KNOWLEDGE SPILLOVERS ACROSS REGIONS

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ABSTRACT
This study leverages a unique research design, a proximate industry peer's outbound relocation, to examine how knowledge spillover drives the positive relationship between agglomeration and firm innovation. We expect a firm's innovation performance to decrease when a proximate industry peer moves to another region, because the change in proximity disrupts knowledge spillovers. To evaluate this, we utilize novel data on relocations of nanotechnology R&D firms over 24 years. Contrary to our expectation, we find that a proximate industry peer's outbound relocation increases a focal firm's innovation performance. Taking an abductive approach, we investigate the nature of the impact and offer a theoretical explanation for this finding. We argue that a proximate industry peer's outbound relocation creates an inter-region knowledge channel, which creates opportunities for firms to absorb distant knowledge from the relocated peer's new region. By showing that exit from a cluster can enhance cluster innovation – under certain circumstances, we provide novel and nuanced insights into cluster dynamics.

INTRODUCTION

Scholars in strategy have long examined how the geographic co-location with industry peers, a phenomenon known as “agglomeration” or “clustering”, influences firm innovation. There is much empirical evidence that agglomeration increases innovation performances of firms (e.g., Bell, 2005; Folta, Cooper & Baik, 2006; Gilbert, McDougall, & Audretsch, 2008; McCann & Folta, 2011; Funk, 2014; Mathias, McCann, & Whitman, 2020). The main mechanism that has been invoked for driving this relationship is knowledge spillover between industry peers. Research finds that geographic co-location increases the likelihood of alliances, employee mobility, and serendipitous encounters between firms and also between their employees (Saxenian, 1996; Almeida & Kogut, 1999; Reuer & Lahiri, 2014; McCann, Reuer & Lahiri, 2016). Through these interactions, firms gain valuable knowledge from rivals. Agglomeration with industry peers, therefore, positively affects a firm’s innovative activities by increasing access to knowledge spillovers.

Given that agglomeration of industry peers confers advantage to a firm’s innovative activities, understanding how agglomeration affects firm innovation has long been of central importance to strategy literature. Although extant research repeatedly suggests that knowledge spillover is the driving force in the relationship between agglomeration and firm innovation, there have been limitations in isolating the mechanism of knowledge spillover. This is partly an empirical issue. Prior work in the literature (e.g., Feldman & Audretsch, 1999; Folta, Cooper & Baik, 2006; McCann & Folta, 2011) has mainly relied on using cross region variance to estimate the impact of agglomeration on firm innovation (i.e., comparing firms in agglomerated regions to those in less agglomerated regions). However, because knowledge spillovers and innovation performance might correlate with other regional differences, the results from these studies potentially capture any other systematic difference across regions.

We advance the extant research by teasing out the mechanism in the relationship between agglomeration and firm innovation. To overcome empirical challenges, we leverage a unique research design that produces more direct variance in a firm's knowledge spillover gains from the region: the geographic relocation of an industry peer. Because knowledge spillovers decrease over spatial distance (Kolympiris, Kalaitzandonakes, & Miller, 2011; Sohn, 2021) and transmissions of tacit knowledge are facilitated by face-to-face interactions (Daft & Lengel, 1986; Von Hippel; 1994), a proximate industry peer's move to another region directly reduces the focal firm's knowledge spillover gains. This feature of outbound relocation of a proximate peer allows us to capture the impact of knowledge spillover *within* the region and to perform a more stringent test of the underlying mechanism of knowledge spillover. Moreover, because relocations are often driven by factors affecting the focal firms (i.e., expected lower state taxes (Chow et al., 2021) or cost savings (Strauss-Kahn & Vies, 2009)), and not the future innovation of regional peers, this research design mitigates many endogeneity concerns.

We apply this research design to the context of the nanotechnology industry and use data on U.S. nanotechnology R&D firms from 1985 to 2008. Consistent with the mechanism of knowledge spillovers, our central expectation is that a firm's innovation performance will decrease following a proximate industry peer's outbound relocation. Before employing our research design, we first replicate analyses from McCann and Folta (2011) to compare results when using the standard research design. Consistent with McCann and Folta (2011), we find that innovation performance of firms in the region are positively affected by the region's agglomeration level. However, when leveraging our research design, we find that a focal firm's innovation performance surprisingly increases after an outbound relocation of a proximate industry peer. This is contrary to our expectation and inconsistent with prior research that suggests higher level of agglomeration of industry peers lead to higher innovation performances for firms.

We abductively explore this finding through a series of ex post analyses to help us better understand the underlying mechanisms driving the enhanced innovation performance (King, Goldfarb, & Simcoe, 2020; Seo, Luo & Kaul, 2021). We employ an abductive approach because we did not expect this finding from the beginning. This effort reflects our attempt to offer a plausible theoretical explanation to our finding, and to provide insights for future research.

Several noteworthy results emerge from this analyses. First, we find that only firms that are proximately located (e.g., within 10 miles radius) to the relocating industry peer are affected by the peer's relocation. Second, positive impacts of outbound relocations are driven by relocations in which the relocating peer moves to a less innovative region. Third and most importantly, we find that focal firms cite more patents from the relocated industry peer's new region after the peer's relocation, suggesting that the focal firms continue to benefit from knowledge spillovers even after the outbound relocation even after their peers move to different regions.

Taken together, we propose that knowledge spillovers continue between industry peers even after one firm's relocation to another region. A proximate industry peer's outbound relocation creates an inter-region knowledge channel between the focal firm and the relocated industry peer's new region. External knowledge sourcing through the inter-region knowledge channel allows focal firms to recombine more distant knowledge with their knowledge stock to develop more innovative ideas.

BACKGROUND

Agglomeration generally refers to geographic concentration of economic activity. Concentration of similar industry peers is theorized to generate agglomeration externalities, such as accesses to knowledge spillover, specialized pool of labor, and specialized pool of inputs, to firms constituting the agglomeration (Marshall, 1920; Ellison, Glaeser & Kerr, 2010). Co-location foster interactions between industry peers that promotes knowledge and information spillovers (Jaffe et al., 1993; Saxenian, 1996; Almeida & Kogut, 1999) and also attract industry relevant resource providers to also co-locate, leading to low-cost access to resources (Kolympiris, Kalaitzandonakes, & Miller, 2011). Since geographic proximity and interconnections among industry peers create agglomeration externalities, as the number of peers within the region grows, suggested net externalities of co-locating with industry peers also increase.

For firm's innovation, the greatest benefit of being agglomerated with industry peers is having increased access to knowledge spillovers. Innovation is either a product of combining familiar and unfamiliar knowledge components or combining familiar components in a new way (Schumpeter, 1939; Nelson & Winter, 1982; Fleming, 2001). As external knowledge from industry peers is relatively unfamiliar and distant compared to a firm's own knowledge stock, knowledge acquired from other industry peers is a key source of increasing firm's innovativeness (Cohen & Levinthal, 1990). Knowledge spilled over from industry peers can lead to more recombination with internal knowledge stock, thereby increasing the likelihood of more novel innovations being produced. Hence, having more industry peers in the region can increase the focal firm's novelty of innovations by increasing the variability and amount of knowledge that can be spilled over to the focal firm.

Firms enjoy increased access to knowledge spillovers in agglomerated regions as increased proximity to industry peers create a fertile environment for knowledge exchange between firms. Spatial co-location with industry peers increases chances of serendipitous interactions (Saxenian, 1996; Powers, 1998; Andrews, 2019; Roche, 2019), employee mobility (Almeida & Kogut, 1999), and R&D alliance formations (Reuer & Lahiri, 2014; McCann, Reuer & Lahiri, 2016). These interactions between firms and between their employees lead to both unintentional and intentional knowledge spillovers that could potentially benefit a firm's innovative activities. Although knowledge can be exchanged between firms in different geographic regions, research shows that knowledge spillover is likely to be geographically bounded (Jaffe et al., 1993). Additionally, spatial proximity is an important factor in formation of knowledge exchange relationships (Catalini, 2018). This is partly because spillover of tacit knowledge is more accessible with co-location. While tacit knowledge is not easily codifiable nor transferrable, geographic co-location assists the transmission of tacit knowledge between firms with face-to-face interactions (Daft & Lengel, 1986; Von Hippel; 1994). As proximity increases both chances and feasibility of knowledge exchanges, firms in agglomerated enjoy advantages in terms of having access to knowledge from their industry peers compared to firms in isolated region.

This positive association between agglomeration and firm innovation is well-documented in agglomeration literature. Studies show that innovation performances of firms that are located in agglomerated regions are higher than firms located in relatively isolated regions (Folta, Cooper & Baik, 2006; McCann & Folta, 2011). While studies argue that higher innovation performances are attributed to greater stock of knowledge in agglomerated regions that might spill over between industry peers, extant empirical approaches of measuring knowledge spillover with region-level measures does not clearly connect agglomeration and knowledge spillover. In other words, it is unclear whether knowledge spillover is the driving force behind the relationship between agglomeration and firm innovation. In this study, we leverage outbound regional relocation of a proximate industry peer to focus on understanding the role that knowledge spillover plays in this relationship.

RESEARCH DESIGN AND METHODS

Research Design

Firm's Outbound Regional Relocation. We investigate changes in a focal firm's innovation performance as a function of a proximate industry peer's headquarter relocation into another region. Firms move their headquarters to a different region for several reasons. Recent study finds that firms are likely to relocate their headquarters to another state when the corporate tax rate of the state of their headquarters rises (Chow et al., 2021). Relocations also occur for reasons of spatial expansion, cost savings or operating efficiency, capacity reduction, facilities consolidation, and access to human capital (Strauss-Kahn & Vives, 2009). Additionally, transportation infrastructures determine relocation decisions. For example, Archer-Daniels-Midland stated that the absence of a major airport as one its reasons of leaving Decatur, Illinois in 2013 and moving to Chicago (Mercer & O'Connor, 2013). While various factors play a role in a firm's decision to relocate to another region, studies do not suggest that a proximate industry peer's innovation to influence a firm's relocation decision. To this advantage, we use outbound relocations as an exogenous shock to the focal firm's innovation.[1]

Source of Variance for Knowledge Spillover. We utilize the outbound relocation of a proximate industry peers as the source of variance in knowledge spillover gains for the focal firm. The logic behind this research design is that when a proximate industry peer relocates to another region, and the physical distance from the focal firm to the industry peer increases as a result of the relocation, the focal firm would have lower levels of access to the industry peer's knowledge. Hence, relocation of a proximate industry peer would result in reduced levels of knowledge spillover gains for the focal firm.

We make several assumptions in using this research design. First, proximity increases the likelihood and level of knowledge exchanges between industry peers. Geographic proximity fosters various interactions between firms and between employees, which leads to fertile knowledge exchanges between industry peers. Since occurrences of these interactions are reduced over distance, both the likelihood and level of knowledge exchanges between industry peers decrease over distance (Kolympiris, Kalaitzandonakes, & Miller, 2011; Sohn, 2021). Hence, the focal firm would gain knowledge from a proximate industry peer, but an outbound relocation of the industry peer would reduce knowledge spillovers from the industry peer to the focal firm. Second, external knowledge gained from local spillovers are critical components of focal firm's innovation activities. Knowledge can be exchanged over geographic distance since firms can establish alliances with firms in other regions or can transfer knowledge internally from R&D centers in different regions. However, the nature of knowledge built into innovation

[1] In the Appendix, we include analyses that examine the likelihood of a firm's outbound relocation as a function of industry peers' innovation performances. We do not find statistically significant results.

is tacit, and tacit knowledge is transferred effectively under face-to-face interactions (Daft & Lengel, 1986; Von Hippel; 1994). Hence, knowledge spillovers from local industry peers become important ingredients to firm's external sourcing of knowledge. Third, knowledge from other industry peers are unfamiliar concepts and components, relative to the firm's own knowledge stock. Even if knowledge exchange is pervasive between local industry peers, firms have different human capital, values, and processes in developing one's own knowledge and technology. Each firm would therefore have different knowledge stocks developed within the firm and possess knowledge that are distant and diverse relative to those of industry peers.

