Paper to be presented at

DRUID15, Rome, June 15-17, 2015

(Coorganized with LUISS)

Clusters and the Great Recession

Mercedes Delgado
Temple Univ
Strategic Management
mdelgado@temple.edu

Michael E Porter
HBS
Strategy
mporter@hbs.edu

Scott Stern
MIT Sloan
TIES
sstern@mit.edu

Abstract

This paper evaluates the role of clusters in the resilience of regional employment to economic downturns. Agglomeration economies arise in regions specialized in clusters (groups of closely related and complementary industries operating within a particular region), and could mitigate the effects of economic recessions. However, an alternative hypothesis is that cluster specialization could propagate negative shocks among related industries, increasing the impact of recessions. This paper explores these issues over the period of the Great Recession. Using a newly available set of cluster definitions (Delgado, Porter, and Stern, 2015), we examine the annual employment growth in region-industries (6-digit NAICS) in the United States from 2003 through 2011. We find that larger regional industries overall experienced lower employment growth, but industries located in a strong cluster (in terms of employment and innovation) mitigated this convergence effect from 2003 to 2011, especially during the financial crisis. Our findings hold across many cluster categories, including those that experienced cluster-specific negative shocks (e.g., Financial Services). The results suggest that strong clusters not only improve regional employment growth over time, but improve the resilience of regional economies to downturns.

Jelcodes:R11,R12

Clusters and the Great Recession

February 23, 2015

This paper evaluates the role of clusters in the resilience of regional employment to economic downturns. Agglomeration economies arise in regions specialized in clusters (groups of closely related and complementary industries operating within a particular region), and could mitigate the effects of economic recessions. However, an alternative hypothesis is that cluster specialization could propagate negative shocks among related industries, increasing the impact of recessions. This paper explores these issues over the period of the Great Recession. Using a newly available set of cluster definitions (Delgado, Porter, and Stern, 2015), we examine the annual employment growth in region-industries (6-digit NAICS) in the United States from 2003 through 2011. We find that larger regional industries overall experienced lower employment growth, but industries located in a strong cluster (in terms of employment and innovation) mitigated this convergence effect from 2003 to 2011, especially during the financial crisis. Our findings hold across many cluster categories, including those that experienced cluster-specific negative shocks (e.g., Financial Services). The results suggest that strong clusters not only improve regional employment growth over time, but improve the resilience of regional economies to downturns.

1. Introduction

This paper examines the role of regional clusters in employment growth over the business cycle with a focus on the recent Great Recession (2007–2009). Clusters are groups of closely related and complementary industries operating within a particular region (Porter, 2003). They contain a mix of industries related by various linkages (knowledge, skills, inputs, demand, and others) and supporting institutions (financial, training, trade, standard setting, or educational). Common examples of clusters include Biopharmaceuticals in Boston or Financial Services in New York City.

The presence of clusters in a region could have differing effects on regional economies that face negative shocks. On the one hand, agglomeration economies arise in regions specialized in strong clusters (see e.g., Porter, 1998; Feldman and Audretsch, 1999; Rosenthal and Strange, 2004; Glaeser and Kerr, 2009; Delgado, Porter, and Stern, 2010, 2014). The presence of strong clusters in a region could make the regional economy more resilient to shocks. On the other hand, cluster specialization could increase a region's vulnerability to negative shocks when the shocks propagate among related industries, and could increase the duration and depth of a recession (Acemoglu et al., 2013).

We study the role of clusters on employment performance over the business cycle, and examine whether industries in strong clusters experience faster growth in terms of employment before, during, and/or after the recession period than industries located in weak clusters. The focus on employment growth is important since the Great Recession destroyed many jobs and has been characterized as the slowest job recovery recession (Greenspan, 2010).

We investigate these ideas using a new publicly available dataset developed by the U.S. Cluster Mapping Project (USCMP). This database includes a set of U.S. Benchmark Cluster Definitions (BCD) developed in Delgado, Porter, and Stern (2014). They group related industries into clusters based on the strength of input-output links, shared labor occupations, and co-location patterns of industries based on employment and establishments.[1] The BCD delineates 51 clusters

[1] The set of U.S. Benchmark Cluster Definitions (BCD) is available at the U.S. Cluster Mapping website at http://clustermapping.us/content/cluster-mapping-methodology.

incorporating 778 traded industries (6-digit NAICS) covering services and manufacturing.[2] Data from the County Business Patterns (CBP) dataset is coded with the BCD to map the economic geography of 177 mutually exclusive Economic Areas (EAs) in the U.S. (as defined by the Bureau of Economic Analysis) including numerous attributes of cluster composition and performance at the region-cluster-industry level.

We find that strong regional clusters improve the resilience of employment across the business cycle. Conditioning on region-industry size, the industries in regions with stronger clusters of related industries experienced higher employment growth during the recession years (i.e., lower vulnerability to the negative shock), as well as faster recovery in the form of higher employment growth after the recession.

The remainder of the paper is organized as follows: Section 2 describes the recent Great Recession and the role of clusters in regional economic performance in the business cycle. Section 3 presents the empirical framework. Section 4 explains the data and the cluster definitions. Section 5 discusses the findings. A final section concludes.

2. The Role of Related Economic Activity During the Great Recession

Recent papers assess the origins of the recent Great Recession. These studies examine whether the recession was the result of changes in the demand for credit due to productivity shocks or to changes in the supply of credit. One conclusion is that the crisis originated with an increase in the supply of credit, which resulted in households becoming more leveraged (Mian and Sufi, 2010).

The NBER's Business Cycle Dating Committee determined that the recession years were December 2007 through June 2009 (NBER), and that the main GDP contraction occurred in December 2008. The economic crisis started earlier in the housing sector (2006) and then affected the financial and manufacturing sectors.

Regardless of its origins, the recent Great Recession has been almost uniquely characterized as having the slowest job recovery of any previous recession (Greenspan, 2010). More than six million jobs were destroyed during 2007-2009 in both the traded and local economy, and as of 2011 traded employment is still 94% below the pre-recession levels (Table A2). Because

[2] Traded industries are those which concentrate in particular regions and sell products or services across regions and countries, in contrast to local industries serving primarily the local market whose employment is evenly distributed across regions (Porter, 2003; Delgado, Bryden and Zyontz, 2014).

of the large job destruction and slow job recovery, how the presence of related economic activity relates to region-industry employment growth during the business cycle becomes a very important question. To our knowledge, this is the first paper to examine the role of clusters of related economic activity during an economic recession for a comprehensive set of traded industries and across all the U.S. regions and their clusters.

Possible Differing Effects of Clusters During the Great Recession

To date, most studies on the Great Recession have focused on the regional level, but there has been little examination of a set of narrowly defined regional industries. This paper examines the role of regional clusters – groups of closely related industries operating in a particular region – in employment growth during the business cycle with a focus on the recent Great Recession.

