How innovating firms manage knowledge leakage: A natural experiment on the threat of worker departure*

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An online appendix is available here

Abstract

Innovating firms face a risk of knowledge leakage as their workers can join competitors. We study the threat of worker departure as the key mechanism through which firms decide on knowledge protection strategies. Our empirical analysis exploits a milestone court decision in 1998 whereby the California Court of Appeal ruled that out-of-state noncompetes are not enforceable in California. Consequently, non-California firms faced a loophole in the enforcement of noncompetes for their workers. When facing a higher threat of worker departure, firms strategically increase patent filings as a means of knowledge protection. The effects are magnified for large-sized firms and those in complex product industries. Further tests on the possession of trade secrets, physical proximity, migration rate, and industry dissimilarity to California support our theoretical account.

Keywords: innovation strategy, knowledge management, patents, worker mobility, out-of-state noncompetes
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1 INTRODUCTION

Firms in knowledge-based industries must constantly innovate to create a competitive advantage. To sustain that advantage, firms must also protect their knowledge from leakage to competitors (Agarwal, Ganco, & Ziedonis, 2009; Argote & Ingram, 2000; Campbell, Ganco, Franco, & Agarwal, 2012; Coff, 1997). The ways in which firms protect their knowledge against leakage to competitors, therefore, have received increasing attention in the fields of strategy and innovation (e.g., Cassiman & Veugelers, 2002; Lobel, 2013; Shaver & Flyer, 2000; Oxley & Sampson, 2004; Srikanth, Nandkumar, Mani, & Kale, 2020).

A pivotal decision that innovating firms must make with regard to knowledge protection is whether to rely on patents or alternative protection mechanisms, notably secrecy (Cohen, Nelson, & Walsh, 2000; Hall, Helmers, Rogers, & Sena, 2014; Liebeskind, 1996). Several survey-based studies indicate that this decision is associated with firm characteristics (e.g., firm size) and with characteristics of the knowledge that firms wish to protect (e.g., process versus product innovation) (e.g., Arundel, 2001; Cohen et al., 2000; Levin et al., 1987). Recent studies further suggest that firms dynamically adjust their reliance on patenting or secrecy in response to changes in legislative protection for trade secrets (Contigiani, Hsu, & Barankay, 2018; Png, 2017b).

Taking a step further from extant research, we examine the threat of worker departure as a key driver affecting firms' decisions on patents versus secrecy. Knowledge protection through secrecy is particularly challenging because knowledge is carried by individual workers (Grant, 1996). Innovating firms constantly face the threat that workers who possess valuable knowledge can separate to join competitors or start their own business (Agarwal, Campbell, Franco, & Ganco, 2016; Agarwal, Echambadi, Franco, & Sarkar, 2004; Carnahan, Agarwal, & Campbell, 2012; Starr, Balasubramanian, & Sakakibara, 2018). Even if state legislation provides strong protection for trade secrets, worker departure can become the major source of knowledge leakage and misappropriation.

While we know that worker departure and consequent knowledge leakage can cause a substantial threat to firms, our understanding is limited as to whether and how this threat of worker departure affects firms' use of patents and secrecy to protect proprietary knowledge.

We argue that firms dynamically change how they protect proprietary knowledge in response to the threat of worker departure. To be specific, if the threat of worker departure is minimal, firms can protect their proprietary knowledge by retaining their workers within firm boundaries (i.e., secrecy). In this case, there is less reason for firms to patent their knowledge, which would bring the concomitant risks of disclosure and cost of filing, maintaining, and enforcing the patents. However, to the extent that the threat of worker departure increases, firms increase their use of patents as an alternative protective mechanism when worker retention becomes more risky and less effective.

To establish a causal relationship between the threat of worker departure and firms' strategic choices on patenting, we take advantage of a milestone court decision that exogenously and substantially increased the threat, for non-California firms, of worker departure to California. *Application Group, Inc. v. Hunter Group, Inc.*, 61 Cal. App. 4th 881 (1998)—henceforth, *Application v. Hunter*—provides us with a nearly ideal setting for a natural experiment. In the United States, many firms prevent their employees from joining competitors by requiring employees to sign noncompetition agreements (henceforth "noncompetes"), contracts in which employees agree not to work with a different firm in direct competition with the current employer once their current employment ends (see e.g., Garmaise, 2011; Marx & Fleming, 2012; Marx, Strumsky, & Fleming, 2009; Prescott, Bishara, & Starr, 2016; Starr, Prescott, & Bishara, 2019). In 1998, the California Court of Appeal refused to enforce *out-of-state* noncompetes written between a non-California employer and a non-California employee. This decision set a strong precedent that California courts may not enforce out-of-state noncompetes, even with a choice-of-law provision that non-California law shall apply. After this decision, non-California workers who were bound by noncompetes could

now move to California employers. As a result, this decision significantly increased the threat of worker departure faced by non-California employers and weakened their ability to prevent outbound worker departure to California via noncompete agreements.

Using a difference-in-differences methodology, we find firms that faced the threat, on average, increased patent filings by about 4.6%. The effect is even greater—up to 26%—for large firms. The effects are also greater for firms in complex product industries, in fast-growing industries, or for those located in Maryland where the court decision was more salient. On the other hand, a placebo test on the patenting filings by individual inventors, who did not belong to businesses and thus were not affected by the decision, showed little change.

Further analyses support the argument that the threat of worker departure is the key mechanism in play. The effects are greater for firms that possess trade secrets, are geographically proximate to California, and are in states where the migration rate (of both the entire population and of high-skilled knowledge workers) to California is high. The combined findings suggest that firms strategically increased patent filings to protect their proprietary knowledge in response to the unexpectedly heightened threat of worker departure to their California competitors.