There are several advantages to this research design. First, outbound relocations of proximate industry peers directly produce variance in knowledge spillover gains of focal firms, thereby allowing us to utilize the *within-region* variation to estimate the impact of agglomeration. Prior studies used region-level agglomeration measures and since knowledge spillovers and innovation performances are both correlated with cross region differences, their estimates of impact of agglomeration captured both *within-region* and *across-region* effects (Feldman & Audretsch, 1999; Folta, Cooper & Baik, 2006; McCann & Folta, 2011). This provides inconclusive evidence that increase in the agglomeration level generates more knowledge spillovers as knowledge spillovers and innovation performances could be correlated with *across-region* differences (e.g., presence of research infrastructures or regional government's investment). Our research design captures within-region effects to better understand how changes in agglomeration level influence knowledge spillover gains for firms.

Second, there are less empirical issues associated with this design. In prior studies that capture across-region effects, there are concerns of selection effects accounting for higher innovation performances of firms in agglomerated regions, as firms that are more innovative and have better resources may prefer to enter in agglomerated locations. Similarly, endogeneity concerns also arise as innovative firms in an agglomerated region may attract other firms to move to the region, which increases the region's agglomeration level. Our research design addresses these issues as it is difficult for firms to predict and select into locations where proximate industry peer's relocate out of, and as mentioned earlier, relocation decisions of industry peers are likely to be not affected by the focal firm's innovation performances.

Third, this design allows assigning different treatment statuses to firms located in the same region by how spatially distant they are from the relocating industry peer. Recent research shows that even when organizations are co-located within the same region, spillover between organizations decrease over distance (Kolympiris, Kalaitzandonakes, & Miller, 2011; Sohn, 2021). In other words, whether a firm gains knowledge spillover benefits from the agglomeration region, depends on where the firm is located relative to the location of other industry peers. If only proximately located focal firms in the region are affected by an outbound relocation of an industry peer, then this would further provide evidence that knowledge spillover is driving the relationship between agglomeration and innovation.

Empirical Context

We test this research design using data on innovation of U.S. based nanotechnology R&D firms. This empirical setting is particularly suited to explore our arguments for three reasons. First, patent activity in the industry is pervasive which provides various possibilities of measuring innovation performances and knowledge spillover. Second, the nanotechnology industry is well recognized as a context where innovation rests on the capabilities of individual inventors. Hence, opportunities for interactions between inventors of different firms are likely to influence the degree of knowledge exchange between inventors' respective firms. Third, firms in this industry are locally clustered across diverse geographic regions. Figure 1 shows geographic distribution of nanotechnology R&D firms by Core-Based Statistical Areas (CBSAs) in 2008.

Insert Figure 1 about here

High number of industry clusters imply that there are many potential destination locations which may facilitate outbound relocations. This leads to a large number of relocations to examine as firms prefer to locate and relocate to regions where industry peers are clustered (Shaver & Flyer, 2000, Strauss-Kahn & Vies, 2009). In our data, there are 73 regional outbound relocations which occurred over the course of 24 years. Additionally, clusters also enable comparing the effects on proximate focal firms to non-proximate focal firms in the same region. Firms located in the same region are likely to be similar after controlling for observable characteristics and the distance to the relocating industry peer is likely to be the only difference between proximate and non-proximate industry peers within in the same region.

Data and Sample

Our empirical analyses draw on multiple data sources. First, data on nanotechnology R&D firms come from a variety of directories and news sources. Major sources include company directories found in the Lux Nanotech Report (2001, 2004, 2006, 2008), the Nanotechnology Opportunity Report (2002), Nano VIP Database (2005), Understanding Nano, BioScan, and Factiva. This data has been featured in prior research on nanotechnology R&D firms (e.g., Funk, 2014). Second, we collected data on patents, inventors, and citations from the U.S. Patent and

Trademark Office (USPTO) PatentsView database. Patent data is widely used by research as a proxy for innovation. To identify patents filed by nanotechnology R&D firms, we manually matched all nanotechnology firms to patent assignee names provided by the USPTO.

Third, following prior research on the nanotechnology industry (e.g., Zucker et al., 2007; Jung & Lee, 2016; Vestal & Danneels, 2018), we obtained data on nanotechnology patents from Nanobank to distinguish nanotechnology patents from non-nanotechnology patents. Fourth, from SDC Platinum Database, we collected data on alliances between nanotechnology firms. Following Rothaermel & Thursby (2007), we collected all alliances by firms in SIC industry codes that are identified as having nanotechnology firms. Then, from the list of all alliances, we matched nanotechnology firm names to firm names involved in alliances. Afterwards, we identified all alliances categorized as “Research and Development Services” and “Joint Ventures” that are formed between nanotechnology firms. Lastly, nanotechnology publication data was collected from Scopus by searching through authoritative journals in nanotechnology research and matching employers of publication authors to our list of nanotechnology firm names. Our final sample encompasses all 452 U.S.-based nanotechnology firms engaged in nanotechnology R&D between 1985 and 2008. During this time period, these firms filed for 47,853 granted nanotechnology patents. The panel consists of 6,927 firm-year observations.

Variables

Dependent Variable. This study examines the effect of a proximate industry peer’s outbound relocations on the focal firm’s innovation performances. We assess a firm’s innovation performance using the firm’s nanotechnology patent-based indicators. Patents are commonly used to measure a firm's innovativeness (e.g., Kumar & Zaheer, 2019). However, patents vary widely in their quality, so the simple count of patents may not accurately represent innovation performances of firms. Hence, to account for this limitation, we operationalize innovation performances of the firm with *Patent Impact*, which is the citation-weighted count of patents (e.g., Kotha, Zheng, & George, 2011; Funk, 2014). We measure the average number of citations received by nanotechnology patents applied by firm *i* at times *t+1* and *t+2*, since patent ideas are generally conceived one or two years before the application is filed. Each patent was weighted by the number of citations that it received from future patents in the first five years after the patent was issued since the majority of citations happen in the first five years of a patent's life (Jaffe, Trajtenberg, & Henderson, 1993; Jaffe & Trajtenberg, 2002).

Independent Variables. To compute *Proximate Industry Peer's Outbound Relocation*, we took the following steps. First, we operationalized regions as CBSAs following prior studies (e.g., Marquis et al., 2013; Dimitriadis et al., 2017). CBSAs include an urban center and surrounding areas that are socially and economically integrated with the center and this is a common way of operationalizing geographic regions in the U.S. context. Second, we identified firms that relocate their headquarters and R&D centers from one CBSA to another CBSA.[2] There were 73 outbound relocations in our time frame. Third, to identify industry peers that are geographically proximate to the relocating firm, we computed geodetic distances between GPS coordinates of each firm's headquarter location. Then for each outbound relocation, we identified a set of proximate focal firms that are located within a 10-mile radius of the relocating firm. Prior studies show that there is a significant decrease in knowledge spillover between organizational entities over distance

[2] Most R&D firms' outbound relocations of headquarters were accompanied by movement of R&D centers. There were 3 outbound relocations in which the R&D center did not move with the headquarter. Including these relocations did not change results.

(e.g., Kolympiris, Kalaitzandonakes, & Miller, 2011; Belenzon & Schankerman, 2013; Singh & Marx, 2013; Sohn, 2021). In particular, Kolympiris, Kalaitzandonakes, & Miller (2011) show that in the biotechnology industry, firms in spatial clusters are influenced by knowledge from proximate industry peers within 10-miles radius but not from peers more than 10-miles away. We follow prior research and define a proximate focal firm as those that are located less than or equal to 10-miles distance to the relocating industry peer.[3] Figure 2 illustrates the difference between proximate and non-proximate industry peers. Firms that are marked as blue dots are located within 10-miles radius of Nanodynamics, which is the boundary drawn by the blue circle. In our study, these four firms are proximate industry peers of Nanodynamics while other firms in the region are non-proximate industry peers. Taken together, *Proximate Industry Peer's Outbound Relocation* takes a value of 1 from t to t+2 if a proximate industry peer relocates to another CBSA at year t, and 0 if otherwise. The effect of outbound relocation is limited to three years following the relocation to capture the immediate impact of loss of knowledge spillover benefits, following the relocation a proximate industry peer, on the focal firm's innovation performances.[4]

Control Variables. To control for alternative mechanisms affecting a firm's innovation performances, we included the following variables. We controlled for *Nano Patent Stock*, defined as the cumulative number of granted nanotechnology patents applied by firm i's headquarter location, depreciated by 15% annually. *Nano Paper Stock* controlled for the cumulative number of published nanotechnology publications by the inventors at the headquarter location, depreciated by 15% annually. Both *Nano Patent Stock* and *Nano Paper Stock* control

[3] We tried several different distance ranges (e.g., 5-miles and 15-miles) to identify focal firms that are proximate to the relocating industry peer. Results were consistent with different ranges.
[4] We tried different year ranges and the results remained consistent.

for unobserved heterogeneity in the innovative capabilities of the firm. We also controlled for *Non-Nano Patent Stock (log)*, depreciated by 15% annually, to account for the size of the firm's non-nanotechnology portfolio. Nanotechnology inventors can draw distant knowledge from the non-nanotechnology portfolio and apply them to develop more novel nanotechnology innovations. Firms can also source external knowledge from other firms through R&D alliances, which can subsequently enhance innovation performances (Ahuja, 2000; Almeida, Song, & Grant, 2002). Hence, the *Number of Alliances* accounts for all R&D alliances that a focal firm has with nanotechnology firms in the five-year window previous to year *t*. Following Corredoira & Rosenkopf (2010), we coded the mobility of nanotechnology inventors between nanotechnology R&D firms. Mobility of experienced inventors out of the firm can reduce the firm's innovative capabilities, while inward mobility of experienced inventors can result in an increase in capabilities as well as knowledge spillover from the inventor's previous firm. *Inventor Mobility Out* controls for the number of experienced nanotechnology inventors leaving firm i at year t, while *Inventor Mobility In* controls for the number of experienced nanotechnology inventors joining firm i at year t. Finally, following Alcacer & Chung (2014), we controlled for *Agglomeration Level (log)* to account for the geographic concentration of nanotechnology activity in the region. *Agglomeration Level (log)* is defined as the log of nanotechnology inventors per CBSA-year, which captures the density of industry peers in the region as well as the emergence of new nanotechnology firms.

Identification Strategy

We measure the impact of a proximate industry peer’s outbound relocation on focal firms’ innovation performances leveraging a difference-in-difference (DID) estimation strategy. The main assumption for our identification strategy would be that a proximate industry peer's relocation decision is an exogenous change to the focal firm. To provide empirical support for the assumption, in Appendix 1, we examined the likelihood of a firm conducting outbound relocation as a function of the patent stock of proximate industry peers in the region. These analyses did not reveal systematic patterns associated with a focal firm's outbound relocation, supporting our assumption.

Another critical assumption for DID estimation is that the pre-treatment trends of the dependent variable (i.e., firm innovation performance) must be parallel between treatment group and comparison group firms, prior to treatment and conditional upon control variables (Angrist & Pischke, 2008). In order for comparison group firms to be valid missing counterfactuals for treatment group firms, the pre-treatment time trends of both control and treated groups should not be statistically different. To test for this assumption, we ran a relative time model analysis that includes a series of dummy variables that indicate the relative temporal distance (i.e., one-year intervals) between an observation period, *t*, and the timing of a proximate industry peer's outbound relocation. Analyses in Appendixes 2 and 3 reveal that there is no evidence of significant differences in pre-treatment trends, which holds the parallel trends assumption of DID.