When faced with a negative economic shock, the presence of clusters in a region could have differing effects on the economic activity of industries that are part of the cluster. In the first instance, clusters could mitigate the effects of the negative shock. Agglomeration economies arise in regional clusters of related economic activity (see among others, Feldman and Audretsch, 1999; Porter, 2003; Feser, Renski, and Goldstein, 2008; Glaeser and Kerr, 2009; Delgado, Porter, and Stern, 2010, 2014; Neffke, Henning, and Boschma, 2011), and the close interconnection of industries (and associated firms) could facilitate a faster recovery from a recession. In the second instance, clusters could actually worsen the effect of the shock. For example, negative shocks could propagate among related industries, and could increase the depth of a recession (Acemoglu et al., 2013).

In the context of the recent Great Recession, we explore which regional industries were more resilient in terms of employment growth, and assess the role that clusters play for these trends. Drawing on prior work, resilience is defined as lower vulnerability to shocks (higher growth during a recession) and/or faster recovery (higher growth post-recession).

Our main hypothesis is that during an economic crisis, after controlling for the convergence effect at the region-industry level, the growth rate of employment in a regional industry will be increasing in the strength (i.e., relative presence) of the regional cluster within which that industry operates. We expect to see this reflected in lower vulnerability during the recession and/or or faster recovery in terms of employment for a region-industry that participates in a strong cluster.

The above hypothesis suggests that strong regional clusters will improve the associated region's resilience to (economy-wide) shocks, where we define resilience as lower vulnerability or faster recovery. The mechanism that brings about this hypothesis lies in economies of agglomeration (Marshall, 1920). Regions specialized in clusters have been shown to give rise to agglomeration economies among the related industries through shared technologies, skills, input-output linkages, social capital, and other links. This provides regions that have strong clusters with more efficient labor markets; better access to complementary knowledge and innovation opportunities; better access to inputs and demand; and stronger supporting institutions, including (but not limited to) financial, training, trade associations, and cluster initiatives. The strong connections within clusters in a location prior to the shock may help to mitigate (or delay) the negative shock through long-term contracts with clients, more efficient labor markets, trust and altruism, and institutions for collaboration that may facilitate credit. In contrast, weak clusters may grow quickly during a boom, but will likely suffer more during a negative shock.

There is some prior evidence for these positive effects, including the resilience of Silicon Valley (Saxenian, 1994; Bresnahan and Gambardella, 2004) and the recent example of mechanical engineering in Germany (Wrobel, 2013), where collaboration and altruism among cluster members were observed during the economic crisis. It also has been shown that companies can respond better to uncertainty in demand if their regions have more flexible supplier-buyer networks versus vertical integration (e.g., Saxenian,1994; Kranton and Minehart 2000; Helper, MacDuffie, and Sabel 2000), and these types of collaborations are more likely in stronger regional clusters.

However, there is also theoretical work suggesting that just the opposite may be true – that specialization in related economic activity could cause a region to feel the effects of a negative shock more acutely (Acemoglu et al., 2013). A negative shock can propagate among related industries and increase the depth and duration of the crisis. Acemoglu et al. (2013) developed a theoretical model that shows that non-trivial input-output linkages between different sectors within the economy can increase the frequency of large economic downturns.[3]

Then, clusters could amplify a negative shock and prolong the recession. For example, industries and firms that require high external financing suffered a large negative shock during the recent crisis; subsequently, they could negatively affect other related industries. Because a shock

[3] They show that an economy with non-trivial intersectoral input-output linkages that is subject to thin-tailed productivity shocks may exhibit deep recessions as frequently as economies that are subject to shocks with significantly heavier tails.

can propagate within a cluster, we expect within-cluster outcomes to be correlated. Thus, a negative (positive) shock in an industry will affect more industries within the same cluster than outside the cluster.

To better understand the mechanisms that influence the degree of resilience of regional clusters, we will study how the performance during the economic crisis varies by type of cluster: knowledge-intensive clusters (e.g., Education and Knowledge), energy clusters (Oil and Gas Production and Transportation), clusters that tend to sell to the federal government (e.g., Aerospace and Defense), service-oriented clusters with a focus on selling to other businesses (e.g., Business Services), clusters that focus on final consumption (e.g., Apparel), enabling clusters (e.g., Distribution and Ecommerce), and clusters that experienced sector-specific shocks during the recession (e.g., Financial Services).

3. Econometric Specification

To examine the role of clusters during the business cycle, we utilize a dataset of annual region-industry growth during 2003–2011 for 177 regions (Economic Areas) and 778 traded industries (6-digit NAICS-2007). We condition on region-industries where we observe 10 or more employees as of 2003, and allow for exit of regional industries resulting in a sample of 497,236 observations.

Drawing on Delgado, Porter, and Stern (2014), to separate convergence and agglomeration forces in regional industry growth, we distinguish between the level of employment in a particular regional industry and the specialization in the cluster around that region-industry. We control for the average annual growth of the industry and the region by including industry-year and region-year fixed effects. Our core econometric specification for region-industry employment growth is:

$$\ln\left(\frac{\text{Industry Employment}_{icr,t}}{\text{Industry Employment}_{icr,t-1}}\right) = \alpha_0 + \delta_t \text{Year}_t * \ln(\text{Industry Employment}_{icr,t-1}) + \beta_t \text{Year}_t * \ln(\text{Cluster Specialization}^{\text{outside i}}_{\text{Employ, } icr,t-1}) + \alpha_{it} + \alpha_{rt} + \varepsilon_{icrt}. \quad (1)$$

The dependent variable is annual employment growth of the industry i in cluster c in region (Economic Area (EA)) r. To capture the potential convergence forces at the region-industry level, we include (log of) regional industry employment (Industry Employment) at year t-1. We allow

the estimated effect to vary yearly (δ_t) and expect convergence in employment at the region-industry level ($\delta_t < 0$).

To capture the cluster-driven agglomeration forces, we include a measure of cluster strength (i.e., relative presence) of the cluster surrounding the region-industry (Cluster Specialization) in year t-1. The core variable is the employment specialization of the region in the set of closely related industries constituting the cluster, excluding the focal region-industry (see Section 4 for a precise definition of this variable). We allow the estimated effect to vary yearly and expect that cluster specialization will facilitate region-industry growth even during the recession years ($\beta_t > 0$).[4]

To illustrate the unit of observation and explanatory variables, consider the Pharmaceutical Preparation Manufacturing industry (NAICS-325411) in the Biopharmaceuticals cluster in the Boston-Worcester-Manchester, MA–NH region. For this region-industry, we look at the region's employment in the industry (Industry Employment) and the region's specialization in related industries in Biopharmaceuticals (excluding industry NAICS-325411; Cluster Specialization variable).[5]

Using equation (1), we compare the growth rates of EA-industries, accounting for differences in the annual growth of the region and the national industry. We estimate the EA-industry growth equation using OLS; to account for correlation of the error terms across industries within a regional cluster, the standard errors are clustered by EA-cluster.

Analysis by individual cluster. We allow the estimated convergence and cluster effects in equation (1) to vary for each of the 51 clusters (δ_{ct}, β_{ct}) because clusters vary in many dimensions (national size, presence of manufacturing and service activity, technology, external financing dependence, and other attributes) that could influence the extent of economies of agglomeration during the economic crisis.