This study contributes to a broad stream of strategy and innovation literature. Linking two important streams of research—on worker mobility and on innovation and patenting—we demonstrate that the threat of worker departure can change the relative efficacy of knowledge protection mechanisms, particularly between patenting and secrecy. This study also offers important implications for innovation scholars on the use of patent-based proxies as a measure of knowledge creation activities. The findings suggest that patent-based proxies may not well capture firms' innovation performance because patent filings are not determined solely by firms' knowledge *creation* but also by their strategies to *protect* their knowledge. It is thus essential for scholars to carefully validate the use of patents for measuring innovation outcomes. Furthermore, we propose

a robust quasi-experiment in a real-business setting that exploits a milestone court decision in California that had substantial influence on the beliefs and behaviors of employers and employees. Unlike legislative changes, this court decision applied retrospectively to firms and their workers, creating an immediate threat of worker departure and knowledge leakage. We believe our study provides a setting that future research can leverage as a natural experiment to study how the threat of worker departure affects different firm behaviors and outcomes. Finally, we show that a court decision on the enforceability of out-of-state noncompetes in California changed the patenting decisions of firms in other states. This sheds light on how legal enforcement in one state could have far-reaching consequences outside of the focal state (Marx & Fleming, 2012; Marx, Singh, & Fleming, 2015).

2 THE THREAT OF WORKER DEPARTURE AND PATENTING

Firms have a range of options when it comes to the protection of knowledge: patents, secrecy, lead-time advantages, and the use of complementary assets or capabilities (Anton & Yao, 2004; Cohen et al., 2000; Hall et al., 2014). Patenting is one of the most frequently used options. Patenting provides formal legal protection of knowledge for a limited period—under the US patent law up to twenty years from the date of filing—and prevents others from using the patented knowledge for their own benefit (Agarwal et al., 2009; Gallini, 1992; Gilbert & Shapiro, 1990; Somaya, 2012). A major disadvantage of patenting, however, is in the risk of disclosure. In exchange for formal protection, patent applicants must publicly disclose the technical details of the knowledge that they seek to protect, which may trigger imitation and reverse engineering by competitors. In addition, patent registration fees, maintenance fees, payments to patent attorneys, and legal uncertainty are important costs for patenting firms (Kitch, 1977; Teece, 1986; Williams, 2013). Thus, in practice, firms use varied knowledge protection strategies and rely on different mechanisms depending on the knowledge that they seek to protect (Arora, 1997; Cohen et al., 2000; Hall et al., 2014; Png, 2017b).

How then do firms choose between patenting and alternative protection mechanisms when protecting their proprietary knowledge? Studies indicate that firms carefully consider the costs and benefits of each option to decide on a knowledge protection mechanism (Cohen et al., 2000; Teece, 1986). Recent studies further suggest that these choices are not static but dynamic, and that firms strategically adjust their decisions in response to changes in their environments that make one option more effective than others (e.g., Contigiani et al., 2018; Png, 2017b). Png (2017b), for example, finds that the enactment of the Uniform Trade Secrets Act, which increased the legal protection of trade secrets, caused firms to rely less on patenting for knowledge protection.

We argue that the threat of worker departure is a key factor that drives firms' choice of knowledge protection mechanisms. Worker departure is one of the most critical sources of knowledge leakage, as individual workers absorb and carry the knowledge created and retained from the innovation process governed by a firm (Arrow, 1972; Grant, 1996; March, 1991; Simon, 1991). As Simon (1991, p. 125) puts it: "All learning takes place inside individual human heads," and organizations learn by "ingesting new members who have knowledge the organization didn't previously have." Proliferating research on "learning-by-hiring" suggests that firms can leverage hiring as an opportunity to absorb external knowledge (e.g., Palomeras & Melero, 2010; Rosenkopf & Almeida, 2003; Song, Almeida, & Wu, 2003). Worker departure to competitors, therefore, is a double loss to a firm, as the firm not only loses its proprietary knowledge but also gives an advantage to its competitor (Agarwal et al., 2016; Agarwal et al., 2004; Agarwal et al., 2009; Campbell, Coff, & Kryscynski, 2012; Somaya, Williamson, & Lorinkova, 2008; Wezel, Cattani, & Pennings, 2006). Thus, to prevent consequent knowledge leakage, innovating firms actively manage and respond to the threat of worker departure that arises from the changing business environment (e.g., Carnahan et al., 2012; Marx, 2011; Starr, 2019).

For several reasons we predict that firms increase their use of patents when facing a

heightened threat of worker departure. First, the threat of worker departure does not undermine the efficacy of patents because the details of knowledge are specified in the patent document and are protected by law. By contrast, other protection mechanisms, such as secrecy, become much more vulnerable to leakage when workers move between firms (i.e., job-hopping). Thus, firms may decide to file patents for both new knowledge and existing knowledge (that they previously protected via secrecy) to reduce the risk of leakage when the threat of worker departure increases. Second, the threat of worker departure increases firms' incentives to *preemptively* file a patent under its own name before exiting workers can do so (often with their new employers). Preemptive patenting minimizes misappropriation risks and potential patent infringement litigations that may arise when workers with valuable knowledge leave their employers (Ceccagnoli, 2009; Cohen et al., 2000; Gilbert & Newbery, 1982). Third, patenting is an effective way to gain bargaining power against workers who possess valuable knowledge. Workers may leverage their knowledge, which was acquired through a firm's innovation processes, and threaten to leave the current employer in an effort to increase their bargaining power and demand higher pecuniary or non-pecuniary benefits (Starr, 2019). By obtaining formal protection of its knowledge through patents, a firm can counter workers who try to bargain. These arguments suggest that firms will increasingly use patents to protect their knowledge (even without any changes in fundamental innovation activities) when facing a higher threat of worker departure.

