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

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Abstract

Knowledge protection strategies are crucial to innovating firms facing the risk of knowledge leakage. We examine the threat of worker departure as a key mechanism through which firms choose between patents and secrecy. We exploit a 1998 California court decision that ruled out-of-state noncompetes were not enforceable in California, thereby creating a loophole limiting non-California firms in their enforcement of noncompetes against their workers. When facing a higher threat of worker departure, firms strategically increased patent filings, exchanging legal protection for public disclosure of the invention. These effects were magnified for large-sized firms and for those in complex and fast-growing industries. Further mechanism tests on the possession of trade secrets, inventor migration, saliency of the decision, and independent inventors 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 the established literature suggest that worker departure can cause a substantial threat to firms in the form of knowledge leakage, 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 file a patent, which would bring the concomitant disclosure of inventions and costs of filing, maintaining, and enforcing the patents. However, to the extent that the threat of worker departure increases (i.e., when knowledge protection through worker retention becomes more risky and less effective), firms increase their use of patents as an alternative protective mechanism.

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 changed the threat of worker departure faced by non-California employers. *Application Group, Inc. v. Hunter Group, Inc.*, 61 Cal. App. 4th 881 (1998)—henceforth, *Application v. Hunter*—provides us with a natural experiment opportunity to test this relationship. 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, 2011; Marx, Strumsky, & Fleming, 2009; Prescott, Bishara, & Starr, 2016; Starr, Prescott, & Bishara, 2019). In 1998, the California Court of Appeal decided not 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 uphold out-of-state noncompetes, even with a choice-of-law provision that a non-California law shall apply. After this decision, non-California workers who were bound by noncompetes could move to California employers because their employers' ability to enforce noncompetes and restrict California-bound workers had become significantly limited. Our in-depth legal analyses confirm that this was a radical decision that unexpectedly and significantly increased the threat of worker departure faced by non-California employers.

Using a difference-in-differences methodology, we compare patent applications of firms in high-enforcing states (treated group) to those in low or non-enforcing states (comparison group), before and after the decision. A key assumption is that, before the decision, noncompetes constrained workers in the treated group from leaving to work for California firms; after the decision, they could move to California firms. In contrast, workers in the comparison group could leave to work for a California firm both before and after 1998, regardless of the decision. We verify this assumption by comparing trends in worker moves to California from high- and low-enforcing states and through interviews with legal experts.

We find that, after *Application v. Hunter*, firms in high-enforcing states increased patent filings by about 5 percent compared to firms in low or non-enforcing states. The effect is even higher—up to 31 percent—for large firms that enjoy the economies of scale in patent application and assertion. The effects are also greater for inventions in complex product industries than in discrete product industries and for fields that are fast-growing rather than stationary. The findings are robust to a stricter comparison group that has industry composition dissimilar to that of California and to a Poisson quasi-maximum likelihood estimation. Note that a later court decision, *Advanced Bionics Corp v. Medtronic, Inc.,* 29 Cal. 4th 697 (2002) (henceforth, *Advanced Bionics v. Medtronic*), provided a workaround and thus weakened the impact of *Application v. Hunter,* our decision of interest. Our examination of long-term effects confirms that the increase in patent filings began to diminish after 2002.

While *Application v. Hunter* provides an appropriate setting to test the impact of the threat of worker departure, a remaining concern is that there may be other channels such as firms' incentives to invest in R&D and a shift in technological areas, among others, that could affect patent filings. We conduct additional analyses to rule out these alternative explanations. To further verify that the threat of worker departure is the key mechanism driving the results, we also show that the effects are greater for firms that possess trade secrets to protect, that are located in Maryland where the court decision was more salient, and that are in states where the migration rate of high-skilled knowledge workers to California is high. Further, a placebo test on patenting filings by independent inventors—that is, those who did not belong to organizations and thus were not affected by the decision—showed no change in patenting. The findings, taken together, consistently indicate that firms strategically increased patent filings to protect their proprietary knowledge in response to the unexpectedly heightened threat of worker departure to California firms.

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 and, consequently, can change innovating firms' propensity to patent. This study 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 always capture firms' innovation performance because patent filings are not determined solely by firms' knowledge *creation* but also by their knowledge *protection* strategies over time. It is thus important for scholars to carefully validate the use of patents for measuring innovation outcomes.