Model Estimation

The unit of analysis is at the firm X year level, and the comparison group is firms that are not experiencing outbound relocations at time t. Since the dependent variable, *Patent impact* is a count variable and nonnegative integer, we use pseudo-maximum likelihood Poisson models with firm and year fixed effects in the form

$$E[y_{it}|x_{it}, \alpha_i] = \alpha_i e^{x'_{it}\beta} \;, t = 1, 2, \dots., T, i = 1, 2, \dots, N,$$

where y_{it} is the dependent variable for firm i at time t, x_{it} are independent variables and control variables, β are the coefficients, and α_i are time-invariant firm fixed effects. Prior studies that examine innovation performances have also used this form of the Poisson model (Funk, 2014; Vestal & Danneels, 2018; Aggarwal, Hsu & Wu, 2020). Pseudo-maximum likelihood Poisson standard errors are robust to overdispersion, which occurs when an outcome's conditional variance is greater than the conditional mean. Firm fixed effects control for unobserved time-invariant heterogeneity and the models rely on within-firm variation. In all our models, we clustered standard errors at the zip code area level and not at the CBSA level because of how treatment is assigned. Within a CBSA, there are both firms that are assigned to a treatment and firms that are not assigned to a treatment. However, within a zip code area, all firms are either assigned to a treatment or not.[5]

ANALYSES AND FINDINGS

Replication of Prior Research

We first replicated McCann and Folta (2011) to understand the impact of agglomeration on firm innovation in nanotechnology context. McCann and Folta (2011) examined the impact of agglomeration on innovation in the biotechnology context and measured agglomeration with

[5] We tried clustering standard errors at both CBSA level, and 3-digit zip code level and results remained consistent.

region-level measures; cluster size was measured as the number of firms in the MSA, and cluster patents was measured as the natural log of the cumulative sum of patents held by all firms in the region excluding those by the focal firm. Using these measures, McCann & Folta (2011) found that firm's innovation performances benefit from agglomeration with industry peers, and particularly, younger firms benefit more from agglomeration.

The purpose of this replication is two folds. First, we show that we obtain similar results using our data on nanotechnology R&D firms. Second, we compare replication results with our main results to show how results differ when we use our research design to infer knowledge spillover instead of a region-level agglomeration measure. Although our replication lacks some control variables from the original analysis, all explanatory variables are present, and we closely follow the analysis of McCann & Folta (2011).

Table 1 replicates Table 6 of McCann & Folta (2011) using our nanotechnology data. Our findings are consistent with McCann & Folta (2011). We find that both cluster size and cluster patents are positively associated with the likelihood of the firm filing a patent and that the firm age negatively moderates both associations. The effect sizes of the main effect does not differ significantly. Table 1 Model 4 shows that the coefficient of cluster size is 0.01 in our analysis, meaning that the odds of successfully filing a patent increase by 1% as the number of firms in the cluster increase by 1 firm, while it is 0.02 in the original analysis. Based on these results, we can conclude that when using region-level agglomeration measures, we find results that are similar to McCann and Folta (2011).

Insert Table 1 about here

Main Analyses – Impact of a Proximate Industry Peer's Outbound Relocation

Table 2 provides descriptive statistics, and Table 3 shows a correlation matrix for key variables. There are 984 firm-year observations that are treated with a proximate industry peer's outbound relocation, which is 14.2% of all observations.

Insert Table 2 and 3 about here

Table 4 presents the main models that show the effect of a proximate industry peer's outbound relocation on the focal firm's innovation performance. Model 1 includes all control variables. The control variables that show statistically significant coefficients are in expected directions. Nanotechnology patent stock has a negative coefficient, which implies that an increase in the firm's nanotechnology patent stock decreases the impact of the firm's subsequent nano patents. As the firm's nanotechnology patent stock grows, the firm may be relying more on its stock to exploit internal knowledge rather than exploring unfamiliar concepts and components through external sourcing of knowledge, and this reliance could reduce the innovativeness of new patents. For similar reasons, the coefficient for nanotechnology paper stock is also showing a negative association. On the other hand, non-nano patent stock of the firm exhibits a positive association as expected, since firms and their inventors could recombine components from their non-nanotechnology patents to produce more innovative nanotechnology patents.

Table 4 Models 2 and 3 shows results with outbound relocation. Our expectation is that firms that experience a proximate industry peer's outbound relocation would have reduced innovation performance, since outbound relocation results in lower level of knowledge spillover gains from the region for the focal firm. However, contrary to our expectation, we do not find a negative association between a proximate industry peer's outbound relocation and the focal firm's innovation performance. Rather, Model 3 shows that innovation performance of firms increase when a proximate industry peer relocates to another region (β=0.29, p<0.05). The effect size is statistically and economically significant; when a proximate industry peer relocates, the focal firm's innovation performance increase by 33.6 percent. Comparison firms in Models 2 and 3 are all firms not experiencing outbound relocations at year *t*. To account for the possibility that our unexpected results are stemming from not having the right comparison firms, we limit comparison firms to firms in the same region that are not affected by the outbound relocation because they are not proximately located (i.e., not within 10-miles radius) to the relocating firm. The rationale behind this new group of comparison firms is that firms within the same region share similar unobservable characteristics such as agglomeration externalities of accesses to labor and specialized input. Models 4 and 5 use this group of comparison firms. Results are similar. Model 5 shows that the outbound relocation of a proximate industry peer increase the focal firm's innovation performance, even when comparing to other firms in the same region (β=0.26, p<0.1). Hence, regardless of the comparison group, when a proximate industry peer relocates, innovation performances of firms increase.

Insert Table 4 about here

Focal Firm and Relocating Industry Peer Heterogeneities

In order to understand the source of the positive effect of the outbound relocation, we gave variation to both outbound relocations and focal firms that are treated by the relocation. In Table 5 models 1 and 2, we check whether proximity between the relocating industry peer and the focal firm matters. If the positive impact is limited to firms that are proximately located to the relocating industry peer, this suggests that knowledge spillover may still be driving the impact, but just in the other direction than our prediction. In models 1 and 2, we include a variable that identifies a firm that is more than 10 miles away from a relocating industry peer when the relocation occurs. In both models, we find that outbound relocations that occur more than 10 miles away from the focal firm has no significant impact on the focal firm. The results imply that the impact of outbound relocation is bounded to geographically proximate industry peers and further suggests that knowledge spillover with the relocating industry peer may be the driver of the positive impact, since spillovers are more likely between proximate peers. These results also show that the use of region-level agglomeration measures may be inaccurate to infer the impact of knowledge spillover on firms because not all firms in the region are closely located to one another.

In Table 5 models 3 to 5, we distinguished relocating industry peers by whether they were important sources of nanotechnology knowledge in the region (i.e., central industry peer) or not (i.e., peripheral industry peer). We speculated that relocations of peripheral industry peers could increase innovation performance of focal firms as peripheral industry peers possess irrelevant knowledge that might have adverse effect in advancing innovation. Hence, the removal of the peripheral industry peer would reduce spillover of insignificant knowledge that could disturb the innovation process of focal firms. This would explain the increase in innovation performance following the relocation. We distinguished central and peripheral industry peers in the following way. If the relocating industry peer’s nano patent stock occupied more than 3% of the region’s cumulative stock of nano patents on the year of the relocation, then the relocating firm was coded as a central firm. If the relocating industry peer’s nano patent stock was less than 3% of the region’s cumulative stock of nano patents, then the relocating firm was coded as a peripheral firm.[6] Model 5 shows that outbound relocations of both central and peripheral industry peers lead to increase in innovation performance of the focal firm (Central peer: β=0.30, p<0.1; peripheral peer: β=0.28, p<0.1). Hence, positive impact of a proximate industry peer's outbound relocation is not driven by relocation of a peripheral industry peer as similar impact can be found when central industry peers relocate.

Insert Table 5 about here

Taken together, these additional analyses show that a proximate industry peer's outbound relocation does not decrease the focal firm's innovation performance even after giving variation to the treatment group and the treatment. In the next section, we provide a potential theoretical explanation to this finding and explore the mechanism of how an outbound relocation of a proximate industry peer's positively impact the focal firm's innovation. Although this phenomenon often has been treated in the empirical literature as a control variable or largely inferred as a part of a negative change in agglomeration level or geographic concentration of industry peers, it is worth considering as an independent question with its own merits. We focus on how a proximate industry peer's outbound relocation influences existing knowledge exchange channels to build predictions about how proximity to and relocation of an industry peer affect focal firm's innovation performance.

Theoretical Explanation – Impact of a Proximate Industry Peer's Outbound Relocation

[6] Alternatively, we assigned relocating industry peers to central and periphery categories by comparing nano patent stock amongst relocating industry peers. If a relocating industry peer had more nano patents than the mean nano patents of relocating peers, then the relocating industry peer was assigned to central category. The results were consistent and coefficients were positive and statistically significant even when a peripheral industry peer relocated.

Within the literature on geography and innovation, an intriguing line of inquiry focuses on the interpersonal relationships of employees as drivers of knowledge spillovers between firms (e.g., Dahl & Pedersen, 2005; Breschi & Lissoni, 2009). Geographical proximity between firms facilitates the formation of interpersonal relationships among firms' employees. For example, physical proximity of working locations increases opportunities of serendipitous encounters as employees of proximate industry peers may be members of similar professional associations or go to the same gathering places (i.e., bars and restaurants) (Saxenian, 1996; Powers, 1998; Andrews, 2019; Roche, 2019). Since individual employees are active agents in the creation and spatial diffusion of knowledge (Almeida & Kogut, 1999), knowledge flows between proximate industry peers increases through interpersonal relationships of employees.

What happens to knowledge exchanges through interpersonal relationships when a proximate industry peer relocates to another region? Research has long suggested that knowledge spillover between firms is bounded by geography (Jaffe et al., 1993; Audretsch & Feldman, 1996). When spatial distance between firms is high, employees' search and communication costs of sharing knowledge with the other industry peer's employees are also high (Catalini, 2018). Geographic distance generates barriers for face-to-face interactions and increase the use of tools such as phones, flights, messengers, etc. as means of communication. Hence, knowledge exchanges between firms' employees are more likely when firms are proximately located.

Research, however, also suggests that interpersonal relationships between employees in different geographic regions lead to knowledge flows, suggesting that proximity plays a lesser role in continuance of knowledge spillovers (Hansen & Lovas, 2004; Agrawal, Cockburn, & McHale, 2006; Bell & Zaheer, 2007). In other words, when considering the possibility that two proximate industry peer's employees formed interpersonal relationships before geographic separation, changes in physical distance would not change existing knowledge flows as expected. For example, the likelihood of subsequent collaboration between scientists that had already engaged in collaboration do not decrease, even if distance increases between them (Catalini, 2018). Because scientists are aware of one another's value, they can continue exchanging knowledge without having to conduct additional search. The increase in communication cost is also not high to demotivate individuals from maintaining their social relationships across regions (Agrawal, Cockburn, & McHale, 2006). While formerly proximate employees who have formed an interpersonal relationship must bear the costs of communicating long distance (phone, transportation tickets, e-mails, etc.), the effort required is likely less than long-distance communication between strangers. The effective cost of communication does not increase as much due to the existence of an interpersonal relationship and becomes less of a preventive feature in continuing knowledge transfers. For example, Agrawal, Cockburn, & McHale (2006) found that social relationships between inventors facilitated knowledge transfer even after formerly proximate inventors were separated geographically, and this knowledge transfer was 50% more likely to go to the inventor's prior location than if the inventor had never lived there.

