Employee Mobility Barriers and Inventor Collaborativeness in Firms

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ABSTRACT

Although robust inventor collaboration is known to enhance innovation in firms, relatively little is known about the firm-level drivers of inventor collaborativeness. Because collaboration may increase knowledge spillovers to competitors by mobile inventors, we posit that barriers to employee mobility may induce firms to increase inventor collaborativeness by reducing these hazards for the capture of value. We leverage a set of natural experiments resulting from quasi-exogenous changes in two legal mobility barriers to show that mobility barriers enhanced inventor team size, formation of new co-inventor ties, and combination of inventors possessing heterogeneous knowledge in U.S. manufacturing firms. These findings contribute towards our understanding of the antecedents of inventor collaboration within firms, and the strategic tradeoffs between value creation and value capture in collaborative innovation.

Key words: Employee mobility barriers, inventor collaboration, innovation, difference-in-differences analysis

INTRODUCTION

Innovation is widely understood as a process of combining existing knowledge in novel ways, and the innovation literature has long recognized the importance of vigorous collaboration among inventors for enhancing innovation by firms (Audia and Goncalo 2007, Fleming and Sorenson 2004, Singh et al. 2016, Toh and Polidoro 2013). Given that inventors possess heterogeneous knowledge, internal inventor collaboration enhances the firm's innovation performance by integrating these diverse knowledge resources embedded in individual inventors (Ahuja 2000, Carnabuci and Operti 2013, Guler and Nerkar 2012). Moreover, transactive memory and mutual trust developed among collaborators enable firms to be more productive in knowledge recombination (Argote 2013, Nahapiet and Ghoshal 1998, Nonaka 1994). Consistent with this logic, many empirical studies have shown that collaborative inventors are more likely to generate impactful inventions (Fleming et al. 2007, Singh and Fleming 2010) and that robust internal collaboration among inventors enhances firm's innovation capabilities (Carnabuci and Operti 2013, Funk 2014, Guler and Nerkar 2012).

Although prior research has extensively documented the performance advantages of internal inventor collaboration for innovation by firms, important research questions remain about why some firms are more internally collaborative than others and what strategic factors influence the degree and scope of a firm's internal collaboration for innovation (Toh and Polidoro 2013). The current paper aims to fill this gap by examining how the risks associated with potential employee mobility shapes the extent of internal inventor collaboration within firms. We theorize that firms may increase inventor collaborativeness when employee mobility barriers are restricted because such barriers may provide safeguards against a major negative consequence of robust internal collaboration, namely a higher risk of knowledge spillovers subsequent to inventor mobility.

In firms with greater internal collaborativeness, individual inventors may have access to more of the firm's knowledge base through their collaboration networks, and access to more tacit and complex knowledge of the type that often underpins firms' inimitable competitive advantage (Rivkin 2000, Singh et al. 2016, Sorenson et al. 2006). Consequently, when these inventors move to competing firms, knowledge spillovers are likely to be more extensive and impactful. To mitigate these concerns, Liebeskind (1997) proposes that firms may intentionally restrict collaboration among employees so that any individual employee is less attractive in the labor market and has access to only a limited fraction of the firm's knowledge. Under circumstances with a high potential for inter-firm inventor mobility, therefore, firms may not undertake internal collaboration at the optimal level that maximizes combinatorial potential of firm's innovation activities.

We posit that employee mobility barriers may help resolve the central dilemma arising from these trade-offs and allow firms to expand collaboration among their inventors. By providing firms with a degree of control over their R&D human capital, mobility barriers may encourage firms to support collaborative innovation without worrying about losing valuable human and knowledge resources. This study focuses on the effects on collaboration of two major legal barriers that limit employee mobility: non-compete agreements (NCAs) and the inevitable disclosure doctrine (IDD). NCAs are clauses in employment contracts that specify companies or fields in which employees pledge not to work for a period of time when their employment ends (Gilson 1999), whereas the IDD is a legal doctrine that extends trade secrecy law to restrict an employee's ability to work for a rival firm if this would "inevitably" disclose the former firm's trade secrets (Klasa et al. 2018). Prior research has found that both mechanisms significantly decrease employee mobility to competitors (Marx et al. 2009, Png and Samila 2013), thus increasing retention of firms' key human capital. Accordingly, we hypothesize that mobility barriers arising from NCAs and IDD will increase internal inventor collaborativeness in firms. We examine the impacts of employee mobility barriers on three dimensions of collaboration in innovation – team size, new tie formation, and inventor knowledge heterogeneity.

To test our hypotheses, we analyzed 1,985 U.S. manufacturing firms from 1975 to 2009. By utilizing quasi-exogenous variations produced by new laws or by major court decisions, we found that—relative to a set of control firms that did not experience these changes—the strengthening of NCAs and adoption of IDDs significantly increased collaborativeness among inventors within firms along each of dimensions described above. Specifically, firms with higher mobility barriers not only increased their average team size in patented inventions, but were more likely to form new co-inventor ties, and to combine inventors possessing heterogeneous knowledge.

Our research seeks to make three main contributions to the strategy and innovation literature. First, this paper provides a more nuanced understanding about collaborative innovation in firms by highlighting the tradeoffs between value creation and value capture in internal inventor collaboration. That is, firm's internal collaborativeness needs to be understood as striking a balance between competing forces. Second, by exploring the strategic antecedents of inventor collaborativeness within firms, this paper contributes toward better understanding of why firms differ in the collaborativeness in innovation. Specifically, the difference in potential employee mobility can explain firm's heterogeneous incentives for collaborative invention. Third, this study contributes to the literature on strategic human capital. The literature has highlighted the importance of mobility barriers for firm's sustainable competitive advantages (Campbell et al. 2012, Chadwick 2017, Coff 1997). By showing how stronger mobility barrier can contribute to firm's innovation activities by reducing the concern of value capture, we add to our understanding about the link between mobility barriers and competitive advantage of firm.