Furthermore, we propose a robust quasi-experiment that exploits a milestone court decision in California that had substantial influence on the beliefs and behaviors of employers and employees related to worker mobility. Unlike legislative changes, this court decision applied retrospectively to firms and their workers, creating an immediate threat of worker departure and knowledge leakage. In addition, *Application v. Hunter* affected non-California firms' ability to retain workers but not their ability to hire workers. This situation ensured a clean natural experiment on the increased threat of worker departure without affecting firm's hiring abilities Future research can leverage this setting 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 finding sheds light on how legal enforcement in one state can 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 public disclosure of the invention. In exchange for formal protection, patent applicants must publicly disclose the technical details of the knowledge that they seek to protect; this closure may trigger imitation and reverse engineering by competitors. In addition, patent registration fees, maintenance fees, payments to patent attorneys, and legal uncertainty are crucial 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; Thompson et al., 2022). Recent studies further suggest that these choices are not static but dynamic, and that firms strategically adjust their decisions in response to changes in legal 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, made firms less reliant 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., 2009; Agarwal et al., 2004; Campbell, Coff, & Kryscynski, 2012; Somaya, Williamson, & Lorinkova, 2008; Wezel, Cattani, & Pennings, 2006). To prevent consequent knowledge leakage, firms must actively manage and respond to the threat of worker departure that arises from the changing business environment.

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. In contrast, other protection mechanisms—for example, 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 and Professions 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 case to set a strong precedent that California courts may invalidate out-of-state noncompetes based on California law, Section 16600. This case involved Dianne Pike (an employee in Maryland) who was seeking to move from Hunter Group, Inc. (a Maryland company) to Application Group, Inc. (a California company). Pike and Hunter Group, Inc. had 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 decided not to enforce this out-of-state 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 non-California firms the ability to use noncompetes to prevent their workers' outbound mobility to California and significantly increased the threat of worker departure facing these firms. Our interviews with a California attorney and a leading legal scholar in this field confirm that *Application v. Hunter* was an unexpected decision that significantly increased the threat of job mobility to California by noncompete-bound workers. This decision was final as the appellant's petition for review by the Supreme Court was denied on May 13, 1998. We provide an in-depth legal analysis on the validity and impact of this seminal court decision in Online Appendix A.

Although *Application v. Hunter* offers an opportune setting that enables us to measure an increased threat of worker departure faced by non-California firms, the threat of worker departure may not be the only factor that this decision affected. It may have changed, for example, firms' incentives to invest in R&D, the resources available to inventors, and the direction of invention. These changes, however, come into effect in the relatively longer term, and the threat of worker departure still is the preceding and primary mechanism through which some channels work. For instance, after *Application v. Hunter*, firms may provide more resources to inventors who are likely to move to California, as an incentive to remain in the firm. This alternative mechanism might increase patenting at the firm level, but the main driver for this shift would be firms' expectation of a greater risk of worker departure and knowledge leakage to California. Nonetheless, to further mitigate concerns due to alternative mechanisms, we show in Section 5 that the R&D investment and the qualitative characteristics of patents have not been changed around *Application v. Hunter*.

Three unique advantages of *Application v. Hunter* make it a particularly appropriate setting to test our argument. 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 non-California firms' ability to retain workers (i.e., restricts outbound mobility), but not their ability to hire workers (inbound mobility). Thus, our research design ensures a clean natural experiment on the threat of worker departure, not confounded by firms' hiring abilities. This advantage is provided by the fact that

Application v. Hunter was a court decision on the enforceability of *out-of-state* noncompetes. In contract, when leveraging court decisions on *in-state* noncompete enforceability as a natural experiment, it is often difficult to disentangle the two effects because such court decisions simultaneously affect a firm's ability to hire and retain workers. For example, Florida's 1996 legislative change that eased restrictions on noncompete enforcement affected not only Florida firms' ability to hire but also their ability to retain employees (Kang and Fleming, 2020).

Third, *Application v. Hunter* is a court decision that applies not only prospectively but also retrospectively to workers who signed the contracts even before the decision. Thus, for firms that had been enforcing noncompetes, the decision immediately introduced a threat that their *existing* workers might leave to join the competing firms in California. This is a unique feature of our setting compared to studies that exploit state-level legislative changes that apply only prospectively (i.e., to those who sign a contract after the effective date of the new law) (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.

