Paper to be presented at the DRUID 2011

on

INNOVATION, STRATEGY, and STRUCTURE -
Organizations, Institutions, Systems and Regions
at
Copenhagen Business School, Denmark, June 15-17, 2011

Job-Hopping in the Shadow of Patent Enforcement

Rosmarie Ziedonis
University of Oregon

rmz@uoregon.edu

Rajshree Agarwal
University of Maryland
Robert H. Smith School of Business
rajshree@umd.edu

Abstract

Job-hopping by skilled engineers and scientists provides a vibrant channel for knowledge dissemination within industries. While prior studies suggest that stronger non-compete regimes reduce fluidity in skilled labor markets, far less is known about the added shadows cast by patent enforcement. Building on the entry-deterrence literature, this study develops and tests a model on how an employer?s reputation for being ?tough? in the enforcement of patents alters the pecuniary benefits associated with retention and, in turn, shapes employee exit decisions. Using a dataset on the US semiconductor industry over a three-decade period, we find that an increase in employer-level litigiousness reduces the likelihood that employee-inventors will leave to join or form rival companies. Consistent with the model, we also find that as employers grow more litigious, the average outside productivity of employee-inventors that choose to leave nonetheless increases. Paradoxically, this latter finding suggests that tough reputations more

powerfully deter exits by workers with fewer opportunities for outside advancement.

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JOB-HOPPING IN THE SHADOW OF PATENT ENFORCEMENT

Rajshree Agarwal*
Robert H. Smith School of Business
University of Maryland
rajshree@umd.edu

Martin Ganco
Carlson School of Management
University of Minnesota
mganco@umn.edu

and

Rosemarie H. Ziedonis
Lundquist College of Business
University of Oregon
rmz@uoregon

Preliminary: Please do not cite

October 2010

* All authors contributed equally; names appear in alphabetical order. This research has benefited from grants from the Ewing Marion Kauffman Foundation, the STEP Board of the National Research Council, the GE Innovation Fund of the Wharton School's Reginald H. Jones Center, and the University of Michigan's Ross School of Business. We are indebted to Atsushi Ohyama for valuable comments on the analytical model and Myles Shaver for insightful suggestions on the empirical implementation. Shravan Gaonkar provided excellent programming support for the development of the matching algorithm, which also benefited from advice from Juan Alcacer. We also thank representatives from Dow Jones' Venture One for data on venture-backed start-ups and Kwanghui Lim for providing access to the National University of Singapore patent database. Matt Daniels, Faria Jabbar, Sai Lan, Natalya Shipakova, Owen Smith, Leslie Schafer, and Yelena Slutskaya provided exceptional research assistance.

ABSTRACT

Job-hopping by skilled engineers and scientists provides a vibrant channel for knowledge dissemination within industries. While prior studies suggest that stronger non-compete regimes reduce fluidity in skilled labor markets, far less is known about the added shadows cast by patent enforcement. Building on the entry-deterrence literature, this study develops and tests a model on how an employer's reputation for being "tough" in the enforcement of patents alters the pecuniary benefits associated with retention and, in turn, shapes employee exit decisions. Using a dataset on the US semiconductor industry over a three-decade period, we find that an increase in employer-level litigiousness reduces the likelihood that employee-inventors will leave to join or form rival companies. Consistent with the model, we also find that as employers grow more litigious, the average outside productivity of employee-inventors that choose to leave nonetheless *increases*. Paradoxically, this latter finding suggests that tough reputations more powerfully deter exits by workers with fewer opportunities for outside advancement.

1 INTRODUCTION

"Job hopping" by skilled engineers and scientists provides a vibrant channel for knowledge dissemination within industries. For firms losing key talent, however, such departures can deliver a double blow—not only do they lose valuable human capital but rivals stand to gain technological know-how at their expense. As a result, competitive advantage can be eroded.

This study examines, both formally and empirically, the extent to which intra-industry employee turnover is shaped by the reputations of employers for being tough enforcers of intellectual property (IP). In contrast to the relative stability of state laws governing the enforcement of non-compete agreements, the federal protection afforded by patents has changed dramatically over the past three decades (Landes and Posner, 2003). Most notably, institutional reforms in the 1980s increased the bargaining power of U.S. patent owners and strengthened the exclusionary protection afforded by those rights (Gallini, 2002). Following these landmark reforms, the number of IP-related lawsuits in the United States exploded, particularly for disputes over patent-protected inventions (Bessen and Meurer, 2006).

While this surge in patent litigation has been linked to competitive dynamics in product markets (e.g., Lanjouw and Schankerman, 2004; Somaya, 2003), far less is known about the effects on labor market activity. Kim and Marschke (2005) show, for example, that sectors experiencing higher turnover rates among skilled workers accumulated patents more aggressively in the wake of the 1980s reforms, thus highlighting a patent's potential role in protecting innovating firms from "insiders" (i.e., potentially mobile workers). Using firm-level data in the U.S. semiconductor industry and controlling for patent portfolio sizes, Agarwal, Ganco, and Ziedonis (2009) further document that as employers grow more litigious over patents, the spillovers predicted for hiring organizations are reduced.