THEORY AND HYPOTHESES

The Dilemma of Internal Inventor Collaboration

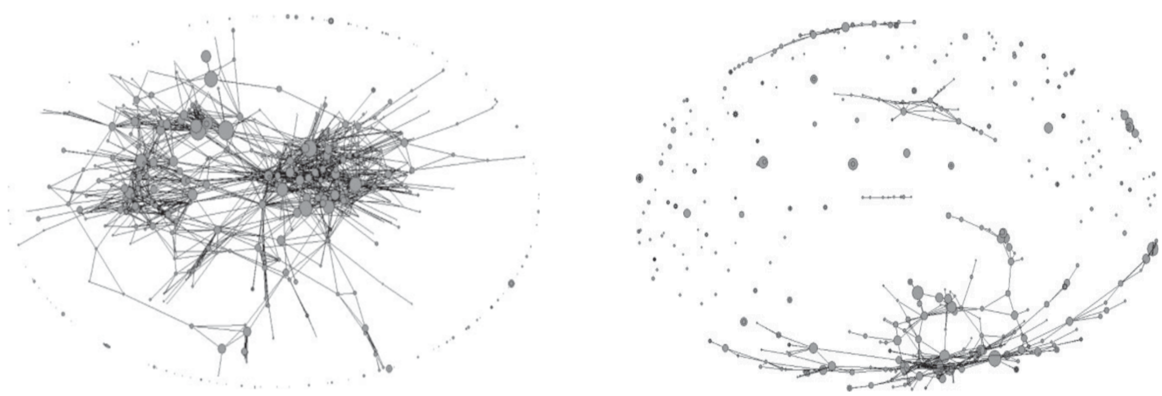
Internal inventor collaboration plays two important roles in facilitating innovation in firms. First, collaboration allows a firm to draw on a diversity of knowledge resources for innovation. Innovation research suggests that impactful inventions tend to be a product of combining heterogeneous knowledge (Fleming 2001, Rosenkopf and Nerkar 2001). However, these heterogeneous knowledge resources are rarely held by a single individual and are instead distributed across inventors within the firm. Thus, through collaboration, firms can generate valuable innovation by integrating diverse knowledge embedded in individual inventors (Alcácer and Zhao 2012, Björkman et al. 2007, Foss and Pedersen 2002). Second, collaboration serves to develop relational resources within firms. During intensive collaborative interactions, for instance, inventors may develop a "transactive memory" system, or a basic understanding about “who knows what”, which promotes better matching between inventors in future R&D projects (Argote 2013, Faraj and Sproull 2000, Rosen et al. 2007). Mutual trust developed among collaborators also contributes to the creation of new intellectual capital within the firm (Nahapiet and Ghoshal 1998), and thus current collaborative invention may enhance future innovation opportunities of the firm by creating and maintaining valuable interpersonal relationships. Consistent with these logics, empirical research has shown that collaborative inventors are more likely to produce breakthrough inventions (Fleming et al. 2007, Singh and Fleming 2010), and that robust internal collaboration enhances firms’ R&D capabilities and performance in innovation activities (Carnabuci and Operti 2013, Funk 2014, Guler and Nerkar 2012).

Given its potential to enhance firms’ innovative performance, it is intriguing to observe a significant heterogeneity in inventor collaborativeness in firms. For instance, Carnabuci and Operti (2013) reported that Micron Technology possessed a highly collaborative network in which most inventors are directly or indirectly connected through strong ties (Panel (A) of Figure 1), while LSI Corporation had a less collaborative network in which a considerable number of inventors are lone or isolated (Panel (A) of Figure 1). Chang, Lee, and Song (2012) analyze patenting activities of two Korean semiconductor firms, Samsung Electronics and Hynix, and find that Samsung Electronics’ invention was much more collaborative than Hynix’s. As such, despite many observable similarities, firms often differ widely in their degree of inventor collaborativeness.

Figure 1. Firm Heterogeneity in Inventor Collaborativeness

Panel (A)
Micron Technology
(1996 – 1998)

Panel (B)
LSI Corporation
(1996 – 1998)



Source: Carnabuci and Operti (2013)

The extant literature provides some understanding about the drivers of inventor collaborativeness in firms. For instance, proximity between inventors—geographic, organizational or socio-cultural—play a key role in the formation of collaboration ties (Crescenzi et al. 2016); thus firms may enhance collaboration by increasing inventor proximity in various ways. Moves by large technology firms to create centralized corporate campuses, for example, are often supported by a need for greater internal collaboration (McDougal 2005). Lee (2019) show that increasing the spatial proximity between workspaces of individuals who were previously physically separated leads to more collaboration. Similarly, Forman and Zeebroeck (2012) show that internet adoption by multi-location firms fostered collaboration by helping to “virtually” increase the proximity between geographically distant inventors. Another potential driver of collaboration is a firm’s capability to collaborate; for example, Howard et al. (2016) find that external collaboration with a highly collaborative partner leads to greater internal collaboration, presumably through the learning of tacit collaborative routines. Finally, firms’ internal collaboration may also be driven by external competition from proximate rival products, which create greater incentives for deeper exploitative search over exploratory search (Toh and Polidoro 2013).

Despite these insights from prior work, however, our understanding of why some firms are more collaborative than others is still quite limited. In this study, we seek to advance this stream of research by highlighting a potential hazard of robust inventor collaboration when the potential mobility of R&D employees is high: namely, a high risk of knowledge spillovers by mobile inventors. Increased collaboration among a firm's inventors will likely result in a greater share of the firm's knowledge base being accessible to any inventor. Research suggests that even tacit and complex knowledge, which is generally difficult to transfer, can be disseminated within a firm through intensive interactions between inventors in collaboration (Hansen 1999, Sorenson et al. 2006, Szulanski 1996). Singh et al. (2016) find evidence that inventors can obtain sticky knowledge such as combinatory knowledge (i.e., how to combine diverse knowledge) through interpersonal collaboration ties. Robust internal collaboration, therefore, necessarily leads to the internal diffusion of a firm's valuable knowledge assets and thus makes the firm vulnerable to knowledge spillovers by mobile inventors (Mawdsley and Somaya 2016, Singh and Agrawal 2011, Song et al. 2003). That is, when a firm's invention activities are highly collaborative, more knowledge, and more consequential knowledge, is likely to spill over to competitors through a mobile inventor.