If interpersonal relationships continue to exist across regions, outbound relocations of a proximate industry peer may enable focal firms to gain indirect access to knowledge originating from the region that the relocating peer moved into. Although local knowledge spillovers from proximate industry peers within the region are important sources of knowledge recombination, non-redundant knowledge from other regions increases the possibilities of new types of knowledge recombination that could occur with the firm's knowledge portfolio (Fleming, 2001). Hence, a disruption in firm's geography in the form of a proximate industry peer's outbound relocation may provide a powerful bridge for increasing the firm's access to distant knowledge.

We suggest that knowledge exchanges through interpersonal relationships between proximate industry peers translates to inter-region knowledge channel once a proximate industry peer moves into another region. This inter-region knowledge channel grants the focal firm an indirect access to knowledge from the relocated peer's new region, and therefore, the focal firm absorbs more distant knowledge that increases their innovative activities. This may explain why we observe positive impact on the focal firm's innovation performance when a proximate industry peer relocates to another region.

Mechanism Testing

An important element of the theory of inter-region knowledge channel is that the relocated industry peer's employees need to have the motivation to continue to share knowledge with their former neighbors in their pre-relocation region. In retaining relationships, deliberate and selective choice plays a prominent role (Kleinbaum, 2018), as individuals may choose to minimize costs of communicating, but also costs of maintaining relationships by discontinuing ones that are less valuable (Blau, 1964). While continuation of knowledge flows via interpersonal relationships may lead to inter-region knowledge channels, knowledge flow may also halt if the cost of retaining interpersonal relationships exceed the value attained from those relationships.

The primary point of departure in this regard is that the motivation to continue knowledge exchange following outbound relocation could be shaped by the path of relocation. In other words, whether a proximate industry peer moves to a more innovative or less innovative region may determine whether the inter-region knowledge channel operates or not. From the perspective of employees of relocating firms, there is higher motivation to retain interpersonal relationships with their former neighbors when their firms move to regions that are less innovative than their pre-relocation regions. Relocated employees would prefer to continue the knowledge flows with their former neighbors since they can source more quality and innovative knowledge from their pre-relocation region than from local firms in the new region. Although costs of building new local relationships would be significantly less than maintaining old ones (Kleinbaum, 2018), the value of maintaining pre-existing knowledge exchange channels across regions would exceed the value of local channels. Hence, outbound relocations to less innovative regions would increase the use of pre-existing inter-region knowledge channels.

On the contrary, when relocated firms move to a region that is more innovative than their pre-relocation region, relocated employees would focus more on interacting with employees of local firms to absorb the knowledge that is more advanced and innovative. Less effort would be exerted in retaining relationships with their pre-relocation neighbors, as the value of building new local relationships and receiving non-redundant knowledge would exceed the value of continuing old relationships. Hence, inter-region knowledge channel is likely to be less used by relocated firms' employees after relocation. Taken together, we predict inter-region knowledge transfers to be more pronounced for firm relocations that move to a region that is less innovative than when moving to a region that is more innovative.

In Table 6, relocations are differentiated by the relocating firm's path of movement. We predict that a proximate industry peer's outbound relocation to a less innovative region would increase the innovation performance of the focal firm more than when a proximate industry peer relocates to a more innovative region. The comparison group for model 1 is firms not experiencing a proximate industry peer's relocation to a more innovative region, while for model

2, the comparison group is firms not experiencing a relocation to a less innovative region. The full sample is utilized in model 3, in which the comparison group is all firms not experiencing any type of relocation. Results show a positive and significant effect for industry peer's outbound relocation – to a less innovative region across models. However, for industry peer's outbound relocation – to a more innovative region, the coefficient is statistically insignificant across models. In model 3, coefficients for the two outbound relocation path variables are statistically different from one another. The results demonstrate that a proximate industry peer's outbound relocation to a less innovative region drive the results in previous analyses. The results are also consistent when restricting comparison group to firms in the same in region in models 4 to 6. Taken together, the findings imply that knowledge exchanges between industry peers that stay and move continue if the peer that moved has motivation to retain the exchange relationship.

Table 7 reports results for analyses that examining our proposed mechanism of inter-region knowledge channel. The unit of analysis is at the firm-CBSA-year level, and the dependent variable, in this case, reports the number of patents from the CBSA that are cited by the focal firm at t+1 and t+2. The comparison group is firm-CBSA pairs that are not experiencing outbound relocations of proximate industry peers. To illustrate, if firm A is closely located to firm B and firm B relocates to CBSA Z, then the pair of firm A – CBSA Z would be treated outbound relocation, while other firm A – CBSA pairs are not treated. If inter-region knowledge channel is established as a result of a proximate industry peer relocating to another region, then the focal firm would be able to source knowledge from the relocated industry peer's new region, and this would show up as forward citations to patent's originating from the region. Models 1 and 2 do not display significant coefficients for an industry peer's outbound relocation. The results show that a firm cites more patents from another region if a proximate industry peer moves to that region. In models 4, 5, and 6, we find that an industry peer's outbound relocation to a less innovative region shows a positive and significant coefficient when differentiating relocations by paths. This result demonstrate that firms cite more patents from the relocated industry peer's new region when the relocated peer moved to a less innovative region, which implies that knowledge transfer is more active in this path of relocation. The results also show that forward citations to the relocated industry peer's new region do not increase when relocating to a more innovative region, thereby suggesting that an industry peer's outbound relocation to a more innovative region does not act as an inter-region knowledge channel. Overall, these results strongly support our theoretical arguments that a proximate industry peer's outbound relocation creates an inter-region knowledge channel between the firm and the relocated industry peer's new region; focal firms gain more distant knowledge through this channel and their innovation performances increase as a result.

Insert Tables 6 and 7 about here

Alternative explanations

There are at least three alternative explanations to why outbound relocation of a proximate industry peer increases innovation performances of the focal firm. One alternative explanation is that inventors from the relocating industry peer join other firms in the region because they do not want to leave the region. These inventors could continue communicating with their former colleagues, and knowledge from the relocated industry peer's new region might be transferred to firms that hired these inventors through this channel. We tested for this explanation two ways. First, we split sampled firms into firms in states that enforce noncompete agreements and states that do not enforce noncompete agreements (i.e., California, Oklahoma, and North Dakota). Noncompete agreements are included in employment contracts that generally specify same industry firms which employees pledge not to work for a period of time (Gibson, 1999). If states do enforce noncompete agreements, then mobility of inventors to other industry peers in the region is restricted, so we might not see the positive impact of outbound relocation if inventor mobility is driving the effect. In Table 8, models 1 to 3 only include states with that do not enforce noncompete agreements, while models 4 to 6 restrict sample to states that enforce noncompete agreements. The results from models 3 and 6 shows that a focal firm benefits from a industry peer's relocation from the region regardless of whether noncompete agreements are enforced or not in the state.

We also tested for this alternative explanation by directly coding inventor mobility between the relocating firm and other industry peers in the region. We find a small number of inventors moving to other firms in the region following their firm's relocation. If the relocating industry peer's inventors join other firms in the region, and if this these mobility events are driving the positive impact of the outbound relocation, then firms that do not have inventors joining from the relocating peer would not experience increase in innovation performances. Comparison group in Table 9 is all firms that do not experience outbound relocations while the treatment group include only those firms that did not have inventors joining them from the relocating industry peer. We find that firms that did not hire inventors from the relocating firm also show positive effects on innovation performance. Overall, these findings provide support that inventor mobility from the relocating firm is an unlikely driver of our effects.

Insert Tables 8 and 9 about here

Second alternative explanation addresses the possibility that the relocated industry peer shares information of focal firms with their new neighbors. The rise in citations of the focal firm's new patents might be driven by the relocating industry peer's new neighbors, who start citing focal firms after gaining information about their technology. If this is the case, then the increase in citation-weighted patents of focal firms may be due to more firms knowing about the focal firm's patents, and not because the focal firm's new patents are more valuable and novel. We tested for this explanation using firm-CBSA-year level data. Table 9 shows that firms in the relocated industry peer's new region are not citing more of patents by focal firms in the relocated industry peer's old region. Hence, increase in citations to the focal firm's new patents are not driven by more firms having information about the firm.

Third alternative explanation is that new knowledge from the relocated industry peer's new region might be transferred through satellite R&D centers of relocated industry peers and shared with other firms in the region. Our interviews with inventors that experienced relocations of their firms shared that some firms leave satellite R&D centers in the region when they leave, so that they can retain employees that do not want to follow the firm to the new region. Inventors that stay in these satellites could communicate with their colleagues in the new region and spillover the knowledge to proximate industry peers. If this is the case, inter-region knowledge channel exists within the firm, between the new headquarter and the satellite R&D center. We tested for this possibility by split sampling outbound relocations into ones that left satellite centers and ones that did not leave satellite centers. Table 10 shows the results of this analysis and model 3 shows that relocations that did not leave satellite centers still had positive impact on focal firms that were proximate to the relocated industry peer.

Not finding any evidence for alternative explanations provide further support for our arguments that inter-region knowledge channels are set up after outbound relocations of proximate industry peers. Through this channel, distant knowledge travels to firms, and firms use this external knowledge source to increase their innovation performance. While outbound relocation reduces local knowledge spillover, at the same time, it is increasing distant knowledge spillover through newly established inter-region knowledge channel.

Insert Tables 10 and 11 about here

DISCUSSION

We examined the well-documented positive relationships between agglomeration level and firm's innovation performance with a novel research design: a proximate industry peer's outbound relocation. Our initial purpose was to provide more insights into the proposed mechanism of knowledge spillover that influences the relationship. However, contrary to our expectation, we found that a proximate industry peer's outbound relocation increases focal firm's innovation performance. We explored the mechanism underlying this result through a series of abductive analyses and found that the positive association between a proximate industry peer's outbound relocation and firm innovation held for firms that are proximately located to the relocating peer, both relocations of peripheral and central peers, and for relocations that move to a less innovative region. Our best explanation of these findings is that a proximate industry peer's outbound relocation constructs an inter-region knowledge channel that temporarily serves as a knowledge conduit between the focal firm and the relocated peer's new region.

By distinguishing outbound relocations by relocation paths, we further examined the mechanism of inter-region knowledge channels being established through interpersonal relationships. We considered the duality of relationships underlying knowledge exchange (i.e., costs and value) by examining both the relocation to a less innovative region and relocation to a more innovative region. If interpersonal relationships are the main means of knowledge channels between formerly proximate firms following the relocation, knowledge channels would only function as long as the interpersonal relationships serve as channels between employees. Relocated employees have more motivation to continue knowledge channels when the firm moves to a less innovative region because relocated employees have more motivation to retain relationships. However, when relocating industry peers moves to a more innovative region, relocated employees may focus more on establishing new local relationships, and therefore, former knowledge channels with former neighbors may not be actively retained. The results support our argument and show that inter-region knowledge channels are mainly driven by outbound relocations to a less innovative region.