These three advantages make the 1998 *Application v. Hunter* decision a suitable setting to test our argument. Yet one important development after *Application v. Hunter* is *Advanced Bionics v. Medtronic*, which dealt with out-of-state noncompete enforceability in California. Although this 2002 case did not overturn the *Application v. Hunter* decision, it provided a work-around for non-California firms to enforce their noncompetes in California using choice-of-venue clauses. Our analysis thus focuses on the period during which *Application v. Hunter* had an uninterrupted impact on out-of-state noncompetes—that is, years through 2002 when *Advanced Bionics v. Medtronic* was decided. We discuss the implications of *Advanced Bionics v. Medtronic* and the longer-term effects of *Application v. Hunter* in Section 4.1 and Online Appendix A.3.

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 in 1998. 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 (comparison group) and do so for four years before and after the year of the decision,

1998. The core idea of the empirical approach is that, in the treatment group, a worker bound by noncompetes could not move to work for a California employer before *Application v. Hunter*; after the decision, however, a worker could move because the decision by the California court denied the use of *out-of-state* noncompetes and choice-of-law provisions. In contrast, in the comparison group, workers could move to a California employer both before and after *Application v. Hunter* as their state law either did not enforce noncompetes or only weakly enforced them. Our interviews with legal experts and analysis of migration trends from high- and low-enforcing states to California support this point.

Many US states enforce noncompetes to some degree, so we have few control states that were not affected by the treatment at all (Garmaise, 2011; Starr, 2019). Since the comparison group was affected in the same way as the treatment group, our research design underestimates and provides the lower bound of the true effects. We thus provide, in Section 4.1 and Online Appendix H, additional tests to check the validity of our comparison group by exploiting the worker migration rate to California before *Application v. Hunter*.

The research design, 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 run the following difference-in-differences estimation:

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

where y_{ist} is the natural log transformation of our outcomes of interest. $Post_t$ is an indicator that equals one after 1998. The remaining terms δ_{is} and γ_t are firm-state and year-fixed effects.[1] 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 (comparison 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).

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 event-study approach in Equation (2), we not only explicitly test the parallel trend assumption for pretreatment years (1994–1997) but also examine the dynamic patterns of the effects (e.g., one-time adjustment

[1] Since we exploit differences in state-level enforceability, to treat firms that have the same assignee identifier (but are in different states) as separate businesses, we include firm-state fixed effects.

versus gradual increase) for post-treatment years (1999–2002):

$$y_{ist} = \sum_{k=1994,k\neq1998}^{2002} Enforce_s \cdot 1\{t = k\} + \delta_{is} + \gamma_t + \epsilon_{ist} \tag{2}$$

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. For an analysis of publicly traded firms, we use CRSP/Compustat-Merged data.

Our sample selection begins with the universe of all patent assignees that filed a patent in the United States from 1994 through 2002. We confine our interest to patent-assignee firms that are companies or corporations and exclude government institutions and individual inventors because they have different incentives and are hardly affected by *Application v. Hunter*. We further exclude firms in states that underwent significant changes in noncompete enforceability during our sample period: Florida, Louisiana, and Texas (Garmaise, 2011; Kang & Fleming, 2020). Firms in Alaska and Hawaii are also omitted in the main analysis to account for geographic barriers that restrict ground transportation. Further, we require that 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. The resultant sample consists of 23,739 assignee firms with 410,859 patent filings. Table 1 provides descriptive statistics.

– Insert Table 1 Here –

4 RESULTS

4.1 Main Results: 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 treated group (i.e., high-enforcing states) increased their patent filings by about 5 percent ($e^{0.049}$–1), compared to those in the comparison group (i.e., low- or non-enforcing states). In 1998, firms in our sample filed an average of 7.3 patents that were eventually granted; the 5 percent increase in patent filings is thus equivalent to 0.37 more patents per year per firm, for every year from 1999 through 2002. In Table 3, column 1, we report the same analysis for publicly traded firms using Compustat data and find an 8.2 percent increase in patent filings after the decision (see Online Appendix G for further analyses).