To address these hazards, firms may restrict interactions and collaboration among its inventors. Organizational structure and policies often serve to achieve this goal. For instance, scientists in one R&D unit may be limited in their interaction with colleagues in other R&D units because the organization structure of the firm inhibits such interaction. Similarly, organizational policies (including both incentives and sanctions) may explicitly prohibit inventors from discussing their projects with each other, who then miss out on valuable collaboration opportunities. Spatial separation is another important tool that firms may use to restrict interactions. Some firms may locate research centers conducting sensitive research in a remote area, or they may literally wall off some R&D teams from other parts of the firm (Lashinsky 2012).[1] Liebeskind (1996, p. 99-100) illustrates how the threat of value capture leads to the

[1] "Apple employees know something big is afoot when the carpenters appear in their office building. New walls are quickly erected. Doors are added and new security protocols put into place. Windows that once were transparent are

compartmentalization of R&D: *"Consider, for example, the team production of a highly valuable software program. If knowledge protection were not an issue, this program might best be produced by four programmers working in close collaboration. However, this job design would allow all four workers access to final product. The firm can reduce this number to one by mandating that the four programmers work separately on different subcomponents of the system, and by having their work supervised and integrated by a single manager…. Disaggregation of tasks in this way is a common feature of many firms (and other organizations) that possess highly valuable knowledge. For instance, in defense contracting, the production of defense systems (such as aircraft, rockets, missiles, or satellites) is frequently disaggregated."* Such efforts to mitigate the potential hazards of knowledge spillovers may implicitly hurt a firm's innovation output and quality, but they may be nonetheless undertaken for a better protection of their knowledge resources.

In sum, intra-organizational collaborations have an intrinsic trade-off with respect to value creation and value appropriation. While robust inventor collaboration may enhance firm's innovation potential, it necessarily increases the potential risk of knowledge spillovers by mobile inventors. Firms are likely to react to this potential risk by reducing the overall degree of collaboration less than its optimal level, the level in which knowledge creation is maximized. Drawing on this logic, we explain how employee mobility barriers can resolve this intrinsic dilemma and ultimately facilitate firms' internal collaboration for innovation.

Employee Mobility Barriers and Inventor Collaborativeness

Prior research reports various barriers that may prevent the free movement of employees, leading to labor market imperfections (Campbell et al. 2012, Chadwick 2017), which can in turn solve key human capital management dilemmas (Coff 1997) in order to derive sustained competitive advantages for firms. We argue that employee mobility barriers can be a significant inducement for firms to enhance their

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now frosted. Other rooms have no windows at all. They are called lockdown rooms: No information goes in or out without a reason" (Lashinsky, 2012: p.31).

internal collaborativeness. Because more intensive internal collaboration may make employee mobility more likely and more impactful, it may pose significant threats to the firm's ability to capture value. Therefore, firms might employ organizational structures and policies that limit inventor collaboration (Liebeskind 1997), even to a point where it is sub-optimal in terms of value creation through innovation. Accordingly, if the inventor mobility concerns are significantly mitigated, firms may have an incentive to be more collaborative, and engage unconnected and more distant inventors in collaborative projects, in order to enhance their innovation.

Building upon this logic, we first expect that stronger mobility barriers would result in the larger team size in firm's innovation activities. As teams grow larger, a firm's knowledge is more likely to be shared by a large number of individuals, and thus the firm becomes more vulnerable to knowledge spillovers when its inventors move to competing firms. One might argue that knowledge spillover is less likely by mobile inventors from a large team, because the inventors may possess only a piece of knowledge about the final product. In contrast, solo inventors may have all necessary knowledge about the inventions that they developed. When solo inventors move, however, only knowledge embedded in a single inventor would be transferred. When collaborative inventors move, on the other hand, they likely transfer firm's knowledge that they have learned from their collaborators. Moreover, recent research shows that firms often recruit a group of people who have been working together effectively in a team, rather than picking a single high-functioning individual in the group (Hausknecht and Trevor 2011). For instance, when Optimus Solution, which sells and services corporate computer systems, employed a manager at a network equipment provider, it also hired the manager's 30-person team at one swoop (McGregor, 2006). Under the possibility of such collective mobility, firms may be less willing to initiate a research project that involves a large number of inventors due to potential risks of knowledge spillovers. If they possess a strong mechanism to protect their employees, however, the firms might have incentive to innovate with larger teams without concerning about knowledge spillovers.

In this paper, we focus on two key legal mobility barriers: 1) non-compete agreements (NCAs), and 2) the inevitable disclosure doctrine (IDD). Non-compete agreements are clauses in employment contracts that specify companies or technical fields in which employees pledge not to work for a period of time (Gilson 1999). Prior studies have shown that enforceable non-competes not only reduce employee mobility (Garmaise 2009, Marx et al. 2009) but also redirect employee mobility away from competitors (Marx 2011, Starr et al. 2016). Inevitable disclosure doctrine, on the other hand, is a legal doctrine adopted by state courts that prevents an employee's mobility if this action would "inevitably" disclose the former firm's trade secrets to a competitor. The use of IDD by a firm does not stem from specific contractual provisions, and instead emerges from an interpretation of trade secrecy law by the courts. Thus, this doctrine can also reduce the turnover of key inventors from firms. Moreover, the IDD may limit mobility differently from the effects of NCAs because it is applicable even when employees have not signed non-compete agreements, even if there is no evidence of bad faith or actual wrongdoing, and also if the rival firm is located in another state (Klasa et al. 2018). Png and Samila (2013) find that the IDD restricts the mobility of workers who are likely to know their firm's trade secrets, and Qiu and Wang (2017) show that adoption of the IDD by U.S. state courts significantly decreases firms' perceived risks of losing skilled talent. Therefore, we posit that employee mobility barriers created by stronger enforceability of NCAs and court adoption of IDDs may be associated with a larger size of team in firm's inventions. Thus, we hypothesize:

HYPOTHESIS 1. *Higher employee mobility barriers (from enforceable non-competes agreement and available inevitable disclosure doctrine) is associated with larger team size in firms' inventions.*

Employees Mobility Barriers and Formation of New Collaboration Ties

In addition, we posit that stronger employee mobility barriers not only make firms innovate with larger teams but also encourage them to combine previously unconnected inventors. Theoretically, creating new collaboration ties is independent of increasing the size of team. It is entirely possible that research teams become larger by only involving repeated collaborators. According to our theory (i.e., mobility barriers resolve firm's potential concerns about knowledge spillovers), however, the restriction of employee mobility would lead to enhancing the formation of new collaboration ties in firm's innovation activities.