This study contributes to several streams of research. In particular, it highlights a novel research design and an overlooked phenomenon—a proximate industry peer's outbound relocation—that firms experience in their geography. Extant research has examined where firms locate their headquarters and facilities and also investigated forces that facilitate firms to relocate their headquarter (Shaver & Flyer, 2000; Birkinshaw et al., 2006; Alcacer & Chung, 2007, 2014; Strauss-Kahn & Vives, 2009). The consequences of such movements on other industry peers in the region are less well known. While research predicts that outbound relocations of firms have adverse effects on the region (Martin et al., 2014), we show that firms in the region may also benefit by utilizing existing relationship with the relocating peer. Moreover, while prior research has emphasized the importance of proximity in forming relationships that involve knowledge exchanges (Reuer & Lahiri, 2014; McCann, Reuer & Lahiri, 2016; Catalini, 2018), less attention has been paid to the role of proximity after the relationship has formed between firms. In this study, we show that proximity plays a less important role in retention of knowledge exchange relationships. Lastly, by documenting that a proximate industry peer's outbound relocation leads to an inter-region knowledge channel, our study sheds light on an unexplored aspect of the knowledge spillover externality of agglomeration. While agglomerated regions are likely destinations of firms (Shaver & Flyer, 2000), firms in agglomerated regions are also more likely to experience a peer's relocation to a different region. Hence, firms in agglomerated regions are not only more likely to gain knowledge spillover from proximate industry peers, but they are also more likely to have indirect accesses to knowledge from other regions than firms in isolated regions.

This work is subject to a number of limitations. First, as discussed, our analysis is dependent on the key assumption that proximate industry peer's outbound relocation is exogenous to focal firm's innovation performance, conditional upon controls. While we have taken numerous steps to evaluate the validity of this assumption (e.g., examining the likelihood of firms relocating to another region and checking pre-treatment trends), it is important to emphasize a proximate industry peer's outbound relocation is not random, and future work that is able to identify valid instruments will make an important contribution.

Second, we lack individual-level data that would allow us to track interpersonal relationships over time. This limitation forces us to use firm-level data and firm-CBSA level data to infer relationships between employees of closely located firms. This also prevents us from directly examining whether interpersonal relationships are serving as the means to inter-region knowledge channels. Researchers with access to such detailed data could make an important impact by studying the micro-foundations of inter-region knowledge channels more directly.

Finally, these findings have relevance for practitioners. As research on the importance of geographic location and proximity for innovation performances mounts, interest has grown in strategically locating firm’s headquarters and facilities near industry peers. If an industry peer relocates to a different location, such efforts by the focal firm could become a waste. However, this study’s findings suggest that when a proximate industry peer relocates to a different region, focal firms may benefit from a peer’s move. Relocations may work to offer indirect access to new knowledge from distant regions. Hence, the findings suggest that firms should develop ways to perpetuate relationships with the relocating firm across regions and time.

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TABLE 1 – Replication of Table 6 from McCann & Folta (2011)

	M1	M2	M3	M4	M5	M6	M7	M8
	DV: Successfully filing a patent							
Cluster Size	0.00	0.01*	0.00	0.01**				
	(0.00)	(0.00)	(0.00)	(0.00)				
Cluster Patents					0.01	0.06**	0.03	0.06**
					(0.02)	(0.02)	(0.02)	(0.03)
Firm Patent Stock	0.39***	0.42***	0.39***	0.39***	0.39***	0.51***	0.39***	0.39***
	(0.03)	(0.05)	(0.03)	(0.03)	(0.03)	(0.07)	(0.03)	(0.03)
Number of Alliances	-0.14***	-0.13**	0.01	-0.13**	-0.13***	-0.13**	0.21**	-0.13**
	(0.05)	(0.05)	(0.08)	(0.05)	(0.05)	(0.05)	(0.10)	(0.05)
Firm Age	-0.04***	-0.04***	-0.04***	-0.03***	-0.04***	-0.04***	-0.04***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Cluster Size X Firm Patent Stock		-0.00						
		(0.00)						
Cluster Size X Number of Alliances			-0.01**					
			(0.00)					
Cluster Size X Firm Age				-0.00**				
				(0.00)				
Cluster Patents X Firm Patent Stock						-0.03**		
						(0.01)		
Cluster Patents X Number of Alliances							-0.07***	
							(0.02)	
Cluster Patents X Firm Age								-0.00**
								(0.00)
Constant	-1.59***	-1.62***	-1.60***	-1.70***	-1.59***	-1.73***	-1.61***	-1.79***
	(0.26)	(0.26)	(0.26)	(0.27)	(0.27)	(0.27)	(0.27)	(0.27)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	6,475	6,475	6,475	6,475	6,475	6,475	6,475	6,475
Log likelihood	-3,374.51	-3,373.86	-3,370.90	-3,371.61	-3,374.78	-3,369.98	-3,367.71	-3,371.03
Chi-Squared	452.64	451.34	464.18	461.86	453.26	453.15	468.07	464.07
Degrees of Freedom	26.00	27.00	27.00	27.00	26.00	27.00	27.00	27.00

Notes: This table replicates Table 6 from McCann and Folta (2011). These models show the relationship between agglomeration and the focal firm's patenting performances. The dependent variable is a binary variable that is "1" if the firm successfully files a patent at a given year. Models 1, 2, 3 and 4 operationalize agglomeration with *cluster size*, which is the number of firms located within the focal firm's metropolitan area. observations. Model 5, 6, 7, and 8 operationalize agglomeration with *cluster patents*, which is the natural log of the cumulative sum of patents held by all firms in the cluster. Both *cluster size* and *cluster patents* are moderated by *firm patent stock, number of alliances, and firm age*. Estimates are from random effects logit models. The results suggest that focal firm's patenting performance benefit from agglomeration and younger firms benefit more. The results are consistent with McCann and Folta (2011). Standard errors clustered at the firm level in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

TABLE 2 – Descriptive Statistics†

	Variable	Mean (full sample)	Mean (relocation)††	Mean (no relocation)	S.D. (full sample)	S.D. (between firms)	S.D. (within firms)	Min (full sample)	Max (full sample)
(1)	Patent impact (t+1 and t+2)	26.24	44.25	23.25	116.88	73.83	94.04	0	2652
(2)	Industry peer's oubound relocation	0.14	1	0	0.35	0.22	0.28	0	1
(5)	Nano patent stock	9.82	13.45	9.22	30.97	19.42	21.65	0	640.24
(6)	Nano paper stock	6.60	6.43	6.63	27.97	23.37	17.08	0	596.48
(7)	Non-nano patent stock (log)	2.13	2.27	2.11	2.52	2.13	0.97	0	9.49
(8)	Number of alliances	0.29	0.37	0.28	0.94	0.55	0.69	0	15
(9)	Inventor mobility out	0.16	0.29	0.14	0.69	0.35	0.56	0	13
(10)	Inventor mobility in	0.15	0.27	0.13	0.57	0.27	0.49	0	8
(11)	Region's agglomeration level (log)	4.41	6.44	4.07	2.36	2.00	1.34	0	7.99

†N = 6,927 for the full sample

††N = 984 for firm-years experiencing inter-region relocations

TABLE 3 – Correlations†

	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	Patent impact (t+1 and t+2)	1.00								
(2)	Industry peer's outbound relocation	0.06	1.00							
(3)	Nano patent stock	0.16	0.05	1.00						
(4)	Nano paper stock	0.02	0.00	0.27	1.00					
(5)	Non-nano patent stock (log)	0.11	0.02	0.29	0.35	1.00				
(6)	Number of alliances	0.13	0.03	0.29	0.33	0.40	1.00			
(7)	Inventor mobility out	0.17	0.08	0.32	0.34	0.38	0.44	1.00		
(8)	Inventor mobility in	0.16	0.08	0.26	0.20	0.33	0.27	0.38	1.00	
(9)	Region's agglomeration level (log)	0.11	0.35	0.15	0.09	0.15	0.14	0.12	0.15	1.00

†N = 6,927

TABLE 4 – A Proximate Industry Peer's Outbound Relocation on Innovation Performances

	M1	M2	M3	M4	M5
	DV: Patent Impact (t+1 and t+2)				
Industry peer's outbound relocation		0.34**	0.29**	0.28	0.26*
		(0.16)	(0.14)	(0.17)	(0.15)
Nano patent stock	-0.01*		-0.01*		-0.00
	(0.00)		(0.00)		(0.00)
Nano paper stock	-0.01***		-0.01***		-0.00
	(0.00)		(0.00)		(0.01)
Non-nano patent stock (log)	0.29***		0.29***		0.13
	(0.10)		(0.10)		(0.13)
Number of alliances	0.01		0.01		0.10
	(0.06)		(0.06)		(0.12)
Inventor mobility out	0.04		0.02		0.03
	(0.06)		(0.06)		(0.10)
Inventor mobility in	0.06		0.06		-0.02
	(0.05)		(0.05)		(0.05)
Agglomeration level (CBSA)	0.05		0.04		-0.03
	(0.04)		(0.04)		(0.07)
Constant	3.75***	4.66***	3.69***	4.92***	4.82***
	(0.29)	(0.04)	(0.30)	(0.05)	(0.67)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	6,749	6,749	6,749	3,815	3,815
Log Likelihood	-130,959.51	-141,235.26	-130,308.17	-98,082.82	-95,897.61
Chi-Squared	28.63	4.63	30.99	2.66	4.39
Degrees of Freedom	7.00	1.00	8.00	1.00	8.00

Notes: These models show the relationship between a proximate industry peer's outbound relocation and the focal firm's innovation performance. The dependent variable is patent impact (i.e., citation-weighted patents). Comparison group firms in Models 1, 2, and 3 are firms not experiencing outbound relocations and comparison group firms in Models 4 and 5 are firms that are located in the same region but are not experiencing outbound relocations (i.e., located more than 10 miles away from the relocating industry peer within the same region). *Industry peer's outbound relocation* is a dummy variable equal to 1 if a proximate industry peer (i.e., within 10-mile radius) relocated to a different region. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 3 suggest that a focal firm's innovation performances benefit from a proximate industry peer's outbound relocation. The results are consistent in Model 5 when comparison group firms are changed to restricted to firms in the same region. Refer to the text for the descriptions of the models and for the detailed definitions of the control variables. Robust standard errors clustered at the focal firm's zip code area level in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

TABLE 5 – Focal Firm and Relocating Industry Peer Heterogeneities

	M1	M2	M3	M4	M5
	DV: Patent Impact (t+1 and t+2)				
Industry peer's outbound relocation		0.28**			
		(0.13)			
Industry peer's outbound relocation – more than 10 miles away	-0.12	-0.15			
	(0.14)	(0.11)			
Industry peer's outbound relocation – central peer			0.29		0.30*
			(0.19)		(0.17)
Industry peer's outbound relocation – peripheral peer				0.25*	0.28*
				(0.14)	(0.15)
Nano patent stock	-0.01***	-0.01*	-0.01***	-0.01*	-0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Nano paper stock	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Non-nano patent stock (log)	0.45***	0.30***	0.33***	0.33***	0.30***
	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)
Number of alliances	0.05	0.02	-0.01	-0.01	0.01
	(0.10)	(0.06)	(0.09)	(0.05)	(0.06)
Inventor mobility out	0.15*	0.03	-0.02	0.03	0.02
	(0.08)	(0.06)	(0.08)	(0.06)	(0.06)
Inventor mobility in	0.09	0.06	0.15*	0.06	0.06
	(0.08)	(0.05)	(0.08)	(0.05)	(0.05)
Agglomeration level (CBSA)	0.01	0.04	-0.00	0.04	0.04
	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
Constant	3.37***	3.71***	3.50***	3.66***	3.68***
	(0.32)	(0.31)	(0.32)	(0.32)	(0.30)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	4,308	6,749	5,005	6,436	6,749
Log Likelihood	-71,753.19	-130,121.00	-85,470.74	-124,711.41	-130,290.32
Chi-Squared	87.07	36.17	65.99	28.90	31.76
Degrees of Freedom	8.00	9.00	8.00	8.00	9.00