– Insert Table 2 Here –

The event-study approach 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 1.8 percent to 6.2 percent after the decision, compared to the filings in 1998. The gradual increase in patent filings is consistent with the time required from project onset until the filing of 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 the treated and comparison groups. We confirm the validity of the comparison group as a counterfactual (i.e., the parallel trend for the two groups) and find a diverging trend after the decision in 1998.[2]

– Insert Figure 1 Here –

Our discussions with legal experts indicate that the effect of *Application v. Hunter* was de facto weakened in 2002 because of the California court's decision in *Advanced Bionics v. Medtronic* regarding enjoining ongoing noncompete litigations in a non-California court (see Online Appendix A.3. for details on the two court decisions). Although this later (2002) court decision limits our ability to estimate the long-term effects of *Application v. Hunter,* it provides us with another opportunity to validate our proposed mechanism. That is, if the threat of worker departure is indeed the key mechanism in play, we should observe the opposite effect (i.e., a decrease in patent filings) around 2002. We show in Figure A.1 in the Online Appendix that during 2003–2006 the number of patent filings gradually declined to the pre-1998 level, bolstering our argument that firms change their patent filings in response to the threat of worker departure.

4.2 Robustness Checks

Stricter comparison group with industries dissimilar to California industries. We refine the comparison 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 would find it more difficult to

[2] 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 percent after the decision (see Online Appendix D for further details).

move to a California firm in the same industry. Thus, the likelihood of worker departure is even smaller for these firms. 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 comparison states. We then restrict our comparison group to firms in states that have above-median industry distance to California. The results shown in Table 2, column 2 are consistent with the main findings.

Poisson QMLE. 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 E).

4.3 Heterogeneity by Firm Size and Industry

Heterogeneity by firm size. We expect that firms will respond differently depending on their size as measured by the number of inventors they employ. Firms with more inventors face a 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 quality 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 31 percent more patents after the decision, equivalent to 4.3 more patents per year per firm; Medium-sized firms increased their patent filings by 11 percent, or 0.7 more patents per year per firm.

– Insert Figure 2 Here –

Extremely large corporations that ranked in the top 1 percent 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.

Heterogeneity by industry product type (discrete vs. complex). The effectiveness of patenting varies 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 that are embodied in individual workers (Contigiani et al., 2018; Png, 2017a). Consequently, a heightened threat of worker departure creates 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 many of their key inventions (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 prior research (e.g., Vonortas and Kim, 2004; 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 3 and 4, show that the increased patent filings come primarily from complex technology products (4.9 percent; p=0.013) rather than from the discrete (1.5 percent; p=0.184), where the null hypothesis of equality is rejected (p=0.012). This supports the argument that complex technology products have more elements that are kept as secrets and are potentially patentable, compared to discrete technology products.

Heterogeneity by technology field dynamism: Fast-growing versus stationary. Fast-growing and expanding industries exhibit a higher rate of innovation, compared to stationary industries. Firms in fast-growing industries thus face higher risks of knowledge leakage via worker departure to competitors and 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 5 and 6, show that the increase in patenting for fast-growing industries is greater and more precisely estimated (5.1 percent; p=0.03) than that for stationary industries (2 percent; p=0.156). We reject the null hypothesis of equality of the two (p=0.024).

5 TESTS OF THE MECHANISMS

In this section, we report on five analyses to verify that the threat of worker departure is the key mechanism driving our results. For example, if our proposed mechanism is true, the increase in patent filings would be larger for firms that possess important trade secrets to protect. We also seek to rule out two alternative mechanisms by which *Application v. Hunter* may cause firms to increase patenting activities: R&D investments and shifts in technological area.

Trade secrets. The possession of trade secrets provides a valuable opportunity to test the mechanism. We expect that firms with trade secrets would respond more strongly to *Application v. Hunter* because they face a greater risk of knowledge leakage via departing workers. For firms that do not possess trade secrets, in contrast, the risk of knowledge leakage is small even if their workers leave the firm. We identify public firms with trade secrets from their 10-K discussions of trade secrecy and compare the effect between firms with and without trade secrets.[3] 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." Table 3, columns 2 and 3, shows the results from split-sample analyses. Firms with trade secrets increased patent filings (13.1 percent; p=0.028) more than did firms without (–0.002 percent; p=0.960), supporting the argument that increased patenting is driven by a motivation to protect proprietary knowledge. The interaction model in column 4 confirms that the effect is 11.6 percent higher (p=0.016) for firms with trade secrets, compared to those without.