Although patent enforcement appears to cast shadows over behavior in markets for skilled labor, the implications for employee-level exit decisions are unexplored in prior work. To help fill this gap, we draw on a longstanding body of work in strategy and economics on the use of corporate reputations as entry-deterrence mechanisms (Kreps and Wilson, 1982; Milgrom and Roberts, 1982; Weigelt and Camerer, 1988). Viewing patent enforcement as a general "reputation-building" strategy, we model the effects of employer litigiousness on (unobserved) optimal compensation packages and, in turn, on (observed) employee-inventor exit decisions. In doing so, we relax assumptions in prior models of employer-employee expropriation problems where the safeguards afforded by patents are either absent (Anton and Yao, 1995) or ineffectual (e.g., Franco and Filson, 2006). Empirical implications from the model are tested using a database of patent litigation histories and employee-inventors[1] from the US semiconductor industry over a three-decade period.

To foreshadow our results, we predict and find that increases in employer-level litigiousness (i.e., reputations for "IP toughness"[2]) significantly reduce the likelihood that employee-inventors will leave to join or form rival companies. Put differently, as employers assert patent rights more aggressively, their rate of retaining skilled workers increases. In supplemental analyses, we find little evidence that this empirical pattern is explained by reverse causality (where shifts in litigiousness could alter hiring practices rather than employee departures) or endogeneity (where more valuable patents could yield a simultaneous rise in a firm's propensity to litigate and higher retention rates among employee-inventors). We therefore interpret our evidence as consistent with the view that corporate reputations for "IP toughness" reduce the payoffs employees anticipate from switching jobs within an industry, thus deterring voluntary departures.

[1] The terms "employees," "skilled workers", and "employee-inventors" are used synonymously in the paper.

[2] Our conversations with practitioners suggest that a firm's litigiousness over patents correlates with its stance toward safeguarding other forms of IP, including non-competes in employment contracts and trade secrets. Unfortunately, we lack reliable data on these firms' histories of enforcing non-patent forms of IP.

A second finding is also intriguing. Consistent with the model, we find that as employers grow more litigious over patents, the average productivity of employee-inventors that choose to exit nonetheless *increases*. Paradoxically, this latter finding suggests that tough reputations may ignite an adverse sorting process, more powerfully deterring departures by workers with fewer opportunities for outside advancement.

Below, we briefly summarize prior research that relates most closely to this study. Given their salience to arguments we invoke in the formal model, recent studies by Kim and Marsche (2005) and Agarwal et al. (2009) are discussed in some detail. In Section 3, the effects of "IP toughness" on employee mobility decisions are investigated in a formal model. Sections 4 and 5 test several empirical implications from the model and report our findings. Finally, Section 6 summarizes our results, acknowledges limitations in the study, and identifies opportunities for future research.

2 LITERATURE REVIEW

2.1 Learning-by-hiring as an expropriation problem

In pioneering work, Arrow (1962) observed that employment turnover among engineers and scientists was a vehicle for transmitting technological "know-how" and information across firm boundaries. In the ensuing decades, scholars from across the fields of economics, sociology, and management have produced evidence that corroborates Arrow's famous conjecture. In a survey of R&D managers, for example, Levin et al. (1987) report that hiring employees from rivals increases the speed and efficiency with which established firms incorporate new technologies. More recently, numerous scholars have used patent citations to trace the effects of mobility on knowledge diffusion (e.g., Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Oettl and Agrawal, 2008). Echoing results from managerial surveys (Levin et al., 1987; Bhide, 1994), these citations-based studies further suggest that firms learn by hiring skilled engineers and scientists from rivals.

While the "learning-by-hiring" literature investigates the effects of employee turnover on *inter-firm* knowledge transfers, a separate strand of research explores the *intra-firm* (employer-employee) dynamics that give rise to voluntary employee departures (e.g., Pakes and Nitzan, 1983; Anton and Yao, 1995). A common assumption in this latter literature is that "job hopping" poses an expropriation problem to innovating firms: after hiring and training employees and investing in costly R&D programs, engineers and scientists may leave to exploit discoveries on their own.[3] Analytical attention then shifts to the strategic actions firms take to *retain* skilled workers and/or *deter* them from misappropriating technologies conditional upon exit.

Most studies on this employer-employee expropriation problem evaluate the trade-offs associated with contractual solutions. Influential work by Pakes and Nitzen (1983), for example, models the implications of expropriation hazards for the optimal design of rewards systems. Similarly, more evidence suggest that the bargaining power of innovating firms over knowledge workers is greater in states where the non-compete restrictions in employment contracts are more expansively enforced (Stuart and Sorenson, 2003; Fallick et al., 2006; Marx et al., 2009). As Anton and Yao (1995) discuss, however, expropriation problems in labor markets are difficult to solve through incentives and contracts alone. For employees with strong "entrepreneurial" preferences, for example, monetary rewards may be an insufficient mechanism for retention (Franco and Filson, 2006; Campbell et al., 2010). Contractual solutions are further limited by the transaction costs associated with negotiation and enforcement (Acemoglu and Pischke, 1998; 1999). Finally, and of particular importance in the context of our study, many US