3 EMPIRICAL STRATEGY

3.1 Setting: *Application v. Hunter* (1998)

We exploit the *Application v. Hunter* decision by the California Court of Appeal as a naturally occurring experiment to empirically test our research question. A correlational study of the threat of worker departure and patenting would be subject to endogeneity problems. An unobservable confounding factor, such as a firm's ability to identify and attract talented workers, may be correlated

with both a firm's ability to retain workers and its patenting activities. Reverse causality is another empirical concern. Firms that increase their propensity to patent may consequently exert less effort to retain their workers.

California is known for its strong public policy against the enforcement of restrictive covenants in employment. Since the enactment of California Business & Professional Code Section 16600 ("Section 16600") in 1872, California has consistently not enforced *in-state* noncompetes agreed upon between a California employer and employee. However, *out-of-state* noncompetes—signed by an employer and employee *outside* of California—had been construed as enforceable in California.

Application v. Hunter was the first legal case to set a strong precedent that, based on California law, California courts may invalidate out-of-state noncompetes. This case involved Dianne Pike (an employee) who was seeking to move from Hunter Group, Inc. (a Maryland company) to Application Group, Inc. (a California company). Pike and Hunter Group, Inc. signed a noncompete agreement with a choice-of-law provision that Maryland law would govern their contract. In 1998, however, the California Court of Appeal made a final decision not to enforce the noncompete agreement, ruling that California law (rather than Maryland law) should apply to their contract, *despite the choice-of-law provision suggesting otherwise*. The decision suddenly denied firms' ability to use noncompetes to prevent their workers' outbound mobility to California and significantly increased the threat of worker departure faced by non-California employers. We provide in-depth legal analysis and verification of the validity and impact of this seminal court decision in Online Appendix A.

Application v. Hunter offers an excellent setting that suits our research purpose. First, this setting provides an exogenous variation in the threat of worker departure faced by non-California firms. Since *Application v. Hunter* is a court decision (rather than a legislative change), firms or

individuals other than the plaintiff and defendant in the case could exert little influence on its decision (Ewens & Marx, 2018). Our legal analysis of *Application v. Hunter* confirms that the decision was made solely based on California's long-standing statutes (Section 16600) and was not based on any prior discussions or public hearings, or on the State of California's promotion of inbound mobility. Even if the court decision were correlated with legal and business environments (e.g., lobbying) in California, we circumvent this endogeneity issue by examining firms located *outside* of California. Second, a unique feature of *Application v. Hunter* is that it changes only firms' ability to retain workers (i.e., restrict outbound mobility) but not their ability to hire workers (inbound mobility). This feature ensures a clean and focused natural experiment on the threat of worker *departure*, not confounded by firms' hiring abilities. Third, *Application v. Hunter* is a court decision that applies not only prospectively but also retrospectively to workers who signed employment contracts even before the decision. Thus, for firms that had been enforcing noncompetes, the decision immediately increased the threat of departure by *existing* workers. These features overall provide a unique and ideal experimental setting for our research on the threat of worker departure, which is difficult to study by leveraging state-level legislative changes that apply only prospectively (to those who sign a contract after the effective date of the court's decision) or affect both inbound and outbound mobilities (Balasubramanian, Chang, Sakakibara, Sivadasan, & Starr, 2020; Ewens & Marx, 2018; Jeffers, 2019; Marx et al., 2009). We provide a more detailed comparison of our research design to that of prior studies on noncompetes in Online Appendix A.4.

3.2 Methodology

We estimate the difference-in-differences model by exploiting *Application v. Hunter*, which increased the threat of worker departure for non-California firms. Our focus thus is *not* on firms in California but on firms in all other states in the United States. We compare firms in states that strongly enforce noncompetes (treatment group) with those in states that do not or only weakly

enforce noncompetes (control group), and do so for years before and after 1998, the year of the decision. The main idea of this strategy is that *Application v. Hunter* affected only firms in the treatment group because it created a loophole (or a threat) in the enforcement of noncompetes; it did not affect firms in the control group because, even before the decision, these firms were unable to enforce noncompetes. This approach, along with firm- and year-fixed effects, helps us account for unobservable time-varying factors and for time-invariant differences between the two groups. We estimate the following difference-in-differences model:

$$y_{ist} = Enforce_s \cdot Post_t + \delta_{is} + \gamma_t + \epsilon_{ist} \tag{1}$$

where y_{ist} is the natural log transformation of our outcomes of interest. To determine the state-level enforceability of noncompetes, we combine indices of Garmaise (2011) and Starr (2019). We create a state-level indicator, $Enforce_s$, that takes unity if a state's enforceability is above the mean score in both indices (treatment group) and zero if it is below the mean score in both indices (control group). This approach is doubly robust because the two independent indices consistently assigned a high or low score for a state (see Online Appendix B). $Post_t$ is an indicator that equals one after 1998. The remaining terms δ_{is} and γ_t are firm-state and year-fixed effects.[4]

We also conduct more flexible econometric analysis by replacing $Post_t$ with year indicators (distributed leads and lags), omitting a year indicator for 1998 as a baseline. With this flexible estimation in Equation (2), we not only explicitly test the parallel trend assumption for pretreatment years (1993–1997) but also examine the dynamic patterns of the effects (e.g., one-time adjustment versus gradual increase) for post-treatment years (1999–2003):

$$y_{ist} = \sum_{k=1993, k\neq 1998}^{2003} Enforce_s \cdot \mathbf{1}\{t = k\} + \delta_{is} + \gamma_t + \epsilon_{ist} \tag{2}$$

[4] Since we exploit differences in state-level enforceability, by including firm-state fixed effects we treat firms that have the same assignee identifier but are in different states as separate businesses.