– Insert Table 3 Here –

High salience of the decision in Maryland. The plaintiff in the case, Hunter Group, Inc., is a Maryland corporation headquartered in Maryland. The defendant, Dianne Pike, was a Maryland resident. We thus expect that *Application v. Hunter* and its implications for worker mobility were more

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

widely understood by and of greater interest to employers and employees in Maryland than in other states. Table 2, column 5, shows the results of a test that included only Maryland firms in the treated group. Maryland firms increased patent filings by about 11.4 percent, more than twice as much as did all firms in the treated group (5 percent). In a model using the full sample with an indicator variable for Maryland firms (column 6), we find that Maryland firms increased patent filings by 6.3 percent more than other treated firms (p=0.000), in addition to a 4.8 percent increase by treated firms in other states (p=0.006). This test strengthens our proposed mechanism by showing that the court decision had a stronger effect on employers that were more likely to be aware of and interested in the decision.

Placebo test with independent inventors. Since noncompetes are a contract between an employer and an employee, independent inventors who are not affiliated with a firm should remain unaffected by *Application v. Hunter*. This idea provides an opportunity to run a *placebo* test. We constructed industry-state-year level data that measures patent filings of independent inventors and ran a regression analysis with industry-, state-, and year-fixed effects. As predicted, we do not find an increase in patent filings by independent inventors. In Table 3, column 7, the estimate is close to zero in magnitude and statistically not distinguishable from zero (0.4 percent; p=0.850). This finding rules out the possibility that our findings are due to state- or industry-level changes that apply to independent inventors.

Migration rate of high-skilled workers to California. If the threat of worker departure is the key mechanism in play, the effects should be larger for firms in states that exhibit a high migration rate to California. We measure the migration rate of high-skilled workers across states by identifying inventors who filed a patent in one state and then filed another in a different state (Marx et al., 2009). Table 3, columns 8 and 9, shows the results of split-sample analyses, respectively, for firms in states that are above and below the median ratio of inventor moves to California to all inventor moves, 1993–1997. The coefficient for firms in states that exhibit a high migration rate to California is larger and more precisely estimated (6 percent, p=0.005) than that for firms in states with a low migration rate (3.8 percent, p=0.018). In an interaction model using the full sample, the coefficient on the interaction term is positive, though not statistically significant (2.2 percent, p=0.193; column 10), and provides suggestive evidence that the threat of worker mobility to California is the key mechanism.[4]

Realized moves. The treatment in our research design is the *threat* of worker departure, not

[4] In Online Appendix H, we show the results with the population migration rate to California and physical distance (statute miles) to California.

necessarily the realized moves of workers. Nevertheless, if *Application v. Hunter* indeed increased such threats, we expect job-hopping to California by skilled workers to increase from treated states. We test this idea by measuring realized inventor moves to California based on patent inventor data. The results reveal that realized moves of inventors from treated states (Maryland, in particular) to California significantly increased after *Application v. Hunter*. This analysis provides additional evidence that the threat of worker departure was real and substantial; the decision triggered an imminent increase in worker departure from treated states to California (See Online Appendix C.1 and C.2 for details and a case study).

R&D investments. One alternative explanation is that firms may have incentives to change their R&D expenditure in response to the threat of worker departure. If this is the case, our main finding—that firms increased patenting—could be due to a higher input in the innovation processes, rather than to a change in the motivation to protect proprietary knowledge from worker departure. We thus examined whether an increase in patenting was accompanied by an increase in R&D expenditure for public firms. Table 3, column 1, reports that treated public firms increased patent filings by about 8.2 percent (p=0.060) and those possessing trade secrets increased filings up to 13.1 percent (p=0.028). However, we do not find evidence that these firms meaningfully increased R&D expenditure, which is consistent with Garmaise (2011). As reported in Table G.2 in Online Appendix G, this is estimated as 7 percent, which is not distinguishable from zero (p-value=0.168). The main results, therefore, are not likely driven by changes in R&D input. This conclusion is more convincing provided that the R&D expenditure item of 10-K filings includes costs associated with patent filings and wages paid to R&D personnel because these labor and patenting costs would increase the R&D expenditure even if there were no increase in fundamental research activities (Hall and Lerner, 2010).

Patent characteristics. Another alternative mechanism may be due to firms shifting away from technological areas in which they expect greater competition from California competitors who, after *Application v. Hunter*, are better positioned to attract high-quality talent. In this case, an increase in patenting may be due to a change in the firm's area of technological focus. We test this possibility indirectly by examining changes in the qualitative characteristics of patents. Yet we do not find strong evidence of such qualitative changes in patent filings (see Online Appendix F).