Clusters also can vary in the timing and the extent by which they were affected by the financial crisis. While for many clusters, the Great Recession was an economy-wide shock that reduced demand, clusters in finance and related activities experienced a sector-specific shock.

[4] Alternatively, in the sensitivity analysis we specify the Cluster Specialization variable at the initial period, 2003.

[5] The Biopharmaceuticals cluster includes the following NAICS codes: NAICS-325411 Medicinal and Botanical Manufacturing; NAICS-325411 Pharmaceutical Preparation Manufacturing; NAICS-325414 Biological Product (except Diagnostic) Manufacturing; and NAICS-325413 In-Vitro Diagnostic Substance Manufacturing. See Figures A1 and A2.

Thus, in the sensitivity analysis, we also examine the Financial Services cluster and its more closely related clusters: Insurance Services; Business Services; and Marketing, Design, and Publishing (see Table 3).

Analysis by individual region. We also allow the estimated convergence and cluster effects to vary for each of the 177 EAs (δ_{rt}, β_{rt}). We then can assess whether the effect is driven by region-specific attributes (size, specialization in Finance, firm composition, overall cluster composition etc.).

4. Data and Cluster Definitions

Data from the County Business Patterns (CBP) dataset is coded with cluster definitions drawn from the U.S. Cluster Mapping Project.[6] The CBP dataset is a publicly available database that provides annual county-level measures of private-sector non-agricultural employment, establishments, and payroll at the level of six-digit NAICS codes (which we refer to as industries).[7] The data is aggregated to the region-industry level and region-cluster, using six-digit NAICS codes as the primary industry unit, and economic areas (EAs as defined by the Bureau of Economic Analysis) as the main geographic unit.[8]

We use the Delgado, Porter, and Stern (2014) set of U.S. Benchmark Cluster Definitions (BCD), which groups industries that are related based on input-output links, labor occupation links, and the co-location patterns of employment and establishments. The BCD groups 778 (six-digit NAICS) industries into 51 mutually exclusive clusters (see Table A2 for the list of clusters).

The analysis focuses on the 2003–2011 period. It is important to note that the CBP annual employment data corresponds to mid-March. The recession period using this data corresponds to 2007–2009, with the biggest decline in employment growth in 2008 and 2009 (see e.g., Fort et al., 2013).

[6] The U.S. Cluster Mapping website (http://clustermapping.us/) is supported in part by the U.S. Economic Development Administration, U.S. Department of Commerce.

[7] One problem with the CBP data is that cell suppression is used to protect the confidentiality of firms in a certain geography-industry with a small presence of firms. When employment data is suppressed, a range is reported. In our data, we utilize the mid-point in the range.

[8] There are 179 EAs covering the entirety of the United States. To minimize concerns about differences in transportation costs, we exclude the Alaska and Hawaii EAs. The boundaries of EAs are drawn to reflect meaningful economic regions, and have been highly stable over time (Johnson and Kort, 2004).

Sample Description and Dependent Variable

Our dependent variable is EA-industry annual growth in employment (Industry Employment Growth) over the period 2003–2011. The empirical analysis focuses on explaining the growth of existing regional industries (with at least 10 employees) as of 2003. To compute the employment growth rate, we scale the region-industry-year employment data by adding one employee: $\ln(1+\text{Employment}_{ir,t} / 1+\text{Employment}_{ir,t-1})$. To allow for exits of region-industries, the annual employment growth variable is coded as missing if region-industry employment at t and t-1 are both zero.

Explanatory Variables

To examine the impact of region-cluster strength on the growth of regional industries, we need a measure of cluster specialization. We draw on prior work that uses location quotients (LQ) as a primary measure of regional cluster specialization (Porter, 2003, among others).

Cluster Specialization. For a particular EA-industry, the employment specialization of the EA in cluster c is measured by the share of regional employment in the regional cluster (outside the industry) as compared to the share of U.S. employment in the national cluster (outside the industry): $\text{Cluster Specialization}_{\text{Employ},icr,2003} = \dfrac{(1+\text{employ}_{c,r}^{\text{outside i}}) \big/ \text{employ}_{r}}{\text{employ}_{c,US}^{\text{outside i}} \big/ \text{employ}_{US}}$. It is useful to note that in our model (equation 1), the independent variation utilized in the regressions comes from the employment within a given cluster. In our sample, the average $\text{Cluster Specialization}_{\text{Employ}}$ is 1.262 (and the standard deviation is 2.116; Table 1).

Economies of agglomeration channels include firms as well as employees. The presence of numerous establishments can facilitate inter-firm interactions that result in spillovers (Glaeser and Kerr, 2009). To compare this we also compute cluster specialization based on the count of establishments to help capture inter-industry linkages that are facilitated by the number of businesses in a location ($\text{Cluster Specialization}_{\text{Estab}}$). Finally, we define the specialization of a regional cluster in terms of the patenting activity ($\text{Cluster Specialization}_{\text{Patent}}$) to try to capture knowledge spillovers.

We also control for the average size of establishments in the regional cluster in the base year ($\text{Establishment Size in Cluster}_{2003}$) to try to account for the presence of large firms. Prior

studies have shown that large firms can be more resilient to financial shocks than small firms (Raghuram and Zingales, 1998; Fort et al. 2013).[9]

5. Results

The findings suggest that strong regional clusters facilitate employment resilience and growth during the recession years. On average, from 2003-2011 employment losses are lower for regional industries participating in strong clusters. The main findings are reported in Table 2, which examines the role of cluster strength in the employment growth of the regional industries that constitute the cluster. Model 2-1 estimates the average annual effect of Industry Employment and Cluster Specialization. Consistent with the findings of Delgado, Porter, and Stern (2014), we find that cluster strength improves the employment growth of the industries that constitute the cluster.

Model 2-2 estimates our core specification (equation 1), which allows the coefficients to vary by year. We find that there is as expected EA-industry convergence in employment every year, meaning that larger regional industries experience lower growth. The estimated convergence effect is significantly larger in 2008 than in any other year (at 1% level), and by 2011 the convergence effect is similar to the pre-crisis one. Figure A3 shows the estimated convergence effect by year (and the 95% confidence intervals). In 2008, the estimated convergence in region-industry employment was -0.206.

Conditioning on the region-industry size effect, industries participating in a stronger cluster environment register higher annual growth. The estimated cluster effect is positive and significant each year, and is significantly larger during 2008. This suggests that cluster agglomeration mitigates the convergence effect during the whole business cycle in 2003–2011, and is strongest during the deepest recession year. Figure A3 shows the estimated cluster effect by year. In 2008, the estimated coefficient is 0.101. A one standard-deviation increase above the mean in cluster specialization is then associated with a 9.9 percentage point increase in the expected annual employment growth of region-industries in 2008.[10] The positive cluster effect declines after 2008 is similar to that of the pre-recession years (2005, 2006) by 2011.

[9] Raghuram and Zingales (1998) categorize industries with high external financing dependence, including drugs, plastics, and electric machinery. Further, they find that external financing dependence is significantly higher for smaller companies.