3.3 Data and sample

We use PatentsView (December 2020 version), which provides detailed information on patent filing and grant dates, technology classes, claims, assignee firms, and inventors with disambiguated identifiers, their location, and citations. Online Appendix G provides additional analyses of publicly traded companies, using CRSP/Compustat-Merged data for R&D expenses and other information.

Our sample selection begins with the universe of all patent assignees that filed a patent in the United States from 1993 through 2003. We confine our interest to patent-assignee firms that are companies or corporations and exclude individuals and government institutions because they have been little affected by *Application v. Hunter*. We further exclude firms in three states that underwent significant changes in the enforceability of noncompetes during our sample period: Florida, Louisiana, and Texas (Garmaise, 2011; Kang & Fleming, 2020). Assignee firms in Alaska and Hawaii are also omitted to account for geographic barriers that restrict ground transportation to California. Further, we require that assignee firms have at least one inventor during the five years before the decision (1993–1997). This minimal restriction allows us to filter out firms that had no inventor to retain and did not face the threat of worker departure. If a firm did not patent in a given year, we assign a zero for each year between a firm's first and last year of patenting. For firm-years before the first or after the last year of patenting, we assign a missing value. The resultant sample consists of 26,416 assignee firms with 442,679 patent filings. Table 1 provides descriptive statistics.

4 RESULTS

4.1 Main results on patent filings

Table 2, column 1, reports the main results of our difference-in-differences estimation on patent filings. After *Application v. Hunter*, firms in the high-enforcing states increased their patent filing by about 4.6% compared to low-enforcing states. In 1998, firms in our sample filed an average of 9.3 patents that were eventually granted; the 4.6% increase in patent filings is thus equivalent to

0.43 more patents per year per firm, for every year from 1999 through 2003. In Table 3, column 1, we conduct the same analysis for public firms using Compustat data and find an 8% increase in patent filings after the decision (see Online Appendix G for further analyses).

The event-study framework with distributed leads and lags allows for a more flexible and detailed estimation. Figure 1(a) shows that a parallel trend persists until 1998, and the treatment group increased its patent filings by 1.7–5.8% after the decision, compared to the number of filings in 1998.[5] The gradual increase in patent filings reflects the time needed to file patents; surveys indicate that research projects require different time periods to yield patents, 7-12 person-months being the median (Nagaoka and Walsh, 2009, p. 13). Figure 1(b) shows separate event-study estimates for treated and control groups, confirming the validity of the control group as a counterfactual (pre-trend) and a diverging trend between the two groups after the decision.

4.2 Robustness checks

High salience in Maryland. The plaintiff in the case, Hunter Group, Inc., is a Maryland corporation headquartered in Maryland. We thus expect that the *Application v. Hunter* decision and the threat of worker departure it created are better understood by Maryland firms. Table 2, column 2, shows the results of a test including only Maryland firms in the treatment group. Maryland firms increased patent filings by about 11.4%, more than twice as much as did firms in other treated states.

Patents by individuals. Inventors who are not affiliated with an organization are not affected by the *Application v. Hunter* decision. We run a *placebo test* with these unaffiliated inventors and do not find any increase in patent filings; Table 2, column 3 indicates the estimate is negative and statistically not distinguishable from zero. This provides additional evidence that the findings are

[5] To further deal with the pretreatment trend, we include interaction terms between each firm's outcome variable (in logs) in each year prior to 1998 and a full set of year dummies. This specification absorbs all the pre-1998 differences in patent filings (Cantoni, Dittmar & Yuchtman, 2018). Our results from this strict specification again confirm that the treated firms increased their patent filing by about 7.8% after the decision (see Online Appendix D for further details).

not driven by state-level or industry-level changes other than the enforceability of out-of-state noncompetes in California.

Patent Characteristics. We test the qualitative characteristics of patents to see whether firms begin to file a different set of patents in response to the threat of worker departure. We do not find strong evidence of such qualitative changes in patent filings (see Online Appendix E).

Poisson QMLE. To ensure the validity of our findings, we check the robustness of our model choices. Poisson quasi-maximum likelihood estimation (QMLE) provides an effective way to model the count-dependent variable that has an excess number of zero counts. The findings are robust to the choice of model and to a different set of standard errors (see Online Appendix F).

R&D investments. An alternative explanation is that the increase in patent filings comes from higher R&D investments, not from firms' need to protect their knowledge against the heightened threat of worker departure. We test how publicly traded firms changed their patent filings and R&D investments. Public firms increased patent filings by 11.8% (Table 3, column 1). Yet, consistent with Garmaise (2011), we do not find evidence that public firms meaningfully increased R&D investment in response to a heightened threat of worker departure—especially so when we account for the fact that costs associated with patent filings and wages paid to R&D personnel are included in the R&D expenditure item (Hall and Lerner, 2010). That is, our results are not driven by fundamental changes in R&D activities of firms (see Online Appendix G for further details).