6 DISCUSSION AND CONCLUSION

We study and highlight the threat of worker departure and subsequent knowledge leakage as a key driver that shapes how innovating firms manage their knowledge. To causally identify the effects, we take advantage of a milestone court decision in California that created a loophole limiting non-California firms' enforcement of noncompetes. When facing a higher threat of worker departure, firms relied more on patents for knowledge protection although it meant public disclosure of the invention. The effects were greater for medium- to large-sized firms and for inventions in fast-growing fields or complex product industries. Tests on the possession of trade secrets, on high salience of the decision in Maryland, on independent inventors, and on the migration rate of skilled workers to California all provide consistent 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 to study its impact on firm outcomes, one may be concerned that confounding factors that affect the event may also influence the outcomes of interest. Our empirical approach mitigates this endogeneity concern by comparing outcomes of firms *outside* California, which are unlikely to be correlated with factors that affect a California court's decision. In addition, the decision changed non-California firms' ability to retain workers without affecting their ability to hire workers, providing an opportunity to study the threat of worker departure. Another advantage is that we use a court decision that is applied retrospectively to existing workers, creating an immediate threat of worker departure. Future research could leverage this naturally occurring experiment to study how an immediate threat of worker departure affects 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, 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 based on the *Application v. Hunter* decision show that one state's ability to enforce noncompetes is yet 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 always 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, however, show that knowledge *protection* considerations can also significantly affect patenting decisions. We suggest that researchers measuring innovation based on patent data carefully examine the validity of such measures. Further, our result that public firms did not meaningfully change their R&D expenses in the short-term, after *Application v. Hunter*, calls for future study. A fruitful research avenue would be to delve into how the threat of worker mobility affects the interplay between R&D investments and patents in the long term. Studies using granular R&D data on private as well as public firms can provide more comprehensive insights on this question.

Last, but not least, our finding that firms increased their propensity to patent suggests that innovating firms seek legal protection although it means public disclosure of the invention. An interesting future avenue would be to investigate how such disclosures due to legal changes affect the rate and direction of follow-on innovations (Galasso & Schankerman, 2014). We hope that this study connects the research on worker mobility and innovation and contributes to a better understanding of how innovating firms create, acquire, and protect proprietary knowledge while coping with the threat of worker mobility that they face in a competitive business environment.

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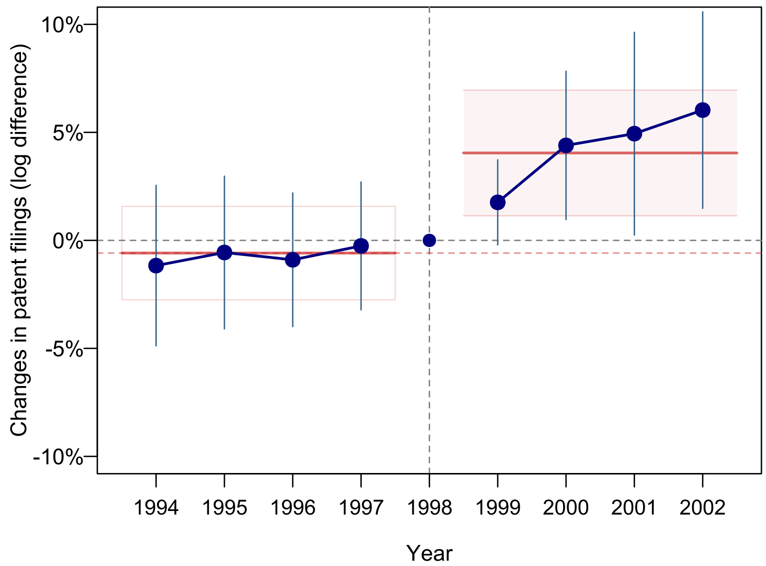
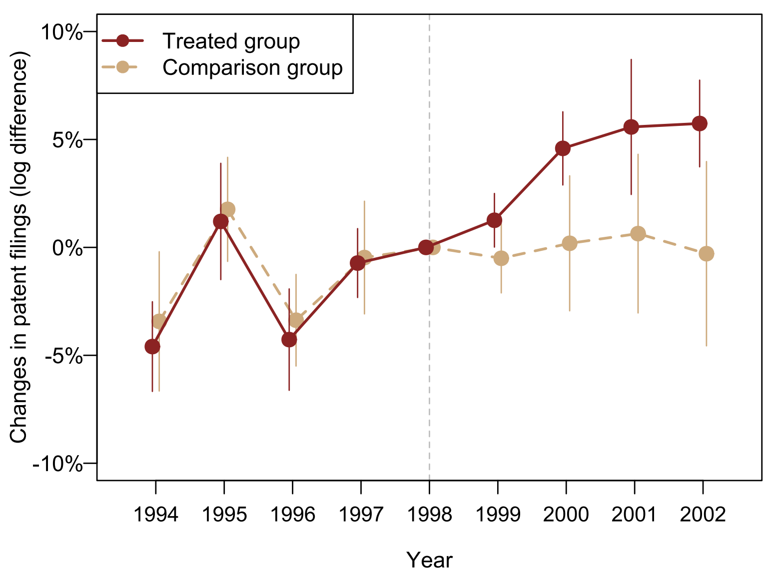
Figure 1. The threat of worker departure and patent filings: Distributed leads and lags