[10] The estimated 9.9% magnitude effect is computed as 100*(Ln(3.41)-Ln(1.28))*0.101.

To rule out serial correlation, in model 2-3 we estimate the employment growth in 2007–2008 with the explanatory variables specified in 2007. The estimated coefficients for that year are essentially the same as in the time-series model (model 2-3 versus model 2-2 in Table 2). This is also the case for the other yearly estimates. The findings are also robust to a specification that focuses on the 2007-2011 period and adds a control for the pre-recession employment trend of the regional cluster the industry belongs to (i.e., the average annual employment growth of the regional cluster (outside the industry) during 2003-2011).

Cluster and Region Heterogeneity. Table A2 shows that national clusters vary greatly in the extent of the negative shock and the recovery. Clusters that experienced larger negative shocks (Average Employment Growth in 2008, 2009), include Trailers, Motor Homes, and Appliances; Apparel; Furniture; Textile Manufacturing; Wood Products; Jewelry and Precious Metals; and Automotive. Clusters in which the job recovering occurred by 2011(Post-Recession/Pre-Recession Employment is greater than 1) include service clusters: Environmental Services; Business Services; as well as Education and Knowledge Creation; Medical Devices; and Energy-related clusters. Many of the recovered clusters are those that experienced a lower negative economic shock and recovery was easier.

To test the robustness of our findings across cluster categories, we estimate equation (1) allowing the coefficients of Industry Employment and Cluster Specialization to be cluster-specific. The findings in model 2-2 are robust across most cluster categories (Figure 1), including some national clusters that experienced large negative shocks, such as Financial Services. The findings are also robust across most regions (Figure 2).

Overall, the results suggest cluster agglomeration economies lead to resilience during negative economic shocks. These facilitate the creation and/or sustainability of employment in the regional industries that constitute the cluster. The industries in regions with stronger clusters were less vulnerable to negative economic shocks (i.e., higher employment growth during the recession) and also saw faster recovery in the form of higher growth after the recession.

Unobserved selection factors may also be impacting this cluster effect, such as higher quality (larger) firms gravitating to strong regional clusters. The analysis suggests that the presence of larger firms in a cluster is not driving the effect. The findings hold when we control for the average size of establishments in the regional clusters as well as when we measure cluster strength based on the relative presence of businesses ($\text{Cluster Specialization}_{\text{Establishment}}$). We could further

explore the role of firm composition by testing a control group of regional clusters with a similar size distribution of firms pre-recession (i.e., similar relative presence of large firms), but with low versus high cluster specialization.

5.1 Set of Robustness Tests

The resilience of regional clusters to economic recessions is robust to using alternative samples. First, we drop the financial services and automotive clusters since they received significant bailout money from the Government during the crisis. Second, we drop the weakest regional clusters (location quotient less than 1) to assess that the main effect is not simply driven by the relatively larger vulnerability of the weakest clusters, but rather by the resilience of stronger clusters. Third, we drop the smallest U.S. industries or alternatively weigh the observations based on the size of their national industry (i.e., weigh more large industries) and the results only change trivially. Our main finding is also robust to using alternative cluster specialization variables: cluster specialization specified in the initial period 2003 (versus specified at t-1), and cluster specialization measured based on the number of establishments (model 2-4 in Table 2) or patenting (model 2-5 in Table 2). We also use alternative specifications that exclude the EA-Year and/or Industry-Year dummies. Finally, the findings are robust to examining regional industry growth in the number of businesses (count of establishments; Table A3), suggesting that the resilience of stronger clusters in terms of employment is not at the expense of business creation.

6. Conclusions

We find that larger regional industries experience lower growth, but that a strong cluster environment improves the resilience of employment across the business cycle from 2003–2011. These findings are robust across many cluster categories and regions.

To explore the question further, we could examine the role of specific channels and mechanisms that drive cluster agglomerations in employment creation during a recession. The industry composition of a regional clusters could play a role: the depth of the clusters (a diversity of related industries present versus specialization in a few industries within the cluster) as well as the presence of related clusters in the region and in nearby regions (versus specialization in one cluster or in a set of unrelated clusters). The firm composition of a cluster could also help explain resilience: the relative presence of large versus small and young firms (Greenstone, Hornbeck, and

Moretti, 2008; Fort et al., 2013), of geographically diversified versus specialized firms (Alcacer and Delgado, 2015), and of supply chain versus downstream firms.

While our analysis focuses on the traded economy, spillovers between the traded and local economy could be at play as well. Strong traded clusters may help the recovery of the local economy, or vice-versa. We could examine the influence of the cluster composition of a region on regional performance.

At the firm level, what type of firms did better during the recession? Did diversified firms with a presence in multiple industries within a cluster perform better in terms of employment and innovation during the recession than single-industry firms (Baptista and Swann, 1999)? Did multi-location firms perform better than single-unit ones? Relatedly, what types of management practices helped firms deal with the crisis?

Finally, an important question is the role of economic downturns on the long-term cluster composition of regions. Clusters that experienced firm loss and a relevant loss of employment in core industries may need to re-invent themselves and undergo major changes to survive (see e.g., Bathelt and Boggs, 2003).

7. References

Alcacer, J. and M. Delgado, 2015, "Spatial Organization of Firms and Location Choices through the Value Chain," Management Science, forthcoming.

Acemoglu D., A. Ozdaglar, and A. Tahbaz-Salehi, 2013, "The Network Origins of Large Economic Downturns," manuscript at http://economics.mit.edu/files/8915.

Barro, R.J. and X. Sala-i-Martin, 1991, "Convergence across States and Regions," Brookings Papers on Economic Activity 1, pp. 107–82.

Bathelt, H. and J.S. Boggs, 2003, "Toward a Reconceptualization of Regional Development Paths: Is Leipzig's Media Cluster a Continuation of or a Rupture with the Past?," Economic Geography 79, pp. 265–93.

Bresnahan, T., A. Gambardella (eds.), 2004, Building High-Tech Clusters. Silicon Valley and Beyond. Cambridge University Press, New York.

Delgado, M., R. Bryden, and S. Zyontz, 2014, "Categorization of Traded and Local Industries in the U.S. Economy," Mimeo, at http://www.clustermapping.us/.

Delgado, M., M.E. Porter, and S. Stern, 2015, "Defining Clusters of Related Industries," Journal of Economic Geography, forthcoming.

Delgado, M., M.E. Porter, and S. Stern, 2014, "Clusters, Convergence, and Economic Performance," Research Policy, 43 (10), pp. 1785–1799.

Delgado M., M.E. Porter, and S. Stern, 2010, "Clusters and Entrepreneurship," Journal of Economic Geography, 10 (4), pp. 495–518.

Feldman, M.P. and Audretsch, D., 1999, "Innovation in Cities: Science-based Diversity, Specialization, and Localized Competition," European Economic Review 43, pp. 409–29.

Findeisen, S. and J. Südekum, 2008, "Industry Churning and the Evolution of Cities: Evidence for Germany," Journal of Urban Economics, 64 (2), pp. 326–339.