Notes: These models show variations of the relationship between a proximate industry peer's outbound relocation and the focal firm's innovation performances. The dependent variable is patent impact (i.e., citation-weighted patents). Models 2 and 5 include all observations. Model 1 exclude firms that experienced outbound relocations of industry peers that are located within 10-miles radius. Model 3 exclude firms that experienced outbound relocations of a peripheral industry peer and model 4 excludes firms that experienced outbound relocations of a central industry peer. *Industry peer's outbound relocation* is a dummy variable equal to 1 if a proximate industry peer (i.e., within 10-mile radius) relocated to a different region. *Industry peer's outbound relocation – more than 10 miles* is a dummy variable equal to 1 if a proximate industry peer that is located more than 10-miles away from the focal firm relocated to a different region. *Industry peer's outbound relocation – central peer* is a dummy variable equal to 1 if the relocating industry peer is a central firm contributing to the region's nano patent stock. *Industry peer's outbound relocation – peripheral peer* is a dummy variable equal to 1 if the relocating industry peer is a peripheral firm contributing to the region's nano patent stock. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 2 shows that a focal firm's innovation performance benefit from a proximate industry peer's outbound relocation only if the relocating industry peer is closely located to the focal firm. Model 5 shows that outbound relocations of both peripheral and central industry peers contribute to increase in the focal firm's innovation performance. Refer to the text for the descriptions of the models and for the detailed definitions of the control variables. Robust standard errors clustered at the focal firm's zip code area level in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

TABLE 6 – A Proximate Industry Peer's Outbound Relocation on Focal Firm's Innovation Performances by Relocation Paths

	M1	M2	M3	M4	M5	M6
	DV: Patent Impact (t+1 and t+2)					
Industry peer's outbound relocation	0.48***		0.48**	0.41**		0.42**
- to a less innovative region	(0.17)		(0.19)	(0.18)		(0.20)
Industry peer's outbound relocation		0.07	0.10		0.06	0.06
- to a more innovative region		(0.19)	(0.19)		(0.19)	(0.19)
Nano patent stock	-0.01*	-0.01	-0.01**	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Nano paper stock	-0.01***	-0.01***	-0.01***	-0.00	-0.01**	-0.00
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Non-nano patent stock (log)	0.29***	0.28***	0.29***	0.05	0.10	0.12
	(0.11)	(0.10)	(0.10)	(0.11)	(0.14)	(0.13)
Number of alliances	-0.03	-0.01	0.01	0.05	0.01	0.10
	(0.07)	(0.06)	(0.06)	(0.12)	(0.13)	(0.13)
Inventor mobility out	0.02	-0.03	0.02	0.02	-0.09	0.03
	(0.07)	(0.06)	(0.05)	(0.09)	(0.10)	(0.09)
Inventor mobility in	0.08	0.08	0.06	-0.03	-0.01	-0.02
	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)	(0.05)
Agglomeration level (CBSA)	0.01	0.04	0.04	-0.06	-0.04	-0.03
	(0.03)	(0.04)	(0.04)	(0.07)	(0.09)	(0.07)
Constant	3.59***	3.89***	3.73***	5.17***	5.20***	4.88***
	(0.34)	(0.30)	(0.31)	(0.64)	(0.74)	(0.67)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5,709	6,082	6,749	3,092	3,319	3,815
Log Likelihood	-108,818.07	-116,761.07	-129,949.33	-76,255.89	-81,699.41	-95,654.50
Chi-Squared	32.18	39.36	38.49	8.07	14.23	7.57
Degrees of Freedom	8.00	8.00	9.00	8.00	8.00	9.00

Notes: These models show the relationship between a proximate industry peer's outbound relocation and the focal firm's innovation performances. The dependent variable is patent impact (i.e., citation-weighted patents). Comparison group firms in Models 1, 2, and 3 are firms not experiencing outbound relocations and comparison group firms in Models 5 and 6 are firms that are located in the same region but are not experiencing outbound relocations (i.e., located more than 10 miles away from the relocating industry peer within the same region). Model 1 and 4 exclude comparison firms that experienced an industry peer's outbound relocation to a more innovative region and models 2 and 5 exclude firms that experienced an industry peer's outbound relocation to a less innovative region. *Industry peer's outbound* relocation is a dummy variable equal to 1 if a proximate industry peer (i.e., within 10-mile radius) relocated to a different region. *Inter-region relocation – to less innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to a less innovative region. *Inter-region relocation – to more innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to a more innovative region. Estimates are from pseudo-maximum likelihood Poisson models. Results from model 3 and 6 suggest that the positive impact of a proximate industry peer's outbound relocation may be driven by relocations to less innovative regions. Refer to the text for the descriptions of the models and for the detailed definitions of the control variables. Robust standard errors clustered at the focal firm's zip code area level in parentheses; *p*-values correspond to two-tailed tests.

*p<0.1; **p<0.05; ***p<0.01

TABLE 7 – A Proximate Industry Peer's Outbound Relocation on Focal Firm's Forward Citations to Patents from the Relocated Peer's New Region

	M1	M2	M3	M4	M5
	DV: Firm's Forward Citations of a Region's Patents (t+1 and t+2)				
Industry peer's outbound relocation	0.22	0.07			
	(0.21)	(0.12)			
Industry peer's outbound relocation			0.20***		0.20***
- to a less innovative region			(0.04)		(0.04)
Industry peer's outbound relocation				0.02	-0.02
- to a more innovative region				(0.06)	(0.04)
Number of citations to nano patents		0.00***	0.00***	0.00***	0.00***
		(0.00)	(0.00)	(0.00)	(0.00)
Target region's cumulative nano patent stock		0.00***	0.00***	0.00***	0.00***
		(0.00)	(0.00)	(0.00)	(0.00)
Target region's cumulative nano paper stock		-0.00***	-0.00***	-0.00***	-0.00***
		(0.00)	(0.00)	(0.00)	(0.00)
Target region's cumulative non-nano patent stock (log)		0.12***	0.12***	0.12***	0.12***
		(0.04)	(0.04)	(0.04)	(0.04)
Target region's agglomeration level (log)		0.01**	0.01**	0.01**	0.01**
		(0.01)	(0.01)	(0.01)	(0.01)
Constant	3.93***	2.34***	2.34***	2.33***	2.34***
	(0.00)	(0.29)	(0.29)	(0.29)	(0.29)
Firm-CBSA fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	261,643	261,643	260,905	261,030	261,643
Log Likelihood	-627374.00	-537509.18	-533157.36	-535245.44	-537472.53
Chi-Squared	1.12	84.43	660.70	84.79	637.33
Degrees of Freedom	1.00	6.00	6.00	6.00	7.00

Notes: These models show the relationship between a proximate industry peer's outbound relocation and the focal firm's citation behavior. The unit of analysis is at the firm-CBSA-year level and all firm-CBSA pairs where the firm cited at least one patent from a given CBSA is included. The comparison group are firm-CBSA pairs that did not experience a proximate industry peer's outbound relocation. The dependent variable is the number of citations that the firms makes to patents from a region (i.e., number of forward citations by the firm to patents of the CBSA at year t+1 and t+2). Model 3 excludes comparison firm-CBSA pairs that experienced an industry peer's outbound relocation to a more innovative region and model 4 excludes comparison firm-CBSA pairs that experienced an industry peer's outbound relocation to a less innovative region. *Industry peer's outbound relocation* is a dummy variable equal to 1 if a proximate industry (i.e., within 10-mile radius) relocated to the focal region. *Industry peer's outbound relocation – to a less innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to the focal region that is less innovative than the pre-relocation region. *Inter-region relocation – to a more innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to the focal region that is more innovative than the pre-relocation region. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 5 suggest that a focal firm cites more from the region following a proximate industry peer's relocation into the region that is less innovative. These results provide support for the mechanism that inter-region knowledge transfer channel is constructed when a proximate industry peer relocates into another region. Cluster-robust standard errors on the target region (i.e., CBSA) are shown in parentheses; *p*-values correspond to two-tailed tests.

*p<0.1; **p<0.05; ***p<0.01

TABLE 8 – Testing alternative explanation: Split-sample analysis of states by enforcement of noncompete agreements

	M1	M2	M3	M4	M5	M6
	DV: Patent Impact (t+1 and t+2)					
	States **NOT** enforcing noncompete agreements			States enforcing noncompete agreements		
Industry peer's outbound relocation	0.32	0.25		0.22	0.33*	
	(0.27)	(0.20)		(0.19)	(0.20)	
Industry peer's outbound relocation			0.39*			0.33*
- to a less innovative region			(0.21)			(0.20)
Industry peer's outbound relocation			-0.32			0.34
- to a more innovative region			(0.35)			(0.25)
Nano patent stock		-0.00	-0.00		-0.01***	-0.01***
		(0.00)	(0.00)		(0.00)	(0.00)
Nano paper stock		0.00	0.00		-0.01***	-0.01***
		(0.01)	(0.01)		(0.00)	(0.00)
Non-nano patent stock (log)		0.21	0.22		0.42***	0.42***
		(0.16)	(0.14)		(0.13)	(0.13)
Number of alliances		0.04	0.04		-0.01	-0.01
		(0.13)	(0.14)		(0.07)	(0.07)
Inventor mobility out		0.04	0.03		0.02	0.02
		(0.08)	(0.08)		(0.06)	(0.06)
Inventor mobility in		0.00	-0.00		0.08	0.08
		(0.06)	(0.05)		(0.08)	(0.08)
Agglomeration level (CBSA)		0.32**	0.23*		0.03	0.03
		(0.15)	(0.14)		(0.04)	(0.04)
Constant	4.49***	1.91*	2.45***	4.81***	3.49***	3.49***
	(0.11)	(0.97)	(0.90)	(0.03)	(0.37)	(0.37)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2,231	2,231	2,231	4,459	4,459	4,459
Log Likelihood	-51,139.21	-49,462.59	-48,880.13	-86,800.43	-74,649.19	-74,636.63
Chi-Squared	1.43	21.33	27.67	1.28	64.91	75.94
Degrees of Freedom	1.00	8.00	9.00	1.00	8.00	9.00

Notes: These models show the relationship between a proximate industry peer's outbound relocation and the focal firm's innovation performance by whether noncompete agreements were enforced in the state. Three states did not enforce noncompete agreements during our time frame: California, Oklahoma, and North Dakota. Other states enforced noncompete agreements, which restricted movement of inventors across industry peers. The dependent variable is patent impact (i.e., citation-weighted patents). Models 1, 2, and 3 restrict the sample to firms in states that did not enforce noncompete agreements and models 4, 5, and 6 restrict the sample to firms in states that did enforce noncompete agreements. *Industry peer's outbound relocation* is a dummy variable equal to 1 if a proximate industry peer (i.e., within 10-mile radius) relocated to a different region. *Industry peer's outbound relocation – to less innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to a less innovative region. *Inter-region relocation – to more innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to a more innovative region. Estimates are from pseudo-maximum likelihood Poisson models. The results from models 3 and 6 shows that a focal firm cites benefits from a more from the region benefits from a proximate industry peer's outbound relocation regardless of whether noncompete agreements are enforced or not in the state. These results suggests that inventor mobility between the relocating peer and the focal firm may not be the driving force of the positive impact of the industry peer's outbound relocation. Robust standard errors clustered at the focal firm's zip code area level in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

TABLE 9 – Testing alternative explanation: Firms without mobility of inventors from the relocating industry peer