Prior innovation and management research strongly highlight the value of new collaboration ties in firm's innovation activities. Repeated collaborators may possess homogeneous mental models as well as similar knowledge pool and thus might not provide substantial insights into firm's innovation activities. Skilton and Dooley (2010) point out that frequent collaborators tend to converge too quickly on prior familiar solutions rather than carefully discussing diverse alternatives before they come to a conclusion. Consequently, a research team packed largely with repeated collaborators is less likely to utilize diverse knowledge in their problem solving. In contrast, new collaborators are likely to bring fresh ideas, thus spurring knowledge recombination in firms (Guimera et al. 2005, Porac et al. 2004). In addition, by forming new collaboration ties, firms can enhance the overall connectivity of their collaboration network, which allows firm's knowledge to circulate faster within the organization (Carnabuci and Operti 2013). Lastly, when it comes to collaboration with new comers (e.g., new hires), the collaboration may act as a kind of informal training and socializing processes and in turn can enhance the overall innovation productivity of the new comers (Feldman 1994).

Collaboration between new inventors, however, is very costly. New collaborators have to learn about the skills, personal values, and behavioral habits of others for a more effective division of labor as well as a more efficient coordination in the collaboration task (Argote 2013, Kogut and Zander 1996, Reagans, Argote, and Brooks 2005). The lack of mutual understanding often becomes a significant cause of interpersonal conflicts in the collaboration process (Hinds and Mortensen 2005, Jehn, Northcraft, and Neale 1999). Management research consistently suggests that it takes a considerable time and effort to develop the partner-specific resources, or relational capital (Adler and Kwon 2002, Leana and van Buren 1999), required for collaboration. This internal relational capital, however, is likely disrupted by employee mobility (Mawdsley and Somaya 2016). Another important cost of new collaboration is the increased potential of knowledge spillovers that can be caused by inventor's mobility. As discussed above, knowledge exchange is more likely and robust when new collaborators work together. Repeated collaborators have possibly already shared their knowledge, and thus further collaboration may not lead to extensive knowledge exchange (Guimera et al. 2005). Accordingly, potential hazard of knowledge spillover by inventor mobility is greater when new collaboration ties are formed.

We argue that mobility barriers can contribute to facilitate the formation of new collaboration ties by mitigating the costs related to it. First, stronger mobility reduces opportunity costs of developing relational capital between new collaborators by ensuring the continuation of their employment. Second, the firms would be less concerned about the dissemination of their knowledge assets within the organization and potential knowledge spillovers by mobile inventors if they possess strong control rights over their human assets. All in all, we argue that when employee mobility is restricted, firms become more willing to facilitate collaboration between previously unconnected inventors. Hence, we also hypothesize:

> HYPOTHESIS 2. *Higher employee mobility barriers (from enforceable non-competes agreement and available inevitable disclosure doctrine) is associated with greater new collaboration ties in firms' inventions.*

Employees Mobility Barriers and Combination of Inventors with Heterogeneous Knowledge

Lastly, we predict that restrictions on employee mobility may lead to collaboration that involves inventors possessing more heterogeneous knowledge assets. Innovation research suggests, inventions combining knowledge across technological boundaries tend to be more impactful than when they draw from a single technological domain (Fleming 2001, Katila and Ahuja 2002, Nerkar 2003, Rosenkopf and Nerkar 2001). However, collaboration between inventors with heterogeneous knowledge is also costly; that is, it requires to develop substantial relation-specific resources (Nahapiet and Ghoshal 1998). For effective knowledge recombination, the different parties must have some overlap in knowledge (Cohen and Levinthal 1990), which entails significant time and effort to cultivate. When inventors possessing different knowledge collaborate, they would need to make these significant investments to enhance their mutual understanding about each other. Moreover, inventors from more diverse knowledge backgrounds may also be more prone to disagreements and conflict, which might require additional investments in building trust and mechanisms to reduce and resolve conflicts. Again, such relational resources developed among inventors are easily disrupted by employee mobility. If firms cannot effectively prevent outward mobility of their inventors, therefore, firms would be less able to combine heterogeneous inventors for their innovation.

Moreover, as Liebeskind (1996) points out, due to the concern about knowledge protection, firms often compartmentalize their R&D, aiming to isolate employees so that only few can have access to the final product. Under the high compartmentalization, only inventors with similar knowledge backgrounds would continue to collaborate. If knowledge protection is ensured, however, firms might decrease the compartmentalization and consequently encourage collaboration of inventors possessing heterogeneous knowledge. From this perspective, we argue that stronger mobility barriers can lead to bringing inventors with heterogeneous knowledge to work together. Additionally, the mobility barriers would facilitate it by reducing the opportunity costs of developing relational capital, which is essential for the collaboration among heterogeneous inventors. Therefore, we hypothesize as follows:

> HYPOTHESIS 3. *Higher employee mobility barrier (from enforceable non-competes agreement and available inevitable disclosure doctrine) is associated with combining inventors possessing heterogeneous knowledge in firms' inventions.*

METHODS

Research Design

We test our hypotheses by examining collaboration among inventors as reported in the U.S. patents of firms. Patent documents provide detailed information not only about newly developed technologies but also the inventors who create them (Song et al. 2003), all of whom must (by law) be disclosed on the patent. Although a focus on patents limits our attention to patented inventions and to those innovation projects that produced inventions, patent data provide a valuable and otherwise inaccessible window into nature of collaboration in innovation. Thanks to improved name disambiguation algorithms, researchers can now more precisely identify inventors who appear in patent documents (Li et al. 2014). Accordingly, patent data allows us to measure and test the patterns of inventor collaboration within a firm in an objective manner (Nerkar and Paruchuri 2005). Leveraging these advantages, we analyze firm's internal inventor collaboration by using patent data.

Unlike most areas of intellectual property law, which are governed by federal statute, the enforceability of non-competes and the legal protection of trade secrets is largely governed by state law. Thus, the enforceability of NCAs and the application of IDD by courts vary significantly across states in the U.S. A simple empirical strategy would therefore correlate the strength of NCAs and the use of IDD in the states in which firms are located with collaborativeness of those firms. However, this cross-sectional analysis is likely to yield biased estimates because the firm's location is itself a strategic choice and thus may be correlated with other firm attributes that may affect collaborativeness. Therefore, cross-sectional variation in the enforcement of NCAs and application of IDD may be endogenous to levels of internal inventor collaboration of firms.