[3] For expropriation to occur, of course, employers must be unable to fully capture the value of technological information "leaked" through labor markets. Instead, former employees and/or hiring organizations must reap some degree of private gains (whether through greater career opportunities and higher wages for former employees or reduced R&D costs for hiring employers). Note that this assumption does not imply that all turnover results in a negative externality to innovating firms. Rather, it more simply requires a positive probability that when employees leave to join rivals, employers are not fully compensated for their prior investments in human capital and R&D. See Acemoglu and Pischke (1998, 1999) for more detailed discussion.

technology companies are based in the state of California, where career restrictions in enforcement contracts are notoriously difficult to enforce (Gilson, 1999).

2.2 Patent acquisition and enforcement as a non-contractual solution

In light of these contractual imperfections, recent studies by Kim and Marschke (2005) and Agarwal, Ganco, and Ziedonis (2009) investigate whether the federal protection afforded by US patents provides innovating firms an alternative means for safeguarding against technological expropriation by insiders. As Merges (1997) explains, legal rights to patents based on discoveries by employees during work are assigned, with rare exception, to employers (Merges, 1997). As a result, increased patenting by the focal firm may restrict the ability of employees exiting the firm (and their new employers) to make, use, or build upon the firm's patented technologies unless explicit permission to do so has been granted through a license agreement. Consistent with this view, Kim and Marschke (2005) document that firms in sectors experiencing higher turnover rates among skilled workers accumulated patents more aggressively in the wake of the 1980s "pro-patent" reforms.

More recently, Agarwal et al. (2009) argue that the strategic action of innovating firms to *enforce* patents—not just the accumulation of such rights—influences labor market activity through a reputation-building process. As a reputation-building mechanism, patent enforcement offers several advantages over the simple accumulation of such rights. First, a patent confers to owners the legal right—but not the obligation—to exclude others from making, using, or building on the claimed invention. Even in technology-intensive sectors, firms may file patents aggressively without choosing to enforce them (Ziedonis, 2003). Second, the costs of patent enforcement dwarf those associated with patent acquisition, thus providing a credible sorting mechanism for distinguishing between "passive" and "tough" employers (Spence, 1974). More specifically, Lemley (2004) estimates that roughly $20,000 is required to file and obtain a US patent of average complexity. In striking contrast, from $3 to $5 *million* is typically required to litigate a patent infringement case of average technological complexity (AIPLA, 2007).

Before turning to our model, several findings from the Agarwal et al. (2009) study warrant brief discussion. As noted earlier, the authors find (based on evidence from U.S. semiconductor firms and controlling for patent portfolio sizes) that as employers grow more litigious in enforcing patents, the spillovers to hiring organizations are reduced. While the authors instrument mobility with a gender-based variable (that affects mobility choice but not spillover levels directly), they do not investigate the broader implications of "IP toughness" on employee-level exit decisions. Consistent with the strategic deterrence literature (Scherer, 1980; Kreps and Wilson, 1982; Milgrom and Roberts, 1982), the authors further document that the "reduced spillover" finding holds irrespective of whether a firm actively litigates against all, or even many, of its ex-employees. These findings suggest that prior litigation against direct product-market rivals (e.g., Intel's longstanding dispute against rival chipmaker, Advanced Micro Devices) influences the perceptions of employee (and potential hirers) about their employers' likely stance against acts of expropriation. If reputations for "IP toughness" alter knowledge flows in labor markets, the effects should reside not only on hiring organizations (as shown in prior work) but also on the exit decisions of individual employees—a matter that we now turn to below.

3 REPUTATIONS FOR "IP TOUGHNESS" AND EMPLOYEE EXIT DECISIONS: A FORMAL MODEL

To analyze more formally how litigiousness affects employee exit decisions, we develop a model along the lines of Pakes and Nitzan (1983) and Kim and Marschke (2005). Instead of the patenting decision in Kim and Marschke (2005), we model reputational stock (based on the prior initiation of patent infringement lawsuits) conditional on patenting. Consistent with insights from the reputations literature discussed above, we assume that employer reputations for "IP toughness" are driven, at least in part, by factors unrelated to the expropriation hazards posed by employees. Assuming that employees are imperfectly informed about their employer's "true type" and that patent litigation is costly, employees use prior litigiousness to infer whether employers are likely to be "tough" or passive in the event that proprietary technologies are misappropriated.

3.1 Intuition

In the model that follows, litigiousness is assumed to influence the focal scientist through the expectation that she will be sued for patent infringement upon departure. We assume that prior aggressive behavior in enforcing patents by the focal firm increases the probability that it will litigate against the focal scientist post-exit. Predictions hinge on two opposing effects. On one hand, as the perceived likelihood of litigation increases, the expected value of implementing the scientist's idea outside of the parent firm decreases. On the other hand, the employer's ability to threaten the scientist with lawsuits if she exits lowers the incentives of the parent firm to offer higher wages. The net effect is non-obvious since litigation is costly.