Fort, T.C., J. Haltiwanger, R.S. Jarmin, and J. Miranda, 2013, "How Firms Respond to Business Cycles: The Role of Firm Age and Firm Size," IMF Economic Review, 61 (3), pp. 520–559.

Glaeser, E.L., and W.R. Kerr, 2009, "Local Industrial Conditions and Entrepreneurship: How Much of the Spatial Distribution Can We Explain?," Journal of Economics and Management Strategy, 18 (3), pp. 623–663.

Greenspan, A., 2010. "The Crisis," Brookings Papers on Economic Activity, pp. 201–261.

Greenstone M., R. Hornbeck, and E. Moretti, 2008, "Identifying Agglomeration Spillovers: Evidence from Million-Dollar Plants," NBER Working Paper No. 13833.

Haltiwanger, J., R.S. Jarmin, and J. Miranda, 2009, "Who Creates Jobs? Small vs. Large vs. Young," Working Paper.

Helper, S., J.P. MacDuffie, and C.F. Sabel, 2000, Pragmatic Collaborations: Advancing Knowledge While Controlling Opportunism, Industrial and Corporate Change, 9(3), 443–483.

Johnson K.P. and J.R. Kort, 2004, "2004 Redefinition of the BEA Economic Areas," at http://www.bea.gov/scb/pdf/2004/11November/1104Econ-Areas.pdf.

Kranton, R.E. and D. Minehart, 2000, Network versus Vertical Integration, Rand J. Econ. 31(3), 570–601.

Mian A. and A. Sufi, 2010. "The Great Recession: Lessons from Microeconomic Data," American Economic Review: Papers & Proceedings, 100 (2), 1–10.

Marshall, A., 1920, Principles of Economics, London: MacMillan.

NBER, "US Business Cycle Expansions and Contractions." Available at: http://www.nber.org/cycles/cyclesmain.html (last accessed 2/28/2014).

Porter, M.E., 1990, The Competitive Advantage of Nations, Free Press, New York.

Porter, M.E., 1998, "Clusters and Competition: New Agendas for Companies, Governments, and Institutions," in M.E. Porter (ed.), On Competition, Harvard Business School Press, Boston, pp. 197–299.

Porter, M.E., 2003, "The Economic Performance of Regions," Regional Studies, 37, pp. 549-578.

Raghuram and Zingales, 1998, "Financial Dependence and Growth," AER, pp. 559–586.

Saxenian, A., 1994, Regional Advantage: Culture and Competition in Silicon Valley and Route 128, Cambridge, MA: Harvard University.

Sorenson, O. and P.G. Audia, 2000, The Social Structure of Entrepreneurial Activity: Geographic Concentration of Footwear Production in the United States, 1940–1989, Amer. J. Sociology, 106(2), 424–462.

Storper, M., 1995, The Resurgence of Regional Economies, Ten Years Later: The Region as a Nexus of Untraded Interdependencies, Eur. Urban and Regional Studies 2, 191–221.

Wrobel, M., 2013, "One for all and all for one: Cluster, employment, and the global economic crisis. Evidence from the German mechanical engineering industry," Papers in Regional Science, 92(4).

Table 1: Variables' Definitions and Descriptive Statistics, 2003–2011 (N=497,236)

Variables	Definitions	Mean (Std)
Industry Employment Growth$_{irt}$ *	Economic Area (EA)-industry annual employment growth 2003–2011; $\ln(1+emp_t/1+emp_{t-1})$	-0.062 (0.666)
Industry Employment Growth$_{ir2004}$	EA-industry employment growth 2003–04	-0.085 (0.617)
Industry Employment Growth$_{ir2005}$	EA-industry employment growth 2004–05	-0.052 (0.638)
Industry Employment Growth$_{ir2006}$	EA-industry employment growth 2005–06	-0.019 (0.573)
Industry Employment Growth$_{ir2007}$	EA-industry employment growth 2006–07	-0.054 (0.640)
Industry Employment Growth$_{ir2008}$	EA-industry employment growth 2007–08	-0.110 (0.941)
Industry Employment Growth$_{ir2009}$	EA-industry employment growth 2008–09	-0.099 (0.669)
Industry Employment Growth$_{ir2010}$	EA-industry employment growth 2009–10	-0.058 (0.604)
Industry Employment Growth$_{ir2011}$	EA-industry employment growth 2010–11	-0.015 (0.558)
Industry Employment $_{irt-1}$	EA-industry employment at t-1	695.431 (3,359.982)
Cluster Specialization $_{Employment\ icrt-1}$	EA-cluster employment specialization (outside the industry) at t-1	1.277 (2.133)
Cluster Specialization $_{Establishments\ icrt-1}$	EA-cluster establishment specialization (outside the industry) at t-1	1.171 (1.405)
Cluster Specialization $_{Patents\ crt-1}$	EA-cluster patent specialization at t-1	1.384 (1.604)
Establishment Size in Cluster $_{icr2003}$	EA-cluster employment per establishment (outside the industry) at 2003	40.581 (61.081)

Notes: The employment indicators are based on CBP data. The CBP employment data is collected in mid-March of each year. *The core sample uses EA-industries with positive employment as of the initial period 2003; if employment at t and t-1 are both zero, the observation is dropped.

Table 2: EA-Industry Annual Employment Growth, 2003–2011

	EA-Industry Annual Employment Growth				
		Cluster Specialization in Employment		Cluster Specialization in Establishments	Cluster Specialization in Patents
			2007–08		
	2-1	2-2	2-3	2-4	2-5
Ln(Industry Employment) $_{t-1}$	-0.113**				
Ln(Cluster Specialization) $_{t-1}$	0.059**				
$Year_{2004}$*Ln(Industry Employment) $_{t-1}$		-0.053**		-0.057**	-0.043**
$Year_{2005}$*Ln(Industry Employment) $_{t-1}$		-0.096**		-0.099**	-0.086**
$Year_{2006}$*Ln(Industry Employment) $_{t-1}$		-0.083**		-0.088**	-0.083**
$Year_{2007}$*Ln(Industry Employment) $_{t-1}$		-0.106**		-0.110**	-0.074**
$Year_{2008}$*Ln(Industry Employment) $_{t-1}$		-0.206**	-0.206**	-0.215**	-0.189**
$Year_{2009}$*Ln(Industry Employment) $_{t-1}$		-0.137**		-0.141**	-0.127**
$Year_{2010}$*Ln(Industry Employment) $_{t-1}$		-0.116**		-0.119**	-0.107**
$Year_{2011}$*Ln(Industry Employment) $_{t-1}$		-0.090**		-0.094**	-0.083**
$Year_{2004}$*Ln(Cluster Specialization) $_{t-1}$		0.049**		0.095**	0.016**
$Year_{2005}$*Ln(Cluster Specialization) $_{t-1}$		0.058**		0.098**	0.014**
$Year_{2006}$*Ln(Cluster Specialization) $_{t-1}$		0.047**		0.094**	0.010**
$Year_{2007}$*Ln(Cluster Specialization) $_{t-1}$		0.058**		0.103**	0.018**
$Year_{2008}$*Ln(Cluster Specialization) $_{t-1}$		0.101**	0.101**	0.205**	0.034**
$Year_{2009}$*Ln(Cluster Specialization) $_{t-1}$		0.058**		0.108**	0.021**
$Year_{2010}$*Ln(Cluster Specialization) $_{t-1}$		0.051**		0.094**	0.013**
$Year_{2011}$*Ln(Cluster Specialization) $_{t-1}$		0.043**		0.083**	0.016**
EA-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.086	0.091	0.130	0.093	0.086
Obs.	497,236	497,236	62,340	497,236	497,236