We address this empirical challenge by using plausibly exogenous changes in the enforceability of NCAs and the application of IDD caused by legislation or major court decisions, which are identified and cataloged in prior research (Ewens and Marx 2017, Garmaise 2009, Klasa et al. 2018, Png and Samila 2013). As shown in Table 1, from 1975 to 2009, six states strengthened the enforceability of NCAs (Michigan 1985, Florida 1996, Ohio 2004, Vermont 2005, Idaho 2008, Wisconsin 2009). Over the same time-period, as shown in Table 2, thirteen states had a change in their application of IDD (Arkansas 1997, Minnesota 1986, Connecticut 1996, Delaware 1964, Missouri 2000, New Jersey 1987, New York 1919, Florida 1960-2001, Georgia 1998, Michigan 1966-2002, North Carolina 1976, Illinois 1989, Ohio 2000, Indiana 1995, Pennsylvania 1982, Iowa 1996, Texas 1993-2003, Kansas 2006, Utah 1998, Massachusetts 1994, Washington 1997). These changes are arguably an exogenous source of variation for our focal hypotheses. Put differently, in changing the enforceability of NCAs and the application of IDD, state legislators and judges did not directly intend to influence firms' collaboration patterns, nor were they influenced by factors that would simultaneously affect collaboration within firms. Moreover, these changes were unlikely to be anticipated by firms, at least in terms of the timing of the changes. Using these variations, therefore, we can obtain unbiased estimates of the impact of these mobility barriers (NCAs and IDD) on firms' internal inventor collaborativeness. Thus, the changes in NCAs and IDD provide the treatment effects of mobility barriers for firms located in those states.

Insert Table 1 and 2 about here

During the sample period, three states (Texas 1994, Louisiana 2001, Oregon 2008) experienced the decreased enforceability of NCA. In this study, we excluded these cases by dropping observations in the three states. Ewens and Marx (2017) argue that in states in which the law weakened the enforceability of non-compete agreements, firms may avoid updating their employment agreements so that existing employees would still be bound under the previous provisions. Thus, in those states, only newly hired employees would be affected by the weakened law, which may not result in a substantial decrease in overall inventor collaborativeness. In these regards, we focus only on the strengthened enforceability of NCA, excluding firms in Texas, Louisiana, and Oregon in our regression analysis. We will examine whether our results remain consistent with their inclusion in a robustness check.

In the difference-in-difference analysis, it is important to construct an appropriate counterfactual to estimate a causal effect (Angrist and Pischke 2009). The baseline is to use *all* firms in other states which did not experience changes in NCAs or IDD during the time period as a control group. Firms in different industries, however, might not be appropriate to be compared because they might behave differently to the same treatment. To enhance the validity of causal inference, therefore, we only compare firms in similar industries by including 2-digit SIC code-year-fixed effects, instead of simple year-fixed effects, in our regression. Thus, treated firms are compared only with those sharing the same 2-digit SIC code. In a robustness check, we will examine whether our results are still hold just when including only year-fixed effects. Hence, our regression models are specified as below:

$$y = \alpha + \beta_1 NCA + \beta_2 IDD + \boldsymbol{X}\gamma + \mu + \tau + \varepsilon,$$

where *y* is a dependent variable (i.e., a collaboration outcome), *NCA* and *IDD* are indicator variables, *X* is a set of control variables, μ refers to firm-fixed effects, τ represents 2SIC-year-fixed effects, and ε is an error term. In the specification with both *firm-* and *2SIC-year-fixed effects*, $\beta_1$and β_2 are the difference-in-differences estimators.

Standard errors in all our regression models are clustered at the state level, which accounts for correlations of observations within states. This is appropriate because both *NCA* and *IDD* are state-level variables and thus the regression errors may be correlated within state groupings. These clustered standard errors are also robust to heteroscedasticity and many types of serial correlation in errors within states.

Sample and Data

We analyzed the publicly traded manufacturing firms located in the U.S. from 1975 to 2009. To construct the sample, we combined data from several sources. We first collected data of original utility patents from the PatentView database. PatentView contains detailed information on granted patents, including application/issue date, patent class, and citations. More importantly, this database provides the disambiguated information about individual inventors, which is provided by Li et al. (2014) and Balsmeier et al. (2015). Thus, we can observe collaboration activities between inventors with a robust identification of these patterns. We then collect data from the CRSP/COMPUSTAT database, which contains detailed information on firm's location and financial resources. During the sample period, 10,514

U.S. firms were identified in two-digit SIC codes from 20 to 39. We matched the firms to our patent data based on their company identifier (PERMNO) and application year, provided by the Indiana and MIT patent databases. Some observations (i.e., 31 observation of 5 firms) had to be dropped due to the change of the firm's headquarter location. We also dropped observations in which a firm did not possess more than three patents. The resulting final sample used in our regression analyses contains 15,007 observations of 1,985 firms from 1975 to 2009.

Measures

Our dependent variables include 1) *team size*, 2) *new co-invention tie*, and 3) *knowledge heterogeneity* between connected inventors. Team size is measured by the average number of inventors in a firm's patents. This measure basically captures the extent that firms conduct innovation projects involving larger numbers of inventors. On the other hand, new co-invention tie is measured as the average number of inventor-pairs that have not appeared in the preceding five years in a firm's patents. This variable represents whether firms conduct innovation projects combining previously unconnected inventors, which is theoretically independent of team size in that teams can also be enlarged by adding prior collaborators. Lastly, to measure the knowledge heterogeneity between inventors, we first calculate the knowledge heterogeneity in every inventor pair of a firm's patents as below:

$$Knowledge\ Heterogeneity_{ij} = 1 - \frac{\sum_{k=1}^{N} u_{ik} u_{jk}}{\sqrt{\sum_{k=1}^{N} u_{ik}^2}\sqrt{\sum_{k=1}^{N} u_{jk}^2}},$$

where u_{ik} represents the fraction of prior-5-year patents of an inventor *i* in the patent class *k*, while u_{jk} represents the fraction of prior-5-year patents of an inventor *j* in the patent class *k*. This value equals zero if two inventors have patents in classes with a same fraction while it equals one if there is no overlap between the two inventors. Then, we summed the value within a patent and calculate its *average* at the firm level. This variable, therefore, captures the extent that a firm connects inventors possessing heterogeneous knowledge. All our dependent variables are natural logged (after plus one if the minimum value is zero) so that the coefficients of the difference-in-differences analyses can be interpreted as percentage point changes.