As the expectation of litigation increases, the costs anticipated from litigious action rise accordingly. To avoid costly lawsuits post-exit, the employer has an incentive to offer higher wages. The increase in litigation likelihood thus results in higher rates of employee retention. Importantly, the increase in the likelihood of litigation (through higher expected costs and consequently a higher wage offer) is sufficient to induce those scientists to stay who have ideas with outside value closest to a certain threshold. While the value of this threshold increases with litigiousness, scientists above this threshold will always move. In other words, the deterrent effects of litigiousness are predicted to be stronger for employees with lower (versus higher) potential outside productivity.

3.2 Formal Model

The basic setup is as follows: an employer wants to develop and market a product but to do so she needs to hire a scientist. After the scientist is hired, development and production takes two periods. In the first period, an idea is developed into a product; in the second, it is sold. The employer does not need the scientist in the second period to sell the product. At the beginning of the second period, everyone learns the value of the developed idea for the firm, ρ_i ($\in R^+$), which is a random variable realized at the beginning of the second period. By the end of the first period, the scientist has the knowledge to market the idea independently outside of the firm, yielding a value to the scientist from competing with his former employer, ρ_e ($\in R^+$). ρ_i and ρ_e are distributed according to joint density f ex-ante known to everyone. If the scientist decides to exit and market the product independently, the competition from the scientist lowers the employer's payoff by $\lambda\rho_i$ with $\lambda\in[0,1]$.

Analogous to the patenting decision modeled in Kim and Marschke (2005), we model the effect of patent enforcement conditional on patenting, thus implicitly invoking the assumption that reputation stocks move slowly. With some probability γ the employer is expected to litigate against the scientist. The likelihood γ is known to both parties ex-ante and is a function of the employer's past litigiousness (i.e., its reputation for "IP toughness").[4] We assume that if the scientist exits, the employer does not know if the scientist will infringe the patent. In case of exit, however, the expected loss for the employer will be lowered due to the possibility of litigation to $(1-\gamma)\lambda\rho_i$. If the employer litigates against the scientist, she will have to pay attorney and court fees, L ($\in R^+$). We assume that in case of litigation the scientist loses his entire profit ρ_e, either due to fees or infringement settlement.

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[4] As noted earlier, "reputations for IP toughness" can be built from patent lawsuits initiated against product market rivals or imitators more generally. The decision to sue a particular scientist over a particular innovation is therefore not endogenous to the model.

Both parties are assumed to maximize expected income and be risk neutral. At the beginning of period one, the scientist decides whether to accept his employer's wage offer, w_0 , or work outside the R&D sector; the scientist is assumed to work for marginal product $\overline{w}$ in both periods if employed in the outside sector.

The timing of the model is as follows:

1) The employer offers w_0; the scientist accepts if $w_0 > \overline{w}$ (this will always hold)
2) The scientist works for the employer to develop the product
3) The scientist and employer learn ρ_i, ρ_e
4) The employer offers w_1
5) If w_1 exceeds the expected value of exiting, the scientist stays; otherwise, he leaves.

The expected payoffs in the second period are summarized as follows:

Scientist moves	Scientist's payoffs	Employer's payoffs
No	W_1	$\rho_i - w_1 + \overline{w}$
Yes	$\rho_e - \gamma\rho_e + \overline{w}$	$\rho_i - (1 - \gamma)\lambda\rho_i - \gamma L$

More formally, the employer maximizes the expected profit from hiring a scientist:

$$\mathrm{E}(\pi) = -\mathrm{w}_0 + \iint_S \left[\rho_i - \mathrm{w}_1 + \overline{w}\right] f(\rho_e, \rho_i) d\rho_e d\rho_i + \iint_M \left[\rho_i - (1-\gamma)\lambda\rho_i - \gamma L\right] f(\rho_e, \rho_i) d\rho_e d\rho_i \qquad (1)$$

where M is a set of ρ_i, ρ_e such that scientist moves and S is a set where she stays. The employer hires a scientist when the expected profit is positive. The scientist accepts the offer at the beginning of the first period if:

$$2\overline{w} \leq \mathrm{w}_0 + \iint_S \mathrm{w}_1 f(\rho_e, \rho_i) d\rho_e d\rho_i + \iint_M \left[\rho_e - \gamma\rho_e + \overline{w}\right] f(\rho_e, \rho_i) d\rho_e d\rho_i \qquad (2)$$

The employer's problem is to choose w_1, w_0 to maximize (1) subject to the participation constraint of the scientist (2). A time consistent equilibrium is assumed such that both the employer and the scientist take the other parties' decision in the second period as given. At the beginning of the second period, the employer offers a wage that maximizes her second period payoff and sets w_0 so that the participation constraint holds with equality. Substituting for w_0 in (1) and simplifying we obtain:

$$E(\pi) = -\overline{w} + \iint_S \rho_i f(\rho_e,\rho_i)d\rho_e d\rho_i + \iint_M \left[\rho_e - \gamma\rho_e + \rho_i - (1-\gamma)\lambda\rho_i - \gamma L\right] f(\rho_e,\rho_i)d\rho_e d\rho_i \qquad (3)$$

The term $\rho_e - \gamma\rho_e$ in the second integral represents wage savings due to the value of the mobility option for the scientist.