(a). Flexible difference-in-differences approach

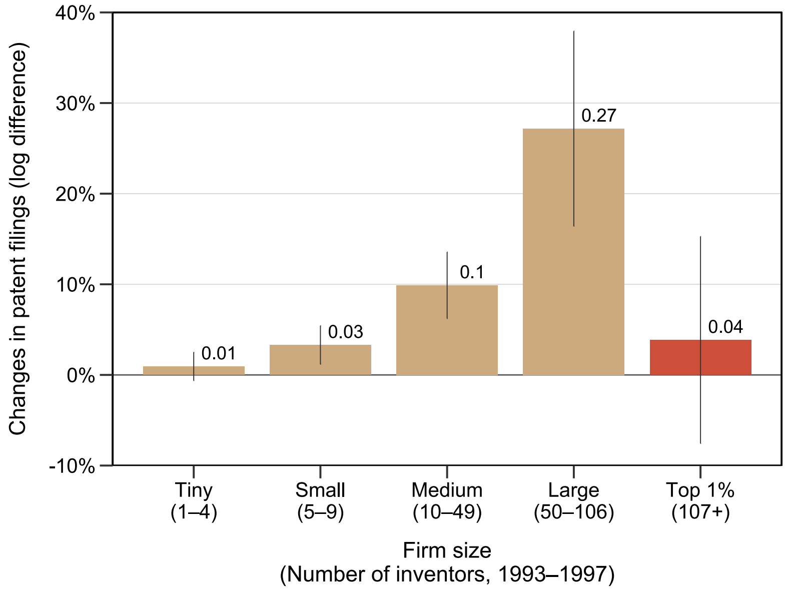


(b). Separate event-study approach



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. The red-shaded area round the horizontal lines represents 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 comparison 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 0.009, (0.016), and [0.555] for Tiny firms (29,721 observations); 0.033, (0.021), and [0.132] for Small firms (9,797 observations); 0.099, (0.037), and [0.011] for Medium firms (10,325 observations); 0.272, (0.108), and [0.018] for Large firms (1,732 observations); and 0.039, (0.114), and [0.739] for Top 1% firms (1,908 observations).

Table 1. Main variables and summary statistics

Variables	Description	Mean	SD	Min	Max
Full sample					
Patent filings	The average number of eventually granted patent applications by firms	9.22	71.85	0.00	4,439.00
	i). in the discrete product industry	2.21	12.59	0.00	492.00
	ii). in the complex product industry	6.27	62.80	0.00	4,090.00
	iii). in the fast-growing fields	6.70	68.16	0.00	4,350.00
	iv). in the stationary fields	2.15	9.71	0.00	468.00
	v). Maryland firms	6.27	20.06	0.00	263.00
	vi). independent inventors (unaffiliated)	1.57	1.42	0.00	32.00
Industry dynamism (industry level)	The compound annual growth rate of patent filings at the 3-digit CPC industry level for 1993–1997	0.06	0.07	–0.07	0.53
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 entire cross-state inventor moves from 1993–1997	0.16	0.08	0.00	0.42
Public firm sample (Compustat)					
Patent filings	The average number of eventually granted patent applications by public firms	20.48	140.91	0.00	4,417.00
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	0.52	0.50	0.00	1.00

Notes. This table reports summary statistics for variables used in the analyses from 1994 through 2002.