4.3 Heterogeneity by firm size

We expect that firms will respond differently depending on their size, measured by the number of inventors they employ. Firms with more inventors face a much higher risk of worker departure and knowledge leakage. Furthermore, larger firms incur lower marginal costs of patenting, have better access to patent attorneys and other legal resources, and enjoy economies of scale in monitoring patent infringement and enforcement. In contrast, small firms typically do not achieve the economies

of scale to access patent attorneys, and they are likely to have already patented their inventions to send signals to investors and markets (Agarwal et al., 2009; Conti, Thursby, & Thursby, 2013; Hsu & Ziedonis, 2013). Figure 2 shows the results from split-sample analyses based on five firm-size categories. As predicted, the effects are greater for Large- and Medium-sized firms than for Small and Tiny ones: Large firms filed 26% more patents after the decision, equivalent to 3.7 more patents per year per firm. Medium-sized firms increased their patent filings by 9%, or 0.48 more patents per year per firm.

Interestingly, extremely large corporations that ranked in the top 1% in terms of their size show little effect. These huge firms—including Microsoft, Motorola, Boeing, Lockheed Martin, and Whirlpool—have dedicated, in-house patent attorneys for their patent filings, maintenance, and enforcement, helping to maintain a high propensity to patent even before the decision. This non-monotonicity of the firm-size effect is consistent with existing studies that examine the relationship between patenting propensity and firm size. Link and Scott (2018), for example, find that the elasticity of patenting with respect to R&D is largest for firms of intermediate size.

4.4 Heterogeneity by industry characteristics

Industry product type (discrete vs. complex). The incentive to and effectiveness of patenting vary across industries according to whether the technological characteristics of products are discrete or complex (Cohen et al., 2000). Theoretically, it is not clear ex ante in which type of industry higher effects will be found. "Complex" technology products (e.g., semiconductors) consist of numerous patentable elements, of which some are patented and others are generally kept as secrets and embodied in individual workers (Contigiani et al., 2018; Png, 2017a). Consequently, a heightened threat of worker departure creates strong incentives for firms in complex product industries to file patents for knowledge that was previously kept as secrets. "Discrete" technology products, on the other hand, are composed of relatively few patentable elements (e.g., new drugs). Thus, among firms

in discrete product industries, switching from secrecy to patenting may occur less often because these firms are likely to have already patented most of their patentable knowledge (Contigiani et al., 2018; Png, 2017a). However, it is also true that discrete technology products are often more vulnerable to imitation by competitors than are complex technology products. Thus, the threat of worker departure may strongly induce firms in discrete product industries to file patents on any unpatented knowledge.

We empirically test the heterogeneous effects by industry product type. We identify patents in discrete or complex product industries using SIC-patent concordance data from Silverman (2002). Following Vonortas and Kim (2004) and Cohen et al. (2000), we categorize industries with SIC codes less than 35 as discrete product industries and those with SIC codes 35 and above as complex product industries. The results in Table 2, columns 4 and 5, show that the increased patent filings come primarily from complex technology products. This is consistent with the argument that, compared to discrete technology products, complex technology products have more elements that are kept as secrets and are potentially patentable.

Technology field dynamism: Fast-growing versus stationary. Fast-growing and expanding industries exhibit a higher rate of innovation. Firms in such industries face higher risks of knowledge leakage via worker departure to competitors and thus have a greater incentive to protect their knowledge with patents. Firms in stationary industries, on the other hand, have relatively flat and static information and do not compete as fiercely for knowledge. The results in Table 2, columns 4 and 5, show that the patenting effects are greater and more precisely estimated ($p<0.01$) for fast-growing industries, where worker departure is much more highly associated with valuable knowledge leakage. The estimate is not distinguishable from 0 for stationary industries ($p=0.131$).

5 TESTS OF THE MECHANISMS

We run further analyses to verify that the threat of worker departure is the key driver for our results.

Trade secret. Firms that possess trade secrets provide a valuable opportunity to test the mechanism. We expect that firms possessing trade secrets respond more strongly because they face a greater risk of knowledge leakage via departing workers. US Security Act Regulation S-K requires public firms with valuable trade secrets to discuss the risk of trade secret misappropriation in Form 10-K, without revealing the nature of the secret (Glaeser, 2018). For example, Intel Corporation stated in its 2020 Form 10-K that "we own and develop significant IP and related IP rights around the world that support our products, services, R&D, and other activities and assets. Our IP portfolio includes patents, copyrights, trade secrets, trademarks, mask work, and other rights." We identify firms with trade secrets from their 10-K discussions of trade secrecy and compare the effect between firms with and without trade secrets.[6] We find that firms with trade secrets increased patent filings more than did firms without, supporting the argument that increased patenting is driven by a motivation to protect proprietary knowledge. Table 3, column 2, shows that firms with trade secrets increased their patent filings by 12.3%, whereas the estimate for firms without trade secrets is smaller in magnitude (0.7%) and not statistically significant (p=0.739), as shown in column 3.

Physical proximity to California. The threat of worker departure is greater for states that are physically close to California because workers in those states have shorter moving distances and lower costs. We use data on state centroids from the United States Geological Survey (USGS) and calculate the distances between each state's centroid and that of California. We divide the treated group with the threshold of 1,311 (half the maximum distance) and find that the effect is larger for treated states that are physically closer to California, while the distant states still show strong effects. These results are shown in Table 3, columns 4 and 5.

Migration rate to California: Population and the high-skilled. A more direct test on the threat of

[6] We thank Stephen Glaeser for generously sharing his data on trade secrecy discussions in 10-K filings.

worker departure is to examine the preexisting migration rate to California. Firms in states that exhibit a high migration rate to California should face a greater risk of worker departure due to the *Application v. Hunter* decision. First, we use the County-to-County Migration Flow Files from the 2000 US Census to measure state-level moves to California in 1995 and run a split-sample analysis for firms in states that are above and below the median migration rate of workers to California, respectively. In Table 3, columns 6 and 7, we find a larger (4.2%) and statistically significant (p = 0.002) effect in the above-median sample, while there is little effect in the below-median sample.