To obtain w_1, we only need to realize that to induce the scientist to stay, the employer has to offer at least $\rho_e - \gamma\rho_e + \overline{w}$.

$$w_1 = \rho_e - \gamma\rho_e + \overline{w} \quad \text{for } \rho_i, \rho_e \text{ such that the scientist stays} \qquad (4)$$

Note that the second period wage offer decreases with the anticipated likelihood of litigation γ. Higher γ decreases the value of mobility for the scientist; the wage offer required to induce the scientist to stay is therefore reduced.

The participation constraint can be used to solve for w_0:

$$w_0 = 2\overline{w} - \iint \left[\rho_e - \gamma\rho_e + \overline{w}\right] f(\rho_e,\rho_i)d\rho_e d\rho_i \qquad (5)$$

Following Kim and Marschke (2005), we assume that $\rho_e = \overline{\rho}_e + \varepsilon_e$ and $\rho_i = \overline{\rho}_i + \varepsilon_i$, where $(\varepsilon_e \in R, \varepsilon_i > -\rho_i)$. ε_e, ε_i are mean zero random variables with joint density q and $\overline{\rho}_e$, $\overline{\rho}_i$ are constant means of ρ_e and ρ_i.

For w_0, we get:

$$w_0 = \overline{w} - \overline{\rho}_e + \gamma\overline{\rho}_e \qquad (6)$$

$$
\begin{aligned}
w_0 &= \overline{w} - (1-\gamma)\int\int \rho_e f(\rho_e, \rho_i) d\rho_e d\rho_i \\
&= \overline{w} - (1-\gamma)\int \rho_e f(\rho_{ei}) d\rho_e \\
&= \overline{w} - (1-\gamma)\overline{\rho}_e
\end{aligned}
$$

Note that the w_0 is increasing with the likelihood of litigation γ. Put differently, an increase in γ lowers the value of the mobility option. Since the value of mobility is part of the wage offer, the employer has to offer a higher initial wage to entice the scientist to join.[5]

Finally, to solve for the mobility condition, we need to realize that the employer's wage offer w_1 (4) can be at most the costs associated with mobility. The scientist therefore moves only if the value of the mobility option exceeds his internal wage offer:

if $\rho_e - \gamma\rho_e > \lambda\rho_i - \gamma\lambda\rho_i + \gamma L$, the scientist moves. (7)

The left side represents the net gains from mobility to the scientist, $\lambda\rho_i - \gamma\lambda\rho_i$ on the right side is the litigation-adjusted loss due to competition, and γL are litigation costs. Rearranging terms, the mobility condition for the scientist is expressed as follows:

$$\rho_e > \lambda\rho_i + \frac{\gamma L}{1-\gamma} \tag{8}$$

Assuming that $\rho_e = \overline{\rho}_e + \varepsilon_e$ and $\rho_i = \overline{\rho}_i + \varepsilon_i$, equation (8) becomes:

$$\varepsilon_e > \lambda\varepsilon_i + \lambda\overline{\rho}_i - \overline{\rho}_e + \frac{\gamma L}{1-\gamma} \tag{9}$$

[5] Consistent with this intuition, Moen (2005) reports that individuals with entrepreneurial aspirations accept pay cuts to apprentice with firms that offer greater post-exit opportunities for advancement.

Equation (9) implies that the ex-ante likelihood of mobility falls as the right hand side of this inequality grows larger. That is, the range of values ε_e that satisfy the inequality will decrease with increases of $\lambda\varepsilon_i + \lambda\overline{\rho}_i - \overline{\rho}_e + \frac{\gamma L}{1-\gamma}$.

To further derive the unconditional probability of exit, we assume that ε_e and ε_i are independent.[6] Since the marginal densities of ε_e and ε_i are also normal, and the two random variables are independent, we have:

$$\varepsilon_i - \lambda\varepsilon_e \sim N\left(0, \sigma_i^2 + \lambda^2\sigma_e^2\right) \tag{10}$$

In the event that the inventor moves (D=1), Equation (10) leads to the following expression:

$$\begin{aligned} \Pr(\mathrm{D}=1) &= \Pr\left(\varepsilon_e - \lambda\varepsilon_i > \lambda\overline{\rho}_i - \overline{\rho}_e + \frac{\gamma L}{1-\gamma}\right) \\ &= \Pr\left(\frac{1}{\sqrt{\sigma_i^2 + \lambda^2\sigma_e^2}}(\varepsilon_e - \lambda\varepsilon_i) > \frac{1}{\sqrt{\sigma_i^2 + \lambda^2\sigma_e^2}}\left(\lambda\overline{\rho}_i - \overline{\rho}_e + \frac{\gamma L}{1-\gamma}\right)\right) \\ &= \Phi\left[-\frac{1}{\sqrt{\sigma_i^2 + \lambda^2\sigma_e^2}}\left(\lambda\overline{\rho}_i - \overline{\rho}_e + \frac{\gamma L}{1-\gamma}\right)\right] \end{aligned} \tag{11}$$

In combination, expressions (9) and (11) yield the following implications:

Implication 1: the likelihood of mobility decreases with the anticipated likelihood of litigation, γ, litigation costs, L, and the competitive impact on the employer, λ.