	M1	M2
	DV: Patent Impact (t+1 and t+2)	
Industry peer’s outbound relocation	0.33*	0.30**
	(0.17)	(0.14)
Nano patent stock		-0.01*
		(0.00)
Nano paper stock		-0.01***
		(0.00)
Non-nano patent stock (log)		0.31***
		(0.10)
Number of alliances		0.01
		(0.06)
Inventor mobility out		0.03
		(0.07)
Inventor mobility in		0.07
		(0.05)
Agglomeration level (CBSA)		0.04
		(0.04)
Constant	4.64***	3.63***
	(0.04)	(0.31)
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
N	6,602	6,602
Log Likelihood	-134,147.35	-123,479.50
Chi-Squared	3.78	32.44
Degrees of Freedom	1.00	8.00

Notes: These models show the relationship between a proximate industry peer’s outbound relocation and the focal firm’s innovation performance for firms that do not have inventors joining from the relocating industry peer. The dependent variable is patent impact (i.e., citation-weighted patents). The comparison group firms in models 1 and 2 are firms in other regions that did not experience a proximate industry peer’s outbound relocation and the comparison group firms in models 3 and 4 include all firms that did not experience a proximate industry peer’s outbound relocation. *Industry peer’s outbound relocation (proximity: region)* is a dummy variable equal to 1 if a proximate industry peer (i.e., firm in the same region) relocated to a different region. *Industry peer’s outbound relocation* is a dummy variable equal to 1 if a proximate industry peer (i.e., within 10-mile radius) relocated to a different region. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 4 show that the focal firm benefits from a proximate industry peer’s outbound relocation even if an inventor does not move from the relocating industry peer to the focal firm. This further suggests that inventor mobility from the relocating industry peer may not be the driving force of the positive impact of the industry peer’s outbound relocation. Robust standard errors clustered at the focal firm’s zip code area level in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

TABLE 10 – Testing alternative explanation: Citation patterns of the relocated industry peer's new neighbors in the new region

	M1	M2	M3	M4	M5
	DV: Region's Forward Citations of a Focal Firm's Patents (t+1 and t+2)				
Industry peer's outbound relocation	-0.12	0.06			
	(0.22)	(0.18)			
Industry peer's outbound relocation			-0.03		-0.03
- to a less innovative region			(0.21)		(0.22)
Industry peer's outbound relocation				0.05	0.06
- to a more innovative region				(0.14)	(0.14)
Number of citations to nano patents		0.00**	0.00**	0.00**	0.00**
		(0.00)	(0.00)	(0.00)	(0.00)
Target firm's nano patent stock		0.00**	0.00**	0.00**	0.00**
		(0.00)	(0.00)	(0.00)	(0.00)
Target firm's nano paper stock		0.00	0.00	0.00	0.00
		(0.00)	(0.00)	(0.00)	(0.00)
Target firm's non-nano patent stock (log)		0.36***	0.36***	0.35***	0.36***
		(0.07)	(0.07)	(0.07)	(0.07)
Target firm's region's agglomeration level (log)		0.01*	0.01	0.01*	0.01*
		(0.01)	(0.01)	(0.01)	(0.01)
Constant	3.57***	0.58	0.58	0.56	0.59*
	(0.01)	(0.35)	(0.36)	(0.36)	(0.35)
CBSA-Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	42,954	42,954	42,189	42,315	42,954
Log Likelihood	-103,489.60	-91,715.11	-89,460.11	-89,788.27	-91,715.83
Chi-Squared	0.29	124.87	121.03	117.93	124.76
Degrees of Freedom	1.00	6.00	6.00	6.00	7.00

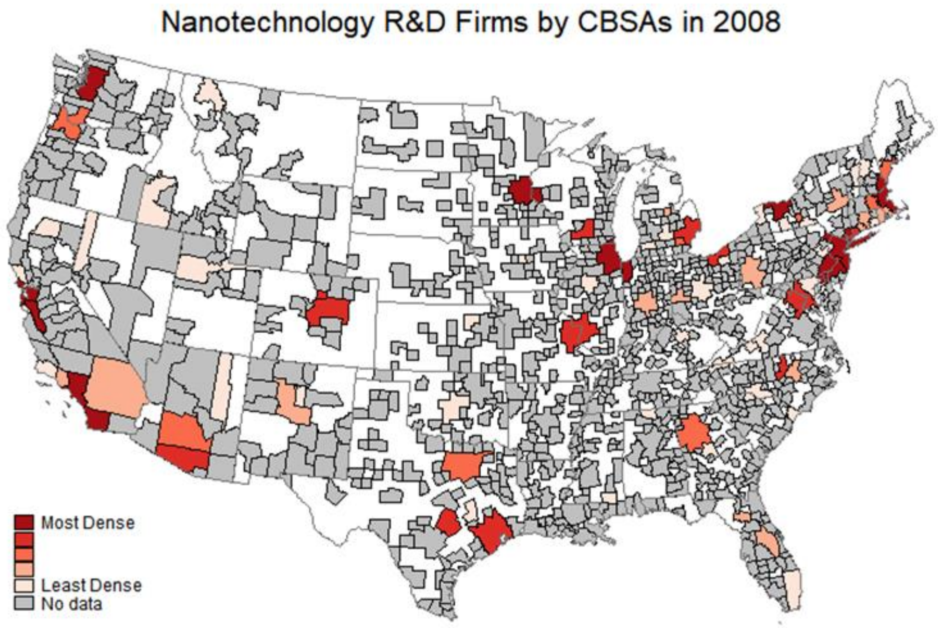
Notes: These models show the relationship between a proximate industry peer's outbound relocation and the relocated industry peer's new region's citation behavior. The unit of analysis is at the firm-CBSA-year level and all firm-CBSA pairs where the region cited at least one patent from a given firm is included. The comparison group are firm-CBSA pairs that did not experience a proximate industry peer's outbound relocation. The dependent variable is the number of citations the region makes to patents from the focal firm (i.e., number of forward citations by the region to patents of the firm at year t+1 and t+2). All models include all observations. Model 3 excludes comparison firm-CBSA pairs that experienced an industry peer's outbound relocation to a more innovative region and model 4 excludes comparison firm-CBSA pairs that experienced an industry peer's outbound relocation to a less innovative region. *Industry peer's outbound relocation* is a dummy variable equal to 1 if a proximate industry (i.e., within 10-mile radius) relocated to the focal region. *Industry peer's outbound relocation – to a less innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to the focal region that is less innovative than the pre-relocation region. *Inter-region relocation – to a more innovative region* is a dummy variable equal to 1 if a proximate industry peer relocated to the focal region that is more innovative than the pre-relocation region. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 2 suggest that a focal region does not cite more from the focal firm following the focal firm's proximate industry peer's relocation into the region. The results are consistent regardless of whether the proximate industry peer relocated in to a less or a more innovative region. Cluster-robust standard errors on the target region (i.e., CBSA) are shown in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

TABLE 11 – Testing alternative mechanism: Distinguishing relocations by whether relocating industry peer leaves satellite R&D center in the region

	M1	M2	M3
	DV: Patent Impact (t+1 and t+2)		
Industry peer's outbound relocation – with satellites	0.08		0.12
	(0.18)		(0.19)
Industry peer's outbound relocation – without satellites		0.28*	0.29*
		(0.17)	(0.17)
Nano patent stock	-0.01***	-0.01*	-0.01*
	(0.00)	(0.00)	(0.00)
Nano paper stock	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)
Non-nano patent stock (log)	0.34***	0.31***	0.30***
	(0.11)	(0.10)	(0.10)
Number of alliances	-0.06	0.01	0.01
	(0.08)	(0.06)	(0.06)
Inventor mobility out	-0.03	0.02	0.02
	(0.06)	(0.06)	(0.06)
Inventor mobility in	0.13**	0.06	0.06
	(0.05)	(0.05)	(0.05)
Agglomeration level (CBSA)	0.01	0.04	0.04
	(0.03)	(0.04)	(0.04)
Constant	3.67***	3.67***	3.69***
	(0.33)	(0.32)	(0.31)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	4,940	6,530	6,749
Log Likelihood	-92,679.92	-127,960.95	-130,201.90
Chi-Squared	58.50	28.27	28.87
Degrees of Freedom	8.00	8.00	9.00

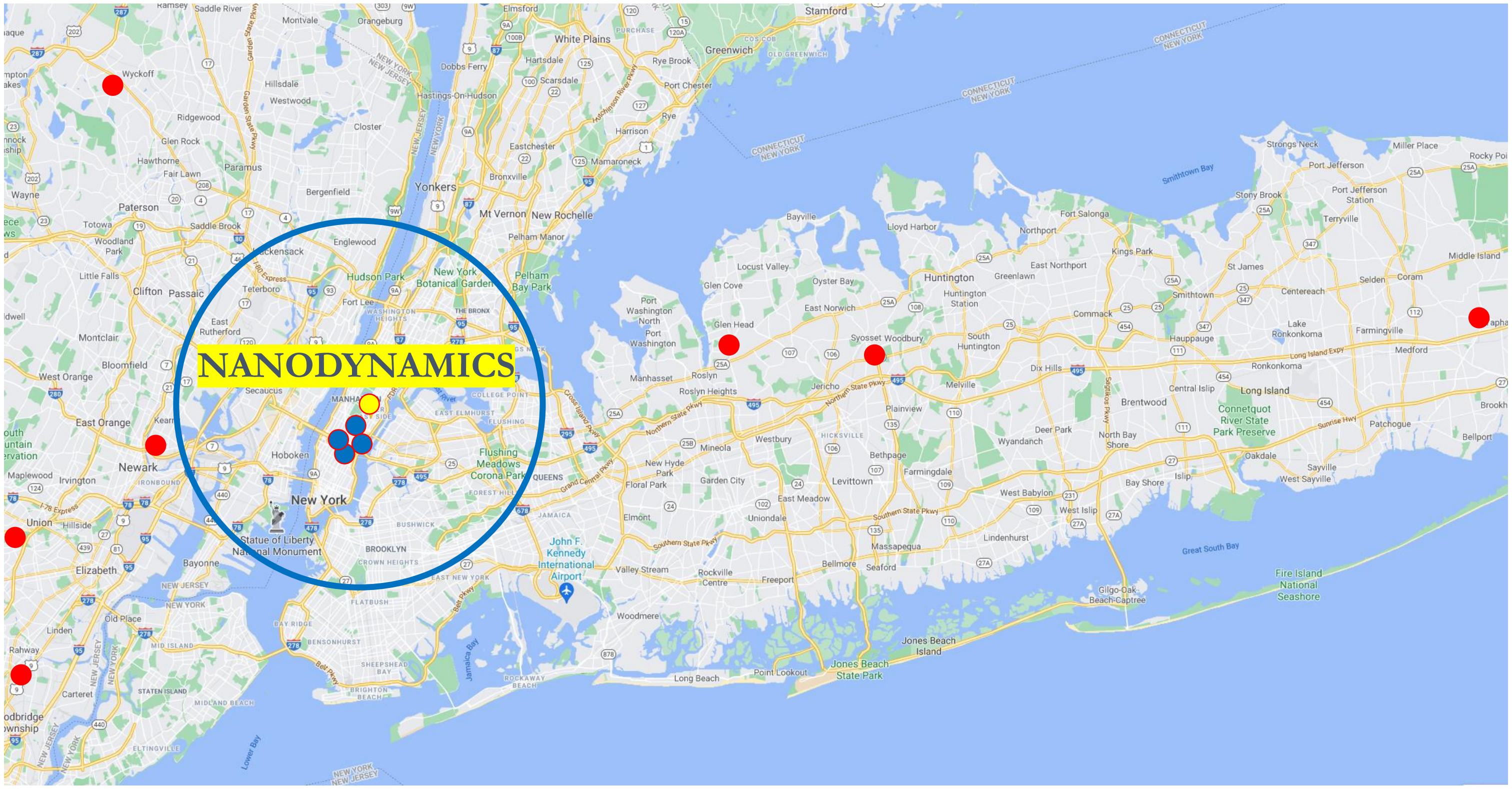
Notes: These models show the relationship between a proximate industry peer's outbound relocation and the focal firm's innovation performance by whether the relocating industry peer leaves a satellite R&D center in the region or not. for firms that do not have inventors joining from the relocating industry peer. The comparison group firms are firms not experiencing an industry peer's outbound relocation. Model 1 excludes firms that experience an industry peer's outbound relocation that does not leave satellites and model 2 excludes firms that experience an industry peer's outbound relocation that do leave satellites. *Industry peer's outbound relocation – with satellites* is a dummy variable equal to 1 if the relocating industry peer leaves a satellite R&D center in the region and *Industry peer's outbound relocation – without satellites* is a dummy variable equal to 1 if the relocating industry peer does not leave a satellite R&D center in the region. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 3 show that the focal firm mainly benefits from a proximate industry peer's outbound relocation when they do not leave satellite R&D center. This suggests that the positive impact of an industry peer's outbound relocation on the focal firm's innovation performance is not through knowledge spillover from the satellite R&D center. Robust standard errors clustered at the focal firm's zip code area level in parentheses; *p*-values correspond to two-tailed tests.
*p<0.1; **p<0.05; ***p<0.01

FIGURE 1 Geographical Distribution of Nanotechnology R&D Firms by CBSAs in 2008



Notes: The figure above shows geographic distribution of nanotechnology R&D firms by CBSAs in 2008. The figure shows that in 2008, nanotechnology firms were located in 83 CBSAs, and 8 CBSAs had more than 10 nanotechnology firms.