Notes: ** refers to coefficients significant at 1% levels. Standard errors are clustered by EA-cluster. Model 2-3 is cross-sectional with EA and Industry FEs. EA-Year Fixed Effects (1,408 dummies) and Industry-Year Fixed Effects (6,207 dummies)

Figure 1: EA-Industry Employment Growth: Convergence and Cluster Effects by Cluster Type and Year (2004–2011)

Fig 1a: Coefficient of Ln Industry Employment (δ_{ct} ; 51 clusters, 8 years)

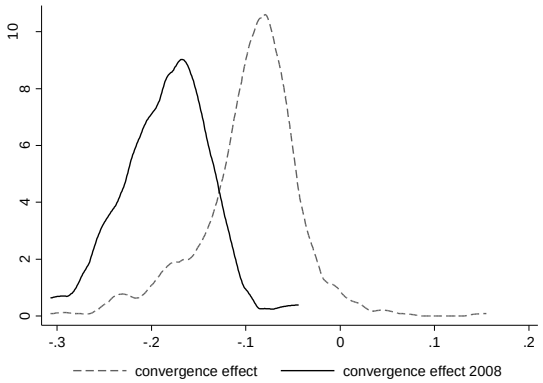
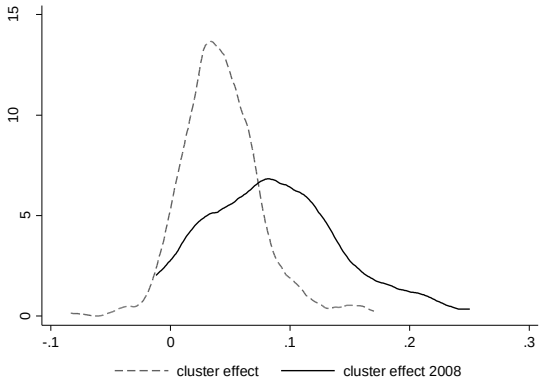


Fig 1b: Coefficient of Ln Cluster Specialization$_{Employ}$ (β_{ct} ; 51 clusters by 8 years)



Note: The graphs plot the Kernel density of the estimated coefficients from estimating equation (1), allowing the Ln Industry Employment and Ln Cluster Spec coefficients to vary for each cluster-year.

Figure 2: EA-Industry Employment Growth: Convergence and Cluster Effects by EA-Year

Fig 1a: Coefficient of Ln Industry Employment (δ_{rt} ; 177 EAs; 2004–2011)

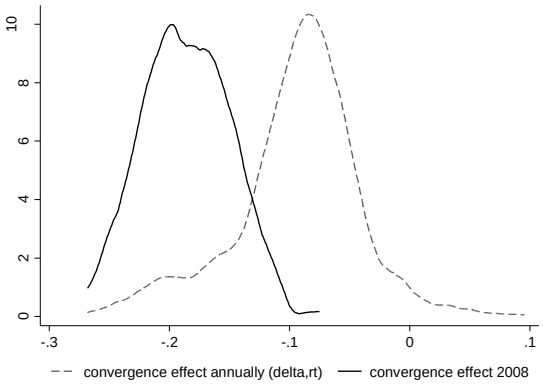
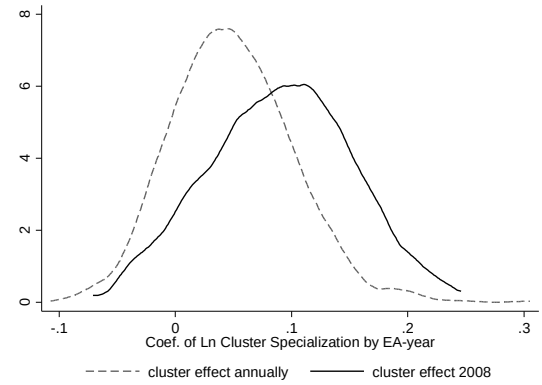


Fig 1b: Coefficient of Ln Cluster Specialization $_{Employ}$ (β_{rt} ; 177 EAs; 2004–2011)



Note: The graphs plot the Kernel density of the estimated coefficients from estimating equation (1), allowing the Ln Industry Employment and Ln Cluster Specialization coefficients to vary for each EA-year.

Table 3: EA-Industry Annual Employment Growth, 2003–2011: Estimated Coefficients for Financial Services and Related Clusters (δ_{ct} and β_{ct} ; Specification in Model 2-2 in Table 2)

	Estimated Convergence Effect δ_{ct}				
	All Clusters Mean (N=51)	Financial Services	Insurance Services	Marketing, Design & Publishing	Business Services
$Year_{2004}$*Ln(Industry Employment) $_{t-1}$	-0.048**	-0.100**	-0.067**	-0.084**	-0.084**
$Year_{2005}$*Ln(Industry Employment) $_{t-1}$	-0.099**	-0.093**	-0.048**	-0.114**	-0.109**
$Year_{2006}$*Ln(Industry Employment) $_{t-1}$	-0.088**	-0.107**	-0.078**	-0.101**	-0.102**
$Year_{2007}$*Ln(Industry Employment) $_{t-1}$	-0.113**	-0.138**	-0.079**	-0.112**	-0.148**
$Year_{2008}$***Ln(Industry Employment)** $_{t-1}$	-0.215**	-0.240**	-0.188**	-0.222**	-0.285**
$Year_{2009}$*Ln(Industry Employment) $_{t-1}$	-0.132**	-0.114**	-0.098**	-0.161**	-0.140**
$Year_{2010}$*Ln(Industry Employment) $_{t-1}$	-0.138**	-0.102**	-0.068**	-0.106**	-0.108**
$Year_{2011}$*Ln(Industry Employment) $_{t-1}$	-0.099**	-0.089**	-0.060**	-0.102**	-0.102**