Second, we run the same test with the migration rate of high-skilled workers. We identify inventor moves by finding inventors who filed a patent with a new employer in a new state (Marx et al., 2009). Table 3, columns 8 and 9, shows the results of split-sample analyses based on the ratio of inventor moves to California to all moves from 1993 through 1997. The results from firms in states that exhibit an above-median value of such ratio is much larger and more precisely estimated than those from firms in states with a below-median ratio. In sum, treated firms in states that exhibit a greater migration rate of the population or of knowledge workers show greater effects, confirming that the threat of departure is the key mechanism that drives increased patent filings after the decision.

Industry dissimilarity to California. We now refine our control group by restricting it to firms in states that have little industry overlap with California. These firms are less affected by *Application v. Hunter* because workers find it more difficult to move to a firm in the same industry in California, and the likelihood of worker departure is thus minimal. We measure industry composition (i.e., share of workers by 2-digit NAICS) for each state and calculate the Euclidean distance (i.e., sum of squared differences of shares in vectors) between the industry composition of California and that of control states. We then restrict our control group to firms in states that have above-median industry distance to California. The results are shown in Table 3, column 10. We find a larger estimate with a smaller p-value using the restricted control group.

Realized Moves. We examine whether realized inventor moves to California increased following the court decision. We find that inventor moves from treated states to California significantly increased after *Application v. Hunter*. Since we focus on the *threat* of worker departure as the key mechanism, the realized moves to California are not required to support our main findings. Yet this analysis provides additional strong evidence that *Application v. Hunter* created not only a substantial threat but also contributed to the realization of worker departure. (Please see Online Appendix C.1 for further details)

6 DISCUSSION AND CONCLUSION

We examine the threat of worker departure as a key driver that determines how innovating firms manage knowledge leakage. To causally identify the effects, we take advantage of a milestone court decision in California that created a loophole in the enforcement of noncompetes for *non*-California firms. When facing a higher threat of worker departure, firms rely more on patents for knowledge protection; the effects are greater for medium- to large-sized firms and for those in fast-growing or complex product industries. As predicted, while the effects are magnified for Maryland firms, they are nonexistent for unaffiliated inventors. Importantly, tests on the possession of trade secrets, physical proximity to California, migration rate to California (for all population and for knowledge workers), and industry distance to California provide consistent and strong support for our theoretical account that the threat of worker departure plays a crucial role in firms' patenting decisions.

Our empirical analysis adopts a novel identification strategy that merits further discussion. When using an event in California as a naturally occurring experiment and studying its impact on California firms, one may be concerned that factors affecting the event may influence the outcomes of interest. Our empirical approach mitigates this endogeneity concern by comparing outcomes of treated and control firms *outside* of California, which are unlikely to be correlated with the factors that affect a California court's decision. This decision applied retrospectively to existing workers,

creating an immediate threat of worker departure from firms outside California. Future research could leverage this naturally occurring experiment to study different firm behaviors and outcomes.

This study provides several important implications outside of academia as well as further research opportunities. First, we show how legal enforcement in one state has far-reaching consequences outside of the focal state. That is, we show that business environments that shape firm strategies are not limited to the local environment but include broader policy and legal institutions and environments (Marx et al., 2015). State governments frequently engage in competition to attract and retain businesses in their jurisdictions by providing favorable business and legal environments—notably by permitting strong enforcement of in-state noncompetes—which often leads to a "race to the bottom" (Glynn, 2008). Our results and the *Application v. Hunter* case show that one state's ability to enforce in-state noncompetes is heavily affected by another state's decision to honor *out-of-state* noncompetes. Business managers and policymakers should thus carefully consider how local policies and laws spill over borders.

Second, our finding that firms patent strategically implies that patent counts may not capture firms' fundamental innovation activities accurately. Studies that use patent-based proxies to measure innovation rely on an implicit assumption that patent filings are primarily determined by knowledge *creation* considerations such as R&D investments. Our findings suggest that knowledge *protection* considerations can also significantly drive patenting decisions. We suggest that researchers carefully examine the validity of such measures. Further, it is important to delve into how the threat of worker mobility affects the longer-term interplay between R&D investments and patents. Our finding—that public firms did not meaningfully change their R&D expenses in response to a heightened threat of worker departure—calls for future study. Such study should use granular R&D data on private as well as public firms to provide more comprehensive insights on how the threat of worker departure affects firms' incentives to innovate and manage knowledge.

Last, but not least, our finding that firms increased their propensity to patent suggests that innovating firms seek legal protection at the cost of disclosure. An interesting future avenue would be to investigate how such disclosures affect the rate and direction of follow-on innovations (Galasso & Schankerman, 2014). We hope that this study connects other research on worker mobility and innovation and contributes to a better understanding of how innovating firms create, acquire, and protect proprietary knowledge according to the degree of worker mobility.