Our independent variables, *NCA* and *IDD*, are a state-level variable defined by the firm's headquarter location. *NCA* equals one for firms headquartered in states where NCA enforceability was strengthened in years following the change and equals zero otherwise. Coefficients of this variable represent the impact of stronger enforceability of NCA (Garmaise 2009). *IDD* equals one for firms in years following the adoption of the IDD and in years before the rejection of previously adopted IDD and equals zero otherwise. Coefficients of this variable therefore indicates the impact of use of IDD by courts (Klasa et al. 2018).

Our regression models include firm fixed effects and 2SIC-year dummies, to control for secular firm and year impacts on our dependent variable. We also include various firm-level control variables to account for other changes in their collaborativness over time. To control for the size of firm's collaboration networks, we included *Number of Inventors* that are identified by the firm's patents in proceeding 5 years. We controlled for firm's technological attributes by including average *Originality* of firm's patents in proceeding 5 years (Trajtenberg et al. 1997). To control for the effects of firms' R&D capabilities, we included *R&D Expenditure* of a firm in a given year. *Total Assets* was included to account for the impacts of firm size. All three aforementioned control variables have a skewed distribution, and thus were employed in logged form.

RESULTS

Table 3 presents descriptive statistics and correlations of our variables. Notably, our two dependent variables, *Team Size* and *New Ties*, are showing a high correlation (0.761). Knowledge Heterogeneity, on the other hand, is not showing such a high correlation with those variables.

Table 4 reports the results of our difference-in-differences regression analyses. We test Hypothesis 1 in Column 1. In support of Hypothesis 1, the coefficient of *NCA* is shown to be positive and strongly significant (β = 0.074, *p-value* = 0.016). Since our dependent variable is natural logged, the point estimate indicates a 7.4 percent increase in the team size of firm's inventions following the increased enforceability of NCA. In support of Hypothesis 1, the coefficient of *IDD* is also shown to be positive and strongly significant (β = 0.036, *p-value* = 0.006). The point estimate represents a 3.6 percent increase in the team size of firm's inventions following the adoption of IDD. Overall, these results provide evidence supporting our theory that stronger mobility barriers can encourage firms to engage in research projects that involve a large number of inventors.

Insert Table 3 and 4 about here

Column 2 in Table 4 tests Hypothesis 2. The coefficient of *NCA* is shown positive and strongly significant (β = 0.132, *p-value* = 0.001), which supports Hypothesis 2. The estimate indicates a 13.2 percent increase in the new collaboration ties of firm's inventions following the increased enforceability of NCA. In support of Hypothesis 2, the coefficient of *IDD* is also shown to be positive and strongly significant (β = 0.055, *p-value* = 0.006). The point estimate indicates a 5.5 percent increase in the new collaboration ties of firm's inventions following the adoption of IDD. The regression results suggest that strong mobility barriers not only encourage firms to innovate through large teams but also lead them to form new collaboration ties in their innovation activities.

Lastly, Column 3 in Table 4 tests Hypothesis 3. In support of Hypothesis 3, the coefficient of *NCA* is shown positive and strongly significant (β = 0.080, *p-value* < 0.001). The estimate indicates an 8 percent increase in inventor's knowledge heterogeneity of firm's invention following the increased enforceability of NCA. The coefficient of *IDD* is shown to be positive and strongly significant (β = 0.035, *p-value* = 0.003), which also supports Hypothesis 3. The result indicates a 3.5 percent increase in inventor's knowledge heterogeneity of firm's invention following the adoption of IDD. The regression results suggest that strong mobility barriers encourage firms to combine inventors possessing heterogeneous knowledge in their innovation activities.

Robustness Checks

We performed a number of additional analyses to check the robustness of our findings. First, we reran our regression including three states where the enforceability of NCA was weakened. As shown columns in Table 5, the treatment effects of NCA and IDD show the similar magnitude and significance for all three dependent variables. Second, we expanded our control groups by including only year-fixed effects. In these models, firms in states where the enforceability of NCA and the use of IDD were changed are compared with *all* other firms in other states that did not experience those changes. As seen in Table 6, the treatment effects of NCA and IDD are very similar for our dependent variables of internal collaboration. Third, considering the fact that IDD rejection might not be a mirror of IDD adoption, we reran regression analysis after dropping observations in which previously adopted IDD was rejected (Florida 2001, Michigan 2002, Texas 2003). As shown in Table 7, we found consistent results. Lastly, we re-conducted our analysis at the patent level. Thus, we analyzed 602,831 patents of 1,985 firms from 1975 to 2009. These patent-level analyses are reported in in Table 8, and are also consistent with our main results.

Insert Table 5, 6, 7, and 7 about here

DISCUSSION AND CONCLUSION

Juxtaposed against the well-known advantages for innovation from collaboration between inventors within firms (Carnabuci and Operti 2013, Fleming and Sorenson 2004, Guler and Nerkar 2012, Singh and Fleming 2010), the current paper highlights that collaboration may also pose significant challenges for value capture by firms due to its effects on inventor mobility and the more consequential types of knowledge spillovers resulting from such mobility. Building from this premise, we examine how employee mobility barriers—exemplified by the enforceability of non-compete agreements and the inevitable disclosure doctrine—affects inventor collaborativeness in the patented inventions generated by firms. Using exogenous variations in NCAs and IDD resulting from legal enactment or court decisions in a differences-in-differences empirical model, we find that the strengthened enforceability of NCAs and the recognition of IDD generally enhances collaborativeness in patented inventions. The mobility barriers are shown to increase the size of team, the formation of new collaboration ties, and the combination of inventors with heterogeneous knowledge. These results are robust to different specifications, controls, and sampling methods, which gives us greater confidence that our empirical evidence supports the theoretical rationale we propose.

