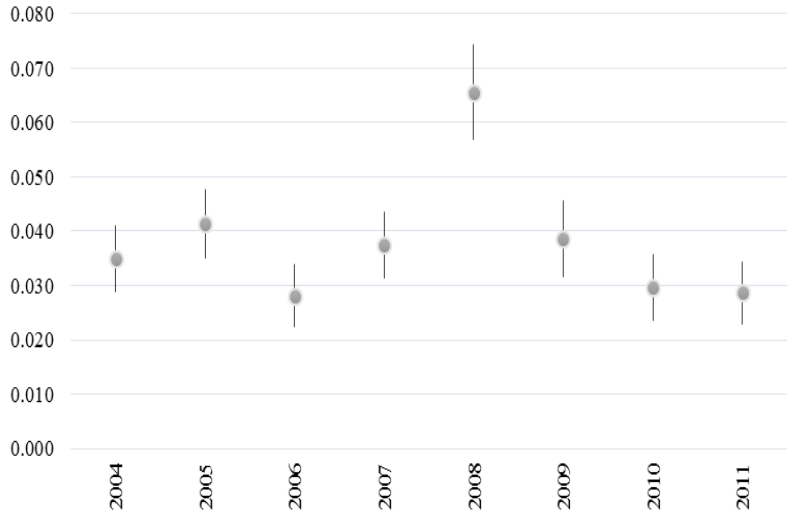


Fig 2c. Coef. *Ln* ***Cluster Specialization Establishments***

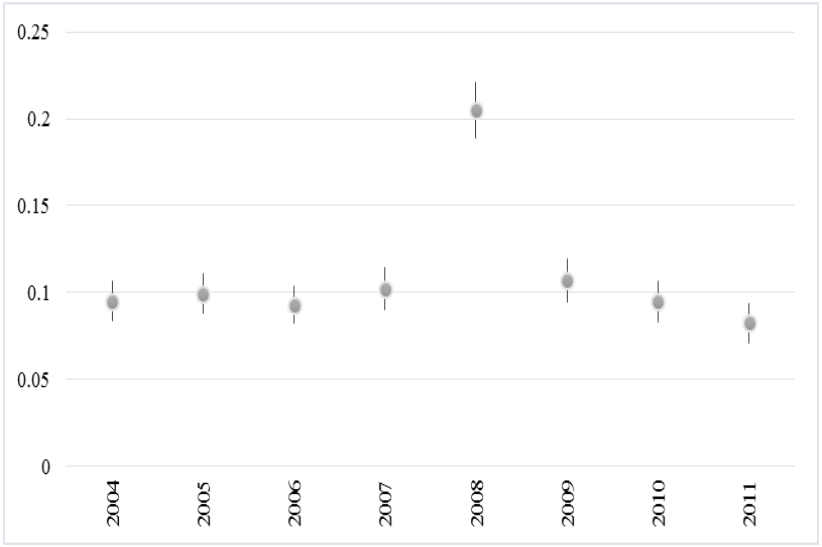
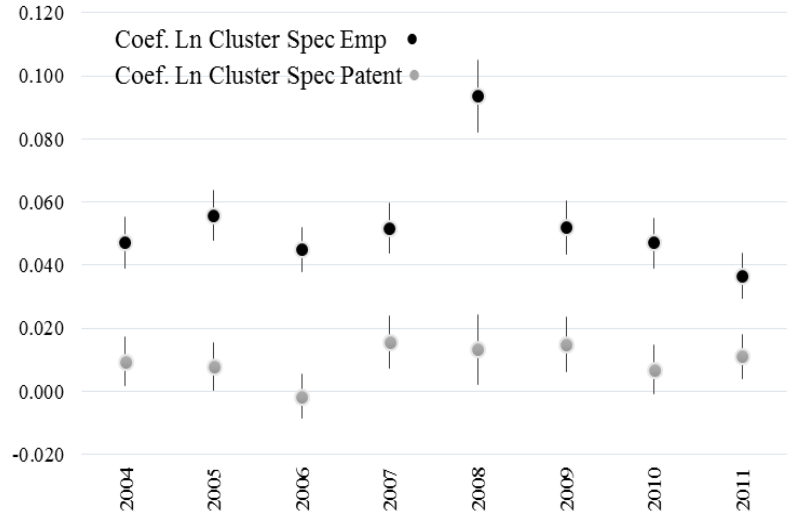


Fig 2d. Coef. *Ln Cluster Specialization* ***Emp & Patent***

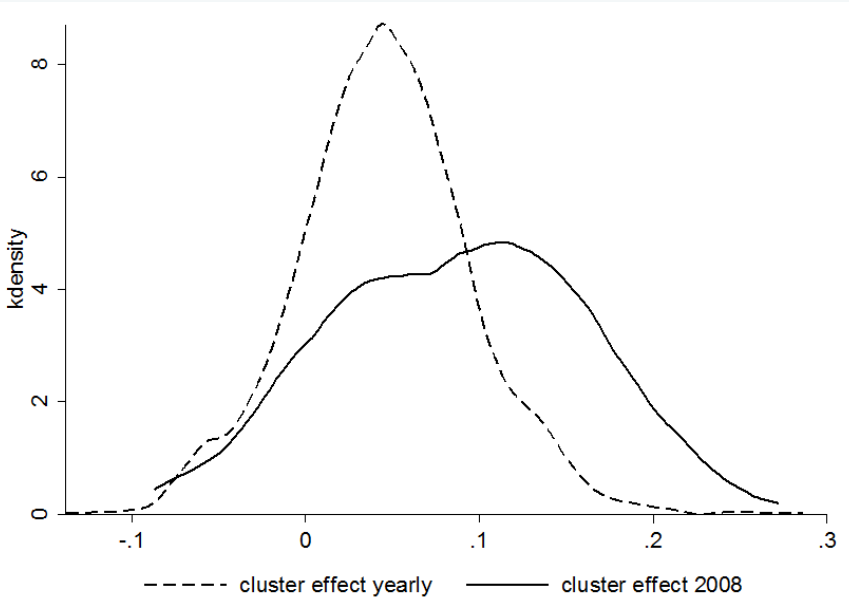


Findings: Region Heterogeneity

Exploring Region Heterogeneity: Estimated Convergence and Cluster Effects by EA *r* (δ_{rt} β_{rt})

- **EAs vary in many dimensions** that could affect the extent of economies of agglomeration during the recession: size, mfg intensity; labor regulations, specialization in Finance, …
- We allow the estimated convergence and cluster effects to vary for each of the 177 EAs
- **Findings are robust for most EAs**: cluster resilience

Fig. Coef. of *Ln Cluster Specialization*$_{Emp}$ (β_{rt}; 177 EAs by 8 years)



Findings: Cluster Heterogeneity