As the total negative impact on the employer $\lambda\rho_i$ increases, it is worth inducing the scientist to stay by increasing his wage offer w_1. The increase in the likelihood of litigation decreases the likelihood of mobility only because future litigation is costly. To

[6] This assumption is necessary to derive insights about the effects of ρ_e and ρ_i. Also note that we still relate ρ_e and ρ_i using $\overline{\rho}_e$ and $\overline{\rho}_i$.

avoid litigation costs, the employer is willing to propose a higher wage offer to induce the scientist to stay. If the future litigation costs are zero, the likelihood of litigation has no effect – in case of infringement, the employer could regain losses for free.[7]

Implication 2: the average value of ideas marketed by the scientist outside of the parent firm increases with γ, L, λ.

An increase in the right-hand side of the inequality (9) increases the threshold of ρ_e, above which the scientist moves. Increases in wage offers w_1 thus induce scientists to stay – but only those who have ideas closest to the threshold of ρ_e. The scientists with the best outside ideas (highest ρ_e) will always exit.

Finally, it is natural to question how the likelihood of scientist's mobility depends on the value of the project. Suppose that $\bar{\rho}_e$ and $\bar{\rho}_i$ are related by $\bar{\rho}_e = g(\bar{\rho}_i)$. Then,

$$\frac{\partial \Pr(\mathrm{D}=1)}{\partial \bar{\rho}_i} = -\frac{1}{\sqrt{\sigma_i^2+\lambda^2\sigma_e^2}}\left(\lambda - \frac{\partial g(\bar{\rho}_i)}{\partial \bar{\rho}_i}\right)\phi\left(-\frac{1}{\sqrt{\sigma_i^2+\lambda^2\sigma_e^2}}\left(\lambda\bar{\rho}_i - \bar{\rho}_e + \frac{\gamma L}{1-\gamma}\right)\right) \quad (12)$$

If the internal and external value of the project, $\bar{\rho}_e$ and $\bar{\rho}_i$ are independent or negatively related, or i.e. if $\frac{\partial g(\bar{\rho}_i)}{\partial \bar{\rho}_i} = 0$, or $\frac{\partial g(\bar{\rho}_i)}{\partial \bar{\rho}_i} < 0$, then the term $\left(\lambda - \frac{\partial g(\bar{\rho}_i)}{\partial \bar{\rho}_i}\right)$ is positive and the likelihood of mobility will decrease with $\bar{\rho}_i$ and increase with $\bar{\rho}_e$. However, if $\bar{\rho}_e$ and $\bar{\rho}_i$ are positively related, i.e. if $\frac{\partial g(\bar{\rho}_i)}{\partial \bar{\rho}_i} > 0$, then the probability of mobility can increase with $\bar{\rho}_i$ or decrease with $\bar{\rho}_e$. In practice, the positive relationship between $\bar{\rho}_e$ and $\bar{\rho}_i$ is very likely – projects that are valuable on the outside market will be also valuable for the parent firm. The model does not, however, make unambiguous predictions about the effects of project values on the likelihood of mobility. For projects

[7] As noted in Section 2, if litigation costs are zero, employees also would no longer be able to discern "tough" employers from their more passive counterparts given the lack of a credible mechanism for sorting between types.

that may lead to significant competition if the scientists exits (high λ), and the ones that have a higher relative value internally than on the outside market (positive but low $\frac{\partial g(\overline{\rho}_i)}{\partial \overline{\rho}_i}$) such that $\left(\lambda - \frac{\partial g(\overline{\rho}_i)}{\partial \overline{\rho}_i}\right)$ is positive, then mobility may decrease with both $\overline{\rho}_e$ and $\overline{\rho}_i$.

4 EMPIRICAL ANALYSIS

The objective of our analysis is to test two main empirical implications of the model. First, we investigate whether reputations for "IP toughness" reduce the departures otherwise expected for a firm's employee-inventors. Second, we test the extent to which, if at all, the deterrent effects of IP toughness are more pronounced for employees with relatively low opportunities for outside advancement.

To test the first implication of the model, we empirically investigate the relationship between the prior litigiousness of the employer (proxied by the number of patent infringement lawsuits initiated by the firm) and employee mobility decisions. We use a lagged explanatory variable to reflect the assumption of our model that the reputations are fixed at the time when the scientist makes the mobility decision. To test the second implication, we examine the relationship between the litigiousness and the post-exit innovative productivity of mobile inventors. We employ a set of controls at both the individual and the firm level in addition to firm and year fixed effects. To further rule out endogeneity and selection, we employ a subsample analysis and an instrumental variable approach discussed more fully below.