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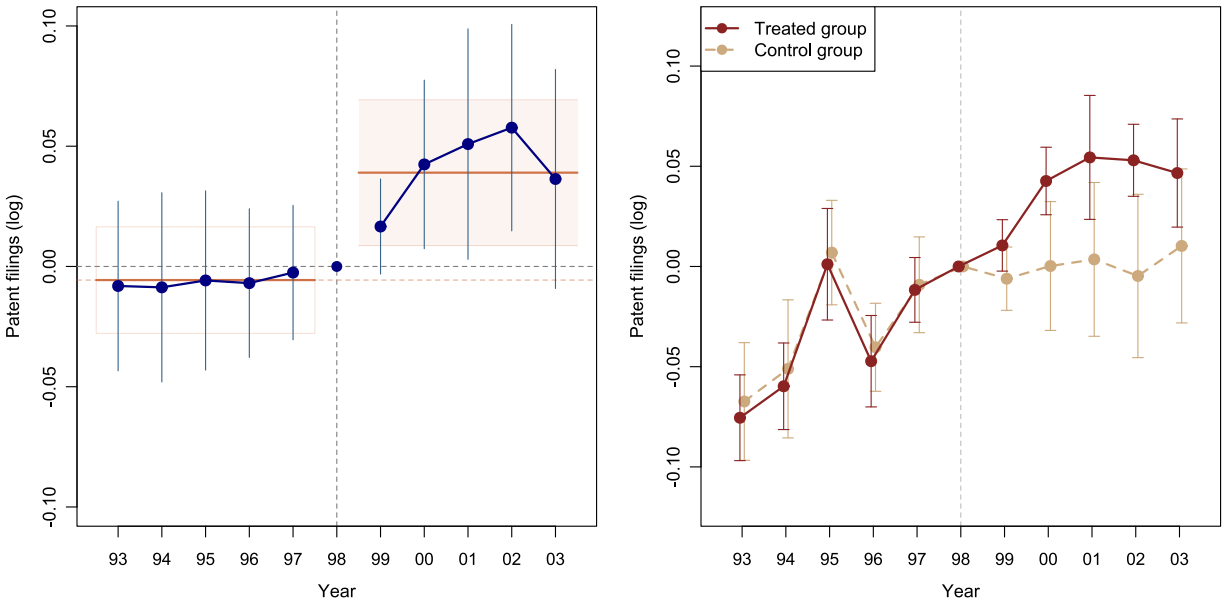
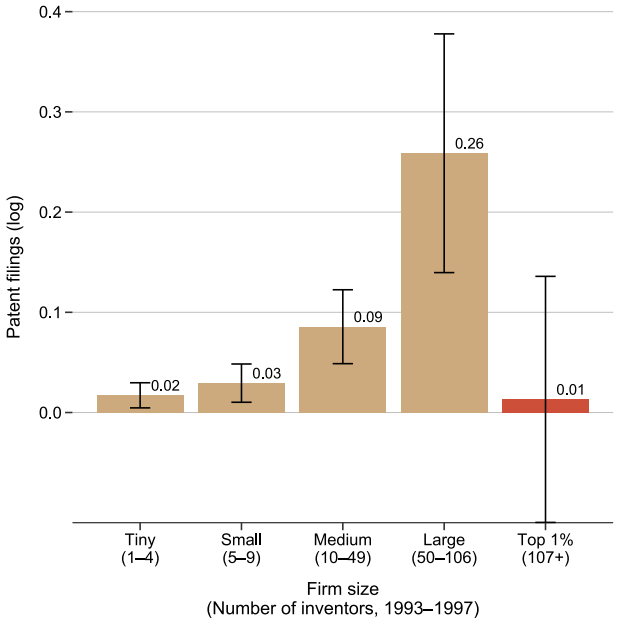
Figure 1. The threat of worker departure and patent filings: Distributed leads and lags

(a). Flexible difference-in-differences approach (b). Separate event-study approach



Notes. Panel (a): The graphs illustrate the results from two different econometric estimations. First, the blue dots represent estimates in the flexible difference-in-differences model interacted with year indicators (event-study approach). The blue vertical lines represent the 95% confidence interval. Second, the red horizontal lines represent estimates in the difference-in-differences model with aggregated indicators for pre- and post-1998 periods. Boxes around the horizontal lines represent the 95% confidence interval. Panel (b): Each series is from a separate event-study regression. The red solid line represents the estimates for the treatment group; the yellow dashed line represents the estimates for the control group. In both panels, the year of the court decision, 1998, is used as a baseline (an omitted category). Standard errors are clustered at the state level.

Figure 2. The threat of worker departure and patent filings: Heterogeneity by firm size



Notes. This bar plot illustrates estimates from five separate difference-in-differences models by firm size, measured by the five-year inventor stock during 1993–1997. We use firm-size classes by the US Bureau of Labor Statistics. We merge size class 3 (10-19 employees) and class 4 (20-49 employees) due to the small number of firms in each class. We expand size class 5 (50-99 employees) to include firms with 100-106 employees and add a Top 1% category (107 or more employees) for outliers. Vertical lines represent one standard error from the mean. Standard errors are clustered at the state level. The regression estimates, standard errors (in parentheses), and *p*-values (in brackets) are 0.017, (0.013), and [0.181] for Tiny firms (N = 35,731); 0.029, (0.019), and [0.135] for Small firms (N = 11,654); 0.086, (0.037), and [0.027] for Medium firms (N = 12,391); 0.259, (0.119), and [0.039] for Large firms (N = 2,118); and 0.013, (0.123), and [0.916] for Top 1% firms (N = 2,352).