Nonetheless, we acknowledge that our research is subject to some limitations. First, our research does not capture collaborations that did not lead to patents. Firms often intentionally do not patent their inventions if they are not patentable, or to keep the inventions secret (Cohen et al. 2000, James et al. 2013, Liebeskind 1997). However, to the extent that there are no systematic differences between collaborations for patented and non-patented inventions that are correlated with our quasi-exogenous treatment effects, the exclusion of non-patented inventions may not bias our results. Second, we focus on the enforceability of NCAs but do not directly examine their actual use. Starr et al. (2016) find in their survey of employees that the correlation between state-level enforceability of non-competes and its actual use in employment contracts is relatively small. However, our theoretical rationale relies on firms' responses to *perceived* employee mobility barriers, and to the extent that legal changes in NCA enforceability change firms' perceptions about mobility barriers, this may be sufficient to induce the behavioral changes we hypothesize and find.

Subject to these limitations, our research makes several important contributions to the strategy and innovation literatures. First, this paper contributes to the literature on inventor collaboration for innovation. A number of studies have now established the pivotal role played internal inventor collaboration for *value creation* in firms' innovation through the generation of novel technologies (Carnabuci and Operti 2013, Fleming 2001, Rosenkopf and Nerkar 2001, Singh and Fleming 2010). Such breakthrough inventions come about through the effective recombination of disparate knowledge from within inventors' collaboration networks (Ahuja 2000, Guler and Nerkar 2012, Singh et al. 2016). However, the challenges posed by greater collaborativeness for firms' *value capture* in innovation (i.e., sustaining competitive advantages) have remained largely unexamined in the literature. We address this gap in prior research by highlighting the adverse consequences for firms' knowledge-based competitive advantages due to employee mobility, which may not only be enhanced by collaborative innovation (Coff and Kryscynski 2011, Cross et al. 2016); but also result in more consequential knowledge spillovers to competitors (Rivkin 2000, Sorenson et al. 2006). Thus, our research shows that firms face a significant strategic dilemma with regard to value capture arising from inventor collaboration, and provides a nuanced understanding of firm's collaborative innovation strategies. By shedding light on these dilemmas, our research suggests that value creation and value capture in collaborative innovation cannot simply be understood *independently*, and should instead be viewed as highly *interdependent* and, more importantly, potentially conflicting considerations (Bae and Gargiulo 2004, Grossman and Hart 1986, Lavie 2007). Considering these interdependences, firm-level strategies with regard to inventor collaborativeness need to be understood as striking a balance between these competing forces.

Drawing on these ideas, our paper also has significant implications for strategy research broadly, which is fundamentally interested in how and why firms differ. In the context of internal inventor collaborativeness, prior studies have recognized the importance of internal inventor collaboration but left us with only a limited understanding of factors that explain heterogeneity in collaboration and collaboration networks between firms (Toh and Polidoro 2013). Prior research demonstrates that these inter-firm differences in collaborativeness can be engineered through conscious policies; for example, by increasing proximity between inventors along different dimensions(Crescenzi et al. 2016, Forman and Zeebroeck 2012, Lee 2019), by enhancing collaboration capabilities within the firm (Howard et al., 2016), or by reducing intra-organizational segregation and secrecy (Liebeskind 1997). Prior research has shown that one factor affecting heterogeneities between firms in how such policies are applied may be the type of product market competition faced by the firm (Toh and Polidoro 2013). The findings of our research adds to this stream of research by demonstrating the role of another factor—the tradeoffs between potential knowledge spillovers by mobile inventors (which can be constrained by mobility barriers) and the opportunities for knowledge recombination arising from knowledge breadth—that may be an important determinant of differences in firms' internal collaborativeness for innovation.

Last but not least, this paper also extends research on strategic human capital by examining the connections between employee mobility barriers and important strategic choices related to firms' innovation. Employee mobility has been a central topic in the strategic human capital literature (Mawdsley and Somaya 2016), and research has highlighted a number of ways in which employee mobility affects firms' innovation-based competitive advantages (Al-Laham et al. 2011, Rosenkopf and Almeida 2003, Song et al. 2003). In turn, the literature has highlighted the importance of mobility barriers as a broad theoretical explanation for how firms sustain competitive advantages by limiting losses of valuable human capital (Campbell et al. 2012, Chadwick 2017, Coff 1997). The current paper not only underscores the importance of these constraints on human capital mobility, but also demonstrates how mobility barriers can enable value creation in innovation by solving key value capture dilemmas in human capital (Coff and Kryscynski 2011). By showing how firms might increase collaborative innovation in response to the availability of stronger enforcement for NCAs and IDD, we add to the growing literature on the specific impacts of NCAs and IDD on firms' strategic choices (Conti 2014, Starr et al. 2016, Younge et al. 2015). Last but not least, we believe that our findings also inform managers with respect to strategies for the retention of inventor human capital and the management of collaborative innovation.

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Table 1. Changes in Enforceability of Non-compete Agreements

State	Legislation or Case	Year	Change
MI	Repealed MCLA §445.761	1985	Strengthened
FL	Repealed FS §542.33	1996	Strengthened
OH	*Lake Land Employment Group of Akron, LLC v. Columber*	2004	Strengthened
VT	*Summits 7, Inc v. Kelly*	2005	Strengthened
ID	Enacted ID §44-2701	2008	Strengthened
WI	*Star Distributing v. Eugene Dal Pra*	2009	Strengthened