4.1 Industry Context and Data Sources

The context of our study is the U.S. semiconductor industry. The industry exhibits a high degree of employee mobility that facilitates inter-firm transfers of technological knowledge (Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003). Firms in this industry also have high propensities to file patents (Hall and Ziedonis, 2001) and appear to have grown more active in enforcing those exclusionary rights of protection (Ziedonis, 2003). Empirically, we trace the innovative activities of 447 U.S. semiconductor firms over a three-decade period. When we track mobility, we distinguish between firms that are *sources* of inventive talent and other firms in the industry that are *recipients*. The sample period starts in 1973 (the first year of available litigation data) and 2003 (the last year in which we observe patent activity).

The source firm sample is drawn from a comprehensive list of publicly-traded U.S. firms that a) compete primarily in semiconductor product markets and b) are founded prior to 1995.[8] Restricting attention to firms that are public by the mid-1990s (n=136) allows a sufficiently long window through which to view possible litigiousness and mobility events. In 2000, these firms collectively generated over $88 billion in annual revenues and spent $12 billion in R&D.

For each source firm, we observe initiations of patent infringement lawsuits filed in U.S. courts between 1973 through 2001 based on data compiled in Ziedonis (2003) that merge case filings reported in legal databases (Litalert by Derwent) with supplemental information reported in archival 10-K filings, news articles, and press releases. Importantly, these data enable us to determine when a firm files a patent infringement lawsuit against a third party, not just whether patents awarded to that firm are involved in litigation as is more common in the literature (e.g., Lanjouw and Schankerman, 2001; Somaya, 2003). We are therefore able to construct a firm-specific indicator of patent "toughness" that is allowed to vary over time.

We identify mobility events using evidence drawn from patent data using a methodology consistent with other citations-based studies (e.g. Almeida and Kogut, 1999; Marx et al., 2009; Rosenkopf and Almeida, 2003). The approach requires both source and recipient firms to receive at least one U.S. patent. For the combined set of 447

[8] However, our sample also includes the time-periods when these firms were private. We control for whether the firm is public or privately funded with a dummy.

firms, we integrate financial data from Compustat and VentureOne, patent data from Delphion and the National University of Singapore, and patent litigation histories (for source firms) from Ziedonis (2003).

4.2 Estimation Methodology

We estimate the regressions using Logit and OLS with the mobility event or the post-mobility patenting productivity as the respective dependent variables. To allow time-invariant sources of heterogeneity among firms (e.g., organizational culture or HR practices) to affect mobility decisions, we use a source firm fixed-effects specification. The estimates therefore test for "within-firm" changes. We control for both inventor- and firm-level variables related to the intensity and nature of inventive activity as well as for time trends. We also employ instrumental variable approach as described below. Our sample is an unbalanced panel with the unit of analysis of an individual inventor.

4.2.1 Dependent variables

Mobility: The dependent variable is a binary indicator set to 1 if our mobility matching algorithm identifies the focal inventor as appearing on a subsequent patent assigned to a recipient firm other than the focal employer. The variable is analogous to that one used by Marx et al. (2009) and captures the intra-industry movement of inventively productive employees. To determine instances in which inventors change firms, we implement the matching algorithm described in Agarwal et al. (2009) that allows us to recreate unique inventor patenting histories, as well as inventor moves within our sample. For 28,123 unique inventor names listed in patents awarded to firms in the sample, the algorithm yields 1,166 mobility events. An inventor is present in the data for 2.2 years on average, measured as the mean difference between the first and last patent application date.

Post-mobility patenting productivity: To proxy the quality of ideas implemented by the focal inventor outside of the parent firm context, we measure the patenting productivity of inventors post-mobility. This productivity is calculated as the number of patents the inventor generates at the recipient firm divided by the difference between the last year of patenting at the recipient minus the first year of patenting at the recipient plus one.[9]

4.2.2 Main explanatory variable

Litigiousness, our measure for IP toughness, is a time-varying measure based on the observed behavior of a focal source firm in enforcing its exclusionary rights to patent-protected technologies. We measure "litigiousness" using a three-year moving sum, lagged one year (sum over t-1 to t-3), of the number of unique patent infringement lawsuits launched by a focal source firm between 1973 and the focal year of observation.[10] We experimented with alternative measures such as lagged cumulative counts or moving sums using different time windows ranging from one year to all available years. The litigation counts are highly correlated over time and using the alternative measures has little qualitative effect on the estimated coefficients. We also examined the use of separate lags with identical results and consistent signs across lags.

4.2.3 Instruments

To address possible endogeneity of the litigiousness variable, we also implement an instrumental variable estimation. Our main endogeneity concern is that the litigiousness may proxy for unobserved quality of the underlying technology: firms with higher quality patents may be more litigiousness and simultaneously be more successful in retaining skilled workers. If true, litigiousness and employee retention may be correlated but not causally related. It is possible, of course, that the time-invariant firm fixed effects and the individual and firm-level controls we employ are insufficient to fully capture this unobserved "high quality technology" effect.

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[9] We obtained similar results using an alternative citation-based inventor productivity measure (based on the number of citations to an inventor's patents at the recipient firm divided by the number of years patenting at the company).

[10] In line with earlier discussion in the paper, to capture reputational effects, we measure the litigious activity of the source firm against all defendants rather than against a particular employee or recipient firm.