Table 1. Main variables and summary statistics

Variables	Description	Mean	SD	Min	Max
Full sample					
Patent filings	Log of the average number of eventually granted patent applications by firms	1.340	0.931	0.690	8.400
	i). by Maryland firms	1.254	0.851	0.693	5.620
	ii). by unaffiliated individuals	0.867	0.332	0.693	3.497
	iii). in the discrete product industry	0.520	0.779	0.00	6.200
	iv). in the complex product industry	0.920	0.956	0.000	8.320
Industry dynamism (industry level)	The compound annual growth rate of patent filings at the 3-digit CPC industry level for 1993–1997	0.064	0.068	-0.070	0.534
Migration rate to CA: all population (state level)	The ratio of each state's outflow moves to California between 1995 and 2000 to the state's population in 2000	0.008	0.009	0.001	0.050
Migration rate to CA: high-skilled workers (state level)	The average ratio of each state's outflow moves of patent inventors to California to the state's all cross-state inventor moves from 1993–1997	0.164	0.082	0.000	0.419
Public firm sample (Compustat)					
Patent filings	Log of the average number of eventually granted patent applications by public firms	1.458	1.278	0.000	8.393
Trade secrets	An indicator variable that takes the value of 1 if a firm reported having trade secrets in its 10-K filing during 1993–1997 and zero otherwise	0.518	0.500	0.000	1.000

Notes. This table reports summary statistics for variables used in the analyses from 1993 through 2003. When we use the logarithm, it is the natural logarithm of the variable plus one.

Table 2. The threat of worker departure and patent filings: Main results and robustness checks

	Dependent variables (log): Patent filings						
	Main analysis	Maryland firms	Patents by individuals	*By industry product type*		*By industry dynamism*	
				Discrete	Complex	Growing	Stationary
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Enforce×Post	0.046	0.114	–0.003	0.016	0.050	0.049	0.017
	(0.012)	(0.012)	(0.021)	(0.012)	(0.018)	(0.014)	(0.013)
	[0.004]	[0.000]	[0.899]	[0.203]	[0.008]	[0.002]	[0.179]
Unit FE	Firm	Firm	Industry, State	Firm	Firm	Firm	Firm
Time FE	Year	Year	Year	Year	Year	Year	Year
R^2	0.796	0.794	0.286	0.791	0.806	0.802	0.769
Adjusted R^2	0.653	0.628	0.244	0.645	0.671	0.663	0.608
Observations	64,246	18,085	2,710	64,246	64,246	64,246	64,246

Notes. This table reports regression coefficients from seven regressions based on Equation (1). The sample includes all patent assignees that had at least one inventor from 1993 to 1997. The dependent variable consists of the number of patent filings: all (column 1); with only Maryland firms in the treatment group (column 2); by independent US and foreign inventors without affiliation at the 3-digit CPC industry-state-year level (column 3); in discrete product industries (column 4); in the complex product industries (column 5); in the fast-growing technology fields (column 6); and in the stationary technology fields (column 7). For columns 4 and 5, following Vonortas and Kim (2004) and Cohen et al. (2000), we code industries with SIC codes less than 35 as discrete product industries; those with SIC codes 35 and above were coded as complex product industries. We identified patents in discrete versus complex product industries using Silverman (2002) IPC-US SIC concordance. For columns 6 and 7, we calculated the compound annual growth rate of patent filings at the 3-digit CPC level for 1993–1997. Technology fields above the median growth rate (5.1%) were coded as fast-growing technology fields, and below the median as stationary. Standard errors, clustered at the state level, are provided in parentheses. *p*-values are provided in brackets.

Table 3. The threat of worker departure and patent filings: Analyses of the key mechanism

	Dependent variables: patent filings (log)									
	Trade Secrets (Sample: Compustat public firms)			*Proximity to California (statute miles)*		*Migration rate to California: All population*		*Migration rate to California: High-skilled workers*		*Industry composition dissimilar to California*
	All	Yes	No	High	Low	High	Low	High	Low	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Enforce×Post	0.080	0.123	0.007	0.053	0.048	0.042	0.022	0.057	0.033	0.052
	(0.041)	(0.054)	(0.035)	(0.020)	(0.017)	(0.011)	(0.019)	(0.016)	(0.017)	(0.014)
	[0.054]	[0.024]	[0.839]	[0.016]	[0.008]	[0.002]	[0.271]	[0.002]	[0.068]	[0.001]
Applied to	–	Treated group	Treated group	Treated group	Treated group	Treated group	Treated group	Treated group	Treated group	Control group
Unit FE	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Time FE	Year	Year	Year	Year	Year	Year	Year	Year	Year	Year
R^2	0.525	0.573	0.521	0.809	0.811	0.817	0.803	0.796	0.796	0.799
Adjusted R^2	0.453	0.500	0.442	0.637	0.662	0.678	0.655	0.653	0.645	0.659
Observations	15,589	9,892	9,461	19,711	47,672	25,795	25,152	43,198	37,590	60,652

Notes. This table reports regression coefficients from ten regressions based on Equation (1). The sample includes all patent assignees that had at least one inventor from 1993 to 1997. The dependent variable consists of the number of patent filings: by public firms in Compustat (column 1); by public firms in Compustat that do or do not possess trade secrets (columns 2 and 3); by firms in states that are physically close or distant to California in statute miles (columns 4 and 5); by firms in states that exhibit high and low migration rate to California for all population (columns 6 and 7), by firms in states that exhibit high and low migration rate to California for high-skilled workers (columns 8 and 9); and where the control group consists of firms in states that have above-median distance in terms of industry composition. For columns 6 and 7, we constructed the migration rate to California variable as the ratio of each state's outflow moves to California between 1995 and 2000 to the state's population in 2000, using the County-to-County Migration Flow Files from the 2000 US Census. Alternatively, we also use the Job-to-Job Flows (J2J) Data for 2000 (the earliest year available) from the Census Longitudinal Employer-Household Dynamics (LEHD). The findings are robust to this alternative measure of interstate job moves. We identified inventor moves by finding inventors who filed a patent with a new employer in a new state. Standard errors, clustered at the state level, are provided in parentheses. *p*-values are provided in brackets.