**Coefficients significant at 1% levels.

	Estimated Cluster Effect β_{ct}				
	All Clusters Mean (N=51)	Financial Services	Insurance Services	Marketing, Design & Publishing	Business Services
$Year_{2004}$*Ln(Cluster Specialization) $_{t-1}$	0.045**	0.135**	0.013	0.060*	0.090**
$Year_{2005}$*Ln(Cluster Specialization) $_{t-1}$	0.056**	0.041	0.011	0.115**	0.117**
$Year_{2006}$*Ln(Cluster Specialization) $_{t-1}$	0.048**	0.133**	0.065**	0.086**	0.107**
$Year_{2007}$*Ln(Cluster Specialization) $_{t-1}$	0.061**	0.144**	0.043	0.059*	0.211**
$Year_{2008}$*Ln(Cluster Specialization) $_{t-1}$	0.094**	0.180**	0.049	0.216**	0.304**
$Year_{2009}$*Ln(Cluster Specialization) $_{t-1}$	0.049**	0.040	0.012	0.153**	0.150**
$Year_{2010}$*Ln(Cluster Specialization) $_{t-1}$	0.051**	0.065**	0.013	0.047*	0.058*
$Year_{2011}$*Ln(Cluster Specialization) $_{t-1}$	0.041**	0.087**	0.007	0.117**	0.122**

**Coefficients significant at 1% levels. *Coefficients significant at 5% levels.

Appendix

Table A1: Correlation Matrix (N=497,236)

		v1	v2	v3	v4	v5
Industry Employment Growth $_{t}$	v1	1.000				
Ln Industry Employment $_{t-1}$	v2	-0.096	1.000			
Ln Cluster Specialization $_{Employment\ t-1}$	v3	0.011	0.167	1.000		
Ln Cluster Specialization $_{Establishments\ t-1}$	v4	0.010	0.164	0.745	1.000	
Ln Cluster Specialization $_{Patents\ t-1}$	v5	0.002	0.038	0.226	0.176	1.000
Ln Establishment Size in Cluster $_{t-1}$	v6	-0.020	0.118	0.531	0.227	0.113

Note: All the reported correlation coefficients are significant at 1% level.

Table A2: U.S. Clusters' Employment Growth and Recovery

	Pre-recession Employment		Annual Employment Growth			Post-/Pre-Recession Employment
	Avg Employ $_{2005-06}$ (1000)	%	Avg 2008, 09	2008	2009	Employ $_{2011}$/Avg Employ $_{2005-06}$
Traded Employment	**42375.3**	**100.0**	**-0.03**	**0.00**	**-0.06**	**0.94**
Trailers, Motor Homes, and Appliances	179.9	0.4	-0.24	-0.14	-0.34	0.59
Apparel	238.8	0.6	-0.17	-0.10	-0.24	0.56
Furniture	537.7	1.3	-0.17	-0.08	-0.25	0.58
Textile Manufacturing	341.1	0.8	-0.16	-0.12	-0.20	0.58
Wood Products	518.2	1.2	-0.15	-0.07	-0.23	0.63
Jewelry and Precious Metals	40.3	0.1	-0.15	-0.14	-0.15	0.64
Automotive	1130.0	2.6	-0.15	-0.05	-0.24	0.68
Footwear	23.4	0.1	-0.13	-0.12	-0.13	0.66
Recreational and Small Electric Goods	258.6	0.6	-0.12	-0.09	-0.16	0.67
Nonmetal Mining	102.5	0.2	-0.12	-0.16	-0.08	0.80
Leather and Related Products	42.7	0.1	-0.11	-0.09	-0.13	0.77
Forestry	81.8	0.2	-0.10	-0.07	-0.14	0.78
Plastics	829.0	1.9	-0.10	-0.03	-0.17	0.78
Vulcanized and Fired Materials	310.7	0.7	-0.09	-0.02	-0.15	0.74
Tobacco	21.1	0.0	-0.08	-0.07	-0.10	0.71
Financial Services	2336.6	5.4	-0.07	-0.06	-0.09	0.81
Upstream Metal Manufacturing	449.8	1.0	-0.07	-0.01	-0.13	0.84
Oil and Gas Production and Transportation	455.4	1.1	-0.06	-0.09	-0.03	1.32
Printing Services	633.3	1.5	-0.06	0.00	-0.12	0.76
Metalworking Technology	535.4	1.2	-0.06	0.04	-0.15	0.87
Paper and Packaging	447.7	1.0	-0.05	-0.03	-0.08	0.81
Downstream Chemical Products	288.1	0.7	-0.05	-0.02	-0.08	0.83
Downstream Metal Products	450.0	1.0	-0.05	0.01	-0.11	0.81
Electric Power Generation and Transmission	124.3	0.3	-0.05	-0.04	-0.06	1.18
Production Technology and Heavy Machinery	998.9	2.3	-0.04	0.02	-0.10	0.87
Construction Products and Services	721.2	1.7	-0.04	0.00	-0.08	0.99
Lighting and Electrical Equipment	336.3	0.8	-0.04	0.02	-0.10	0.83
Environmental Services	73.7	0.2	-0.03	-0.02	-0.04	1.06
Water Transportation	299.2	0.7	-0.03	0.03	-0.09	0.93
Upstream Chemical Products	175.0	0.4	-0.03	0.02	-0.08	0.96
Information Technology and Analytical Instruments	1109.0	2.6	-0.03	0.02	-0.08	0.89
Marketing, Design, and Publishing	1237.1	2.9	-0.03	0.03	-0.09	0.97
Fishing and Fishing Products	42.3	0.1	-0.03	0.01	-0.07	0.88
Transportation and Logistics	1665.4	3.9	-0.03	0.01	-0.07	0.93
Business Services	9830.5	22.9	-0.02	-0.01	-0.04	1.03
Hospitality and Tourism	2944.5	6.9	-0.02	0.02	-0.06	0.99
Agricultural Inputs and Services	90.9	0.2	-0.02	0.00	-0.04	1.08
Metal Mining	29.7	0.1	-0.02	-0.05	0.02	1.37
Performing Arts	301.0	0.7	-0.01	0.05	-0.06	1.01
Distribution and Electronic Commerce	5318.7	12.4	0.00	0.04	-0.04	0.97
Food Processing and Manufacturing	910.1	2.1	0.00	0.03	-0.03	1.01
Biopharmaceuticals	248.8	0.6	0.00	0.05	-0.04	0.92
Aerospace Vehicles and Defense	532.8	1.2	0.00	0.03	-0.02	0.98
Communications Equipment and Services	462.9	1.1	0.01	-0.02	0.03	0.99
Livestock Processing	514.8	1.2	0.01	0.02	0.00	0.96
Medical Devices	260.2	0.6	0.01	0.04	-0.01	1.00
Education and Knowledge Creation	2639.0	6.2	0.02	0.01	0.02	1.14
Insurance Services	1494.4	3.5	0.02	0.06	-0.02	0.97
Video Production and Distribution	189.7	0.4	0.02	0.12	-0.08	0.91
Coal Mining	83.1	0.2	0.03	0.03	0.04	1.15
Music and Sound Recording	22.4	0.1	0.03	0.10	-0.03	1.01

Notes: Column 4 reports the average of the annual employment growth in 2008 and 2009. The last column reports the employment in 2011 (post-recession) relative to the average employment in 2005–2006 (pre-recession).