Table 2. Changes in Recognition of Inevitable Disclosure Doctrine

State	Case	Year	Change
AR	*Southwestern Energy Co. v. Eickenhorst*	1997	Adopted
CT	*Branson Ultrasonics Corp. v. Stratman*	1996	Adopted
DE	*E.I. duPont de Nemours & Co. v. American Potash & Chem. Corp.*	1964	Adopted
FL	*Fountain v. Hudson Cush-N-Foam Corp.* *Del Monte Fresh Produce Co. v. Dole Food Co. Inc.*	1960 2001	Adopted Rejected
GA	*Essex Group, Inc. v. Southwire Co.*	1998	Adopted
IL	*Teradyne, Inc. v. Clear Communications Corp.*	1989	Adopted
IN	*Ackerman v. Kimball Int'l Inc.*	1995	Adopted
IA	*Uncle B's Bakery v. O'Rourke*	1996	Adopted
KS	*Bradbury Co. v. Teissier-duCros*	2006	Adopted
MA	*Bard v. Intoccia*	1994	Adopted
MI	*Allis-Chalmers Manuf. Co. v. Continental Aviation & Eng. Corp.* *CMI Int'l, Inc. v. Intermet Int'l Corp.*	1966 2002	Adopted Rejected
MN	*Surgidev Corp. v. Eye Technology Inc.*	1986	Adopted
MO	*H&R Block Eastern Tax Servs. Inc. v. Enchura*	2000	Adopted
NJ	*Nat'l Starch & Chem. Corp. v. Parker Chem. Corp.*	1987	Adopted
NY	*Eastman Kodak Co. v. Powers Film Prod.*	1919	Adopted
NC	*Travenol Laboratories Inc. v. Turner*	1976	Adopted
OH	*Procter & Gamble Co. v. Stoneham*	2000	Adopted
PA	*Air Products & Chemical Inc. v. Johnson*	1982	Adopted
TX	*Rugen v. Interactive Business Systems Inc.* *Cardinal Health Staffing Network Inc. v. Bowen*	1993 2003	Adopted Rejected
UT	*Novell Inc. v. Timpanogos Research Group Inc.*	1998	Adopted
WA	*Solutec Corp. Inc. v. Agnew*	1997	Adopted

Table 3. Descriptive statistics and correlations

Variables	Mean	SD	Min	Max	1	2	3	4	5	6	7	8
1. Team Size	0.782	0.378	0.000	2.833								
2. New Ties	0.819	0.559	0.000	5.009	0.761							
3. Knowledge Heterogeneity	0.209	0.383	0.000	3.992	0.569	0.236						
4. NCA	0.042	0.200	0.000	1.000	0.064	0.061	0.056					
5. IDD	0.347	0.476	0.000	1.000	0.196	0.136	0.131	0.025				
6. Number of Inventors	3.891	1.487	0.693	8.865	0.203	0.213	0.230	0.079	0.107			
7. Originality	0.313	0.156	0.000	0.668	0.452	0.298	0.316	0.106	0.211	0.111		
8. R&D Expenditures	3.349	1.657	0.000	9.408	0.271	0.274	0.237	0.078	0.109	0.808	0.219	
9. Total Assets	6.288	1.973	0.224	13.081	0.082	0.162	0.063	0.094	0.106	0.772	0.042	0.811

Table 4. Results of Regression Analyses

	(1) Team Size	(2) New Ties	(3) Heterogeneity
NCA	0.074**	0.132***	0.080***
	(0.030)	(0.039)	(0.011)
IDD	0.036***	0.055***	0.035***
	(0.013)	(0.019)	(0.011)
Number of Inventors	0.019**	-0.041*	0.084***
	(0.009)	(0.024)	(0.006)
Originality	0.086	-0.065	0.200***
	(0.063)	(0.096)	(0.073)
R&D Expenditures	0.018*	0.059	0.007
	(0.010)	(0.016)	(0.011)
Total Assets	-0.017**	-0.013	0.004
	(0.008)	(0.020)	(0.014)
Constant	0.741***	0.471***	-0.092
	(0.047)	(0.082)	(0.075)
Firm-Fixed Effects	Yes	Yes	Yes
2SIC-Year-Fixed Effects	Yes	Yes	Yes
Observations	15,007	15,007	15,007

Note: Robust standard errors, clustered by states, in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5. Robustness Check (1): Including Texas, Louisiana, and Oregon

	(1) Team Size	(2) New Ties	(3) Heterogeneity
NCA	0.072** (0.030)	0.128*** (0.039)	0.080*** (0.010)
IDD	0.037*** (0.011)	0.053*** (0.017)	0.043*** (0.012)
Controls	Yes	Yes	Yes
Firm-Fixed Effects	Yes	Yes	Yes
2SIC-Year-Fixed Effects	Yes	Yes	Yes
Observations	15,884	15,884	15,884

Note: Robust standard errors, clustered by states, in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 6. Robustness Check (2): Year-Fixed Effects

	(1) Team Size	(2) New Ties	(3) Heterogeneity
NCA	0.071*** (0.025)	0.137*** (0.031)	0.068*** (0.015)
IDD	0.037** (0.014)	0.049** (0.021)	0.036*** (0.010)
Controls	Yes	Yes	Yes
Firm-Fixed Effects	Yes	Yes	Yes
Year-Fixed Effects	Yes	Yes	Yes
Observations	15,007	15,007	15,007

Note: Robust standard errors, clustered by states, in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 7. Robustness Check (3): Dropping Observations after IDD was Rejected.

	(1) Team Size	(2) New Ties	(3) Heterogeneity
NCA	0.065** (0.027)	0.132*** (0.038)	0.060*** (0.018)
IDD	0.040*** (0.014)	0.054** (0.021)	0.042*** (0.010)
Controls	Yes	Yes	Yes
Firm-Fixed Effects	Yes	Yes	Yes
2SIC-Year-Fixed Effects	Yes	Yes	Yes
Observations	14,862	14,862	14,862

Note: Robust standard errors, clustered by states, in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 8. Robustness Check (4): Patent-level Analysis

	(1) Team Size	(2) New Ties	(3) Heterogeneity
NCA	0.086*** (0.014)	0.089*** (0.012)	0.058*** (0.008)
IDD	0.045*** (0.009)	0.055*** (0.015)	0.026*** (0.007)
Number of Inventors	0.012 (0.011)	-0.053*** (0.015)	0.060*** (0.006)
Originality	-0.069 (0.113)	-0.152 (0.181)	0.063 (0.065)
R&D Expenditures	0.008 (0.001)	0.038*** (0.012)	-0.018** (0.007)
Total Assets	-0.021*** (0.007)	-0.020** (0.009)	-0.014* (0.008)
Number of Claims	0.003*** (0.000)	0.006*** (0.000)	0.001*** (0.000)
Number of Backward Citations	0.002*** (0.000)	0.000 (0.000)	0.002*** (0.000)
Constant	0.890*** (0.031)	0.695*** (0.108)	0.235*** (0.059)
Firm-Fixed Effects	Yes	Yes	Yes
2SIC-Year-Fixed Effects	Yes	Yes	Yes
Observations	602,831	602,831	602,831

Note: Robust standard errors, clustered by states, in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$