Table 2. The threat of worker departure and patent filings: Main results and additional tests

	Dependent variables: patent filings (log)					
	All	All:	By industry product type		By industry dynamism	
		Strict control	Discrete	Complex	Fast-growing	Stationary
	(1)	(2)	(3)	(4)	(5)	(6)
Enforce×Post	0.049	0.056	0.015	0.048	0.050	0.020
	(0.016)	(0.015)	(0.011)	(0.018)	(0.015)	(0.014)
	[*p*=0.005]	[*p*=0.001]	[*p*=0.184]	[*p*=0.013]	[*p*=0.003]	[*p*=0.156]
Unit FE	Firm	Firm	Firm	Firm	Firm	Firm
Time FE	Year	Year	Year	Year	Year	Year
Wald test	–	–	$\chi^2(1)=6.262$, $p=0.012$		$\chi^2(1)=5.069$, $p=0.024$	
R^2	0.810	0.814	0.804	0.819	0.815	0.786
Adjusted R^2	0.660	0.666	0.649	0.676	0.668	0.616
Observations	53,483	50,490	53,483	53,483	53,483	53,483

Notes. This table reports regression coefficients from six regressions based on Equation (1). The sample includes all patent assignees that had at least one inventor from 1994 through 1997. The dependent variable consists of the number of patent filings: all (column 1); all with a stricter comparison group consisting of firms in states that have above-median distance to California in terms of industry composition; patents in discrete product industries (column 3); in the complex product industries (column 4); in the fast-growing technology fields (column 5); and in the stationary technology fields (column 6). For columns 3 and 4, 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's (2002) IPC-US SIC concordance. For columns 5 and 6, 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. For columns 3–4 and 5–6, the Walt test row provides the $\chi^2(1)$ test statistic and the p-value for testing the quality of the estimates for two different outcomes of interest. 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: Testing the threat of worker departure as a key mechanism

	Dependent variable: patent fillings (log)									
	All (public firms)	Trade secret (public firms)			Salience: MD firms		Placebo test	Migration rate to CA: High-skilled		
		Split-sample		Interaction	Subsample	Interaction	Individuals	Split-sample		Interaction
		Yes	No					High	Low	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Enforce×Post	0.079	0.123	–0.002	0.042	0.108	0.047	0.004	0.058	0.037	0.037
	(0.042)	(0.056)	(0.035)	(0.061)	(0.014)	(0.016)	(0.022)	(0.018)	(0.018)	(0.017)
	[p=0.060]	[p=0.028]	[p=0.960]	[p=0.496]	[p=0.000]	[p=0.006]	[p=0.850]	[p=0.005]	[p=0.051]	[p=0.044]
Enforce×Post ×Indicator	–	–	–	0.110	–	0.061	–	–	–	0.022
				(0.046)		(0.009)				(0.016)
				[p=0.016]		[p=0.000]				[p=0.193]
Sample	Compustat	Compustat	Compustat	Compustat	Patent	Patent	Patent	Patent	Patent	Patent
Unit FE	Firm	Firm	Firm	Firm	Firm	Firm	Industry, State	Firm	Firm	Firm
Time FE	Year	Year	Year	Year	Year	Year	Year	Year	Year	Year
R^2	0.530	0.582	0.521	0.530	0.808	0.811	0.296	0.810	0.811	0.811
Adjusted R^2	0.446	0.497	0.429	0.445	0.634	0.660	0.244	0.659	0.652	0.660
Observations	12,798	8,187	7,689	12,790	15,213	53,483	2,195	36,077	31,306	53,483

Notes. This table reports regression coefficients from ten regressions based on Equation (1). The baseline 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 (columns 1 and 4); by public firms in Compustat that do or do not possess trade secrets (columns 2 and 3); with only Maryland firms in the treatment group (column 5); by all firms and with an indicator for Maryland firms (column 6); by independent US and foreign inventors without affiliation at the 3-digit CPC industry-state-year level (column 7); by firms in states that exhibit high and low migration rate to California for high-skilled workers (columns 8 and 9); and by all firms and with an indicator for treated states that exhibit high migration rate to California for high-skilled workers. For columns 8–10, we measured inventor moves by identifying 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.