Table A3: EA-Industry Annual Growth in Number of Establishment, 2003–2011

	Cluster Specialization in Employment 1	Cluster Specialization in Establishments 2	Cluster Specialization in Patents 3
$Year_{2004}$*Ln(Industry No. Establishments) $_{t-1}$	-0.022**	-0.028**	-0.017**
$Year_{2005}$*Ln(Industry No. Establishments) $_{t-1}$	-0.031**	-0.036**	-0.026**
$Year_{2006}$*Ln(Industry No. Establishments) $_{t-1}$	-0.039**	-0.044**	-0.033**
$Year_{2007}$*Ln(Industry No. Establishments) $_{t-1}$	-0.047**	-0.053**	-0.040**
$Year_{2008}$*Ln(Industry No. Establishments) $_{t-1}$	-0.074**	-0.086**	-0.064**
$Year_{2009}$*Ln(Industry No. Establishments) $_{t-1}$	-0.046**	-0.051**	-0.041**
$Year_{2010}$*Ln(Industry No. Establishments) $_{t-1}$	-0.040**	-0.044**	-0.035**
$Year_{2011}$*Ln(Industry No. Establishments) $_{t-1}$	-0.031**	-0.035**	-0.028**
$Year_{2004}$*Ln(Cluster Specialization) $_{t-1}$	0.013**	0.031**	0.004**
$Year_{2005}$*Ln(Cluster Specialization) $_{t-1}$	0.014**	0.029**	0.004**
$Year_{2006}$*Ln(Cluster Specialization) $_{t-1}$	0.014**	0.031**	0.003**
$Year_{2007}$*Ln(Cluster Specialization) $_{t-1}$	0.017**	0.036**	0.003**
$Year_{2008}$*Ln(Cluster Specialization) $_{t-1}$	0.026**	0.065**	0.006**
$Year_{2009}$*Ln(Cluster Specialization) $_{t-1}$	0.014**	0.031**	0.005**
$Year_{2010}$*Ln(Cluster Specialization) $_{t-1}$	0.012**	0.027**	0.002*
$Year_{2011}$*Ln(Cluster Specialization) $_{t-1}$	0.010**	0.022**	0.003**
EA-Year Fixed Effects	Yes	Yes	Yes
Industry-Year Fixed Effects	Yes	Yes	Yes
R-squared			
Obs.	497,236	497,236	497,236

Notes: ** and * refer to coefficients significant at 1% and 5% levels, respectively. Standard errors are clustered by EA-cluster.

Figure A1: Example of Cluster Category: Biopharmaceuticals

Description: Establishments in this cluster produce complex chemical and biological substances used in medications, vaccines, diagnostic tests, and similar medical applications.

NAICS	NAICS Name	Subcluster Name	Within Cluster Relatedness (WCR_{ic})	
			Rank (1=best)	Score
325411	Medicinal and Botanical Manufacturing	Biopharmaceutical Products	1	3.80
325412	Pharmaceutical Preparation Manufacturing	Biopharmaceutical Products	1	4.41
325414	Biological Product (except Diagnostic) Manufacturing	Biological Products	1	3.09
325413	In-Vitro Diagnostic Substance Manufacturing	Diagnostic Substances	1	2.03

Source: Delgado, Porter, and Stern (2015)

Figure A2: Top Biopharmaceuticals Clusters, 2011 (across Economic Areas)

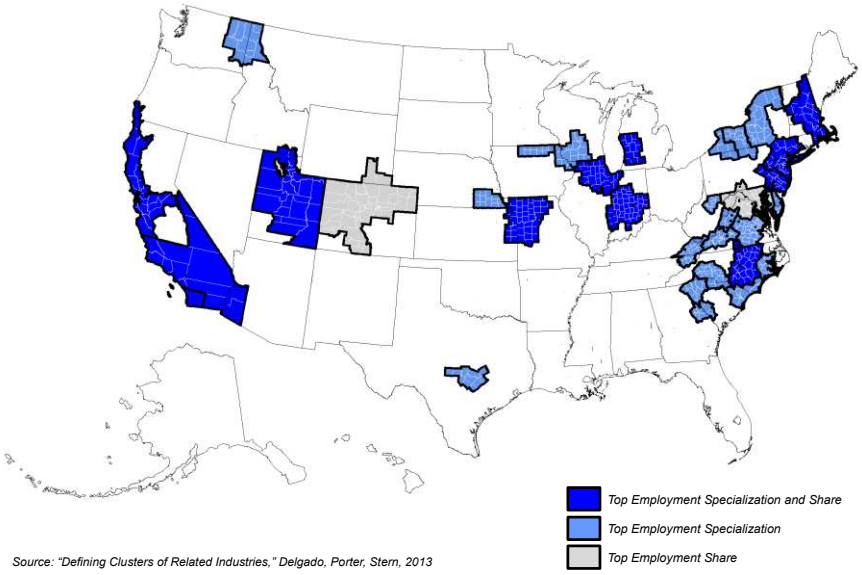
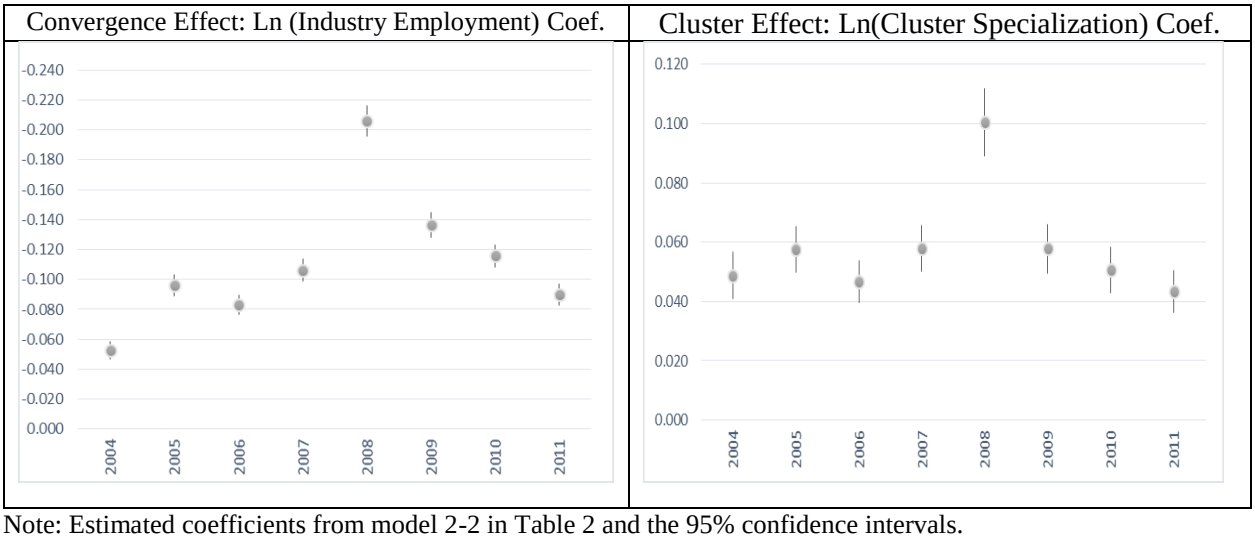


Figure A3: Estimated Convergence and Cluster Effect (Table 2, Model 2-2)



Note: Estimated coefficients from model 2-2 in Table 2 and the 95% confidence intervals.