FIGURE 2 – A Relocating Firm and its Geographically Proximate Firms



Notes: The figure above shows how a proximate industry peer is defined. The figure shows the CBSA that comprises the New York City. Nanodynamics (marked by the yellow dot) is a Nanotechnology R&D firm in Manhattan until it relocated to Buffalo in 2005. There were 25 nano firms in this region. However, only four industry peers are within 10 miles radius of Nanodynamics, which is the boundary drawn by the blue circle. These four industry peer, marked by blue dots, are considered as a geographically proximate industry peer of Nanodynamics, but for other firms in the region, marked by red dots, Nanodynamics is not a proximate industry peer.

APPENDIX 1 – Logistic regression models of a firm's outbound relocation

	M1	M2
	DV: Inter-region relocation	
	Coeff.	Marginal Effect
Nano patent stock of proximate industry peers	0.00	0.00
	(0.00)	(0.00)
Nano patent stock	0.00	0.00
	(0.00)	(0.00)
Nano paper stock	-0.06**	-0.01**
	(0.03)	(0.01)
Non-nano patent stock (log)	-0.20**	-0.04**
	(0.09)	(0.02)
Number of alliances	0.12	0.02
	(0.16)	(0.03)
Inventor mobility out	-1.22	-0.25
	(1.03)	(0.21)
Inventor mobility in	0.24	0.05
	(0.29)	(0.06)
N	4307.00	4307.00
Log Likelihood	-286.60	
Chi-Squared	73.92	
Degrees of Freedom	7.00	

Notes: These models show the relationship between nano patent stocks of proximate industry peers in the region and the focal firm's decision to relocate. The dependent variable is the focal firm's outbound relocation. *Nano patent stock of proximate industry peers* is the cumulative number of nanotechnology patents of industry peers in the region that share the same three digit zip codes, depreciated by 15% annually. Estimates are from conditional logit models and models are conditioned on the year. Marginal effects are calculated for models 2. The results from model 1 and 2 show that a focal firm's decision to relocation to a different region is not a function of nano patent stock of other firms. These results provide support for our assumption that a firm's decision to relocation to a different region is exogenous to proximate firms' innovation performances. Refer to the text for the descriptions of the models and for the detailed definitions of the control variables. Robust standard errors are shown in parentheses; *p*-values correspond to two-tailed tests.

*p<0.1; **p<0.05; ***p<0.01

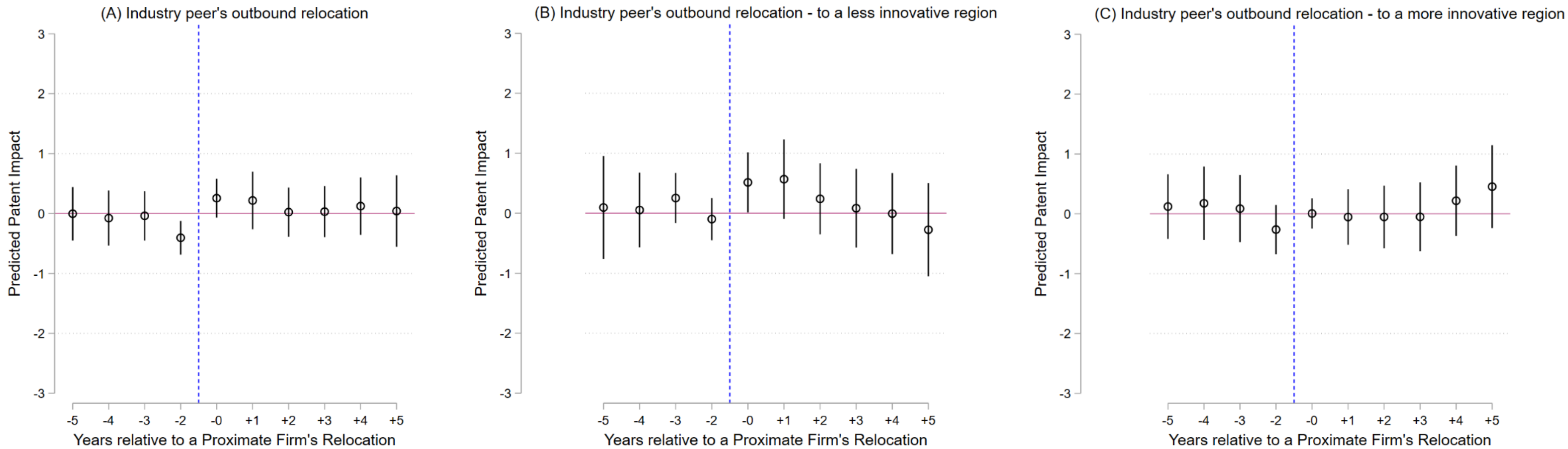
APPENDIX 2 – Relative-time models of a proximate industry peer's outbound relocation and focal firm's innovation performances

	M1	M2	M3	M4	M5	M6
	DV: Patent Impact (t+1 and t+2)					
Years until an industry peer's outbound relocation < -5	-0.04	-0.06	-0.37	-0.45	-0.13	0.09
	(0.33)	(0.32)	(0.37)	(0.37)	(0.36)	(0.33)
Years until an industry peer's outbound relocation = -5	-0.00	-0.00	0.28	0.10	-0.01	0.12
	(0.24)	(0.23)	(0.34)	(0.44)	(0.30)	(0.28)
Years until an industry peer's outbound relocation = -4	0.03	-0.08	0.29	0.05	0.15	0.18
	(0.22)	(0.23)	(0.28)	(0.32)	(0.27)	(0.31)
Years until an industry peer's outbound relocation = -3	0.02	-0.04	0.29	0.25	0.17	0.09
	(0.17)	(0.21)	(0.21)	(0.21)	(0.27)	(0.29)
Years until an industry peer's outbound relocation = -2	-0.35**	-0.40***	-0.01	-0.10	-0.24	-0.26
	(0.15)	(0.14)	(0.20)	(0.18)	(0.20)	(0.21)
Years until an industry peer's outbound relocation = 0	0.30	0.26	0.58**	0.51**	-0.02	0.01
	(0.20)	(0.17)	(0.29)	(0.26)	(0.12)	(0.13)
Years until an industry peer's outbound relocation = +1	0.28	0.22	0.70*	0.57*	-0.07	-0.05
	(0.28)	(0.25)	(0.36)	(0.34)	(0.24)	(0.24)
Years until an industry peer's outbound relocation = +2	0.14	0.02	0.35	0.24	-0.01	-0.05
	(0.22)	(0.21)	(0.28)	(0.30)	(0.27)	(0.27)
Years until an industry peer's outbound relocation = +3	0.12	0.03	0.20	0.08	-0.02	-0.05
	(0.21)	(0.22)	(0.28)	(0.33)	(0.28)	(0.29)
Years until an industry peer's outbound relocation = +4	0.21	0.12	0.10	-0.01	0.26	0.22
	(0.23)	(0.24)	(0.29)	(0.34)	(0.28)	(0.30)
Years until an industry peer's outbound relocation = +5	0.19	0.04	-0.08	-0.28	0.51	0.45
	(0.31)	(0.30)	(0.36)	(0.40)	(0.38)	(0.35)
Years until an industry peer's outbound relocation > +5	0.32	0.07	0.07	-0.27	0.75**	0.80*
	(0.36)	(0.41)	(0.42)	(0.45)	(0.37)	(0.46)
Nano patent stock		-0.01*		-0.01*		-0.01*
		(0.00)		(0.00)		(0.00)
Nano paper stock		-0.01***		-0.01***		-0.01***
		(0.00)		(0.00)		(0.00)
Non-nano patent stock (log)		0.30***		0.30***		0.27***
		(0.10)		(0.10)		(0.10)
Number of alliances		0.01		-0.02		-0.01
		(0.06)		(0.07)		(0.06)
Inventor mobility out		0.03		0.02		-0.02
		(0.06)		(0.07)		(0.06)
Inventor mobility in		0.08*		0.08		0.10*
		(0.05)		(0.05)		(0.05)
Agglomeration level (log)		0.04		0.01		0.04
		(0.04)		(0.03)		(0.04)
Constant	4.68***	3.73***	4.44***	3.60***	4.72***	3.87***
	(0.07)	(0.31)	(0.07)	(0.33)	(0.07)	(0.29)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	6,749	6,749	5,709	5,709	6,082	6,082
Log Likelihood	-141084.36	-129956.74	-117516.96	-107809.63	-126063.05	-115529.21
Chi-Squared	29.40	48.84	23.56	53.21	21.54	76.31
Degrees of Freedom	12.00	19.00	12.00	19.00	12.00	19.00

Notes: These models show the relationship between a proximate industry peer's outbound relocation and the focal firm's innovation performances. Consistent with prior work, we use the period prior to a proximate firm's relocation as the baseline by normalizing the coefficient of period prior to the relocation to zero (Burtch, Carnahan & Greenwood, 2018). The dependent variable is patent impact (i.e., citation-weighted patents). In models 1 and 2, time trends are relative to all outbound relocations of proximate industry peers. In models 3 and 4, time trends are relative to outbound relocations of proximate industry peers moving to less innovative regions. In models 5 and 6, time trends are relative to outbound relocations of proximate industry peers moving to more innovative regions. Estimates are from pseudo-maximum likelihood Poisson models. The results from model 1-6 show that there is no evidence of significant differences in pre-treatment trends. Hence, parallel trends assumption is not violated. Refer to the text for the descriptions of the models and for the detailed definitions of the control variables. Robust standard errors clustered at the focal firm's zip code area level in parentheses; *p*-values correspond to two-tailed tests.

*p<0.1; **p<0.05; ***p<0.01

APPENDIX 3 – Coefficient Plots of a Proximate Firm's Inter-Region Relocation and Innovation Performances



Notes: 95% confidence intervals. The dependent variable is patent impact. Points represent coefficient estimates from the results from Appendix 2 models 2, 4, and 6 respectively. Error bars that span 0 indicate that the corresponding coefficient is not significantly different from 0. Robust standard errors clustered at the focal firm's zip code area level.