To address this issue, we draw insights from the legal literature (Kesan and Ball 2006, 2010), where court-level characteristics (of "effectiveness" and "experience") are shown to dramatically affect litigation outcomes and thereby affect the decisions of firms to file lawsuits. Using annual statistics reported in Kesan and Ball (2006, 2010), we measure the characteristics of the district courts in which the focal firms litigate their patents along several dimensions, including the number of civil and patent lawsuits and the number of judges in these courts. As summarized in Table 1, we then construct several variables to capture court effectiveness and experience - using not only the number of civil and patent lawsuits in total but also cases heard on a per-judge basis (Table 1). The key assumption behind this instrument is that these court-level characteristics impose an exogenous source of variation in the litigiousness decision. It is also unclear why these court characteristics would affect mobility directly (i.e. it is excludable from the second stage regression), which implies that it is also uncorrelated with the unobservable patent quality.[11]

4.2.4 Control Variables

In addition to source firm fixed effects and year dummies we included several inventor- and firm-level controls to capture individual heterogeneity and time-varying firm effects. Table 1 summarizes and defines these independent variables.

5 RESULTS

The results of our estimations are reported in Tables 4 and 5. To test the main prediction of our model that prior litigiousness will reduce employee mobility rates, we run both OLS and Logit models with inventor mobility as the dependent variable.

As predicted, we find results strongly consistent with litigiousness inhibiting intra-industry mobility. Table 4, Model 1 shows the main model. The additional filing of

[11] The legal literature (ADD CITE) suggests that the strategic selection of legal venues in patent cases (i.e., "forum-shopping") is mainly driven by how sympathetic courts are toward patent owners in general and is not necessarily correlated with patent value. If that is the case, then our instrument exogeneity assumption is still valid. We test the validity of our instrument below.

a patent lawsuit by an employer decreases the likelihood of employee-inventor exits by approximately 3 percent. At an average of five lawsuits in the last three years for the litigating firms, this translates into a 15% reduction in employee-inventor exits. Table 4, Model 2 shows the same model using a subsample of inventors who joined the firms that did not litigate in the past (between t to t-3). One could argue that selection might be driving the results – with litigious firms more likely attracting less mobile inventors. We address this issue by focusing only on inventors whose firms started litigating only once they were already there. In support of our argument, Table 4, Model 2 shows consistent results.

To address possible endogeneity, we employ an instrumental variable approach. As described above, we instrument litigiousness with court characteristics (number of patent and civil lawsuits – in total and on a per-judge basis). Table 4, Model 3 and 4 report results for the full sample and for the subsample of employees who joined non-litigating firms, respectively. The models show consistent and robust findings. In the first stage of the instrumental variable estimation, the instruments are significant at a 1% level. In the second stage (Models 3 and 4), the instruments pass the Sargan overidentification test with p-values of 0.13 and 0.23 (Model 3 and 4 respectively). Interestingly, the p-value for the Durbin-Wu-Hausman test is 0.12 suggesting that litigiousness is not necessarily endogenous in our estimation and even the use of the non-instrumented variable is justified.

To test the second main prediction of the model—that litigiousness should increase the average outside performance of mobile inventors by increasing the threshold at which they exit—Table 5 investigates the relationship between litigiousness and the post-mobility patent productivity of ex-employees. We replicate the analysis using the full sample and subsample and with instruments. The results in Models 1-3 of Table 5 are quite consistent. Each additional lawsuit initiated by the employer translates into about

2% increase in post-mobility patenting productivity. The instrumental variable estimation passes the Sargan test with a p-value of 0.31.

Finally, Models 4 and 5 in Table 5 split the sample into two sub-samples: inventors with above average and below average post-exit productivity. Based on our model's predictions, we should anticipate a stronger effect on the lower half of the distribution. That is, IP toughness should have a more pronounced effect in the retention of less productive inventors. The results in Models 4 and 5 are in line with this prediction. "IP toughness" has a significant effect on the retention of inventors at the lower half of the productivity distribution but is insignificant in the upper half of the distribution. This supplemental analysis alleviates concerns that litigiousness simply proxies for the general value of an employer's ideas on the outside market. If true, the relationship between litigiousness and post-mobility performance should be positive and significant across the productivity distribution, which is not the case.

6 CONCLUSION

While prior studies suggest that stronger non-compete agreements reduce fluidity in markets for skilled labor (e.g., Gilson, 1999; Marx et al., 2009), far less is known about the added shadows cast by patent enforcement. This study develops and tests a model on how an employer's reputation for "IP toughness" alters employee-inventor mobility decisions. Using within-firm estimates from the US semiconductor industry over a three-decade period, we find that as employers grow more litigiousness over patent-protected technologies, the likelihood that employee-inventors leave to join or form rival firms is reduced. Consistent with the model, we also find that as employers grow more litigious, the average productivity of employee-inventors that choose to leave nonetheless *increases*. Paradoxically, this latter finding suggests that tough reputations may ignite an adverse sorting process, more powerfully deterring departures by workers with fewer opportunities for outside advancement.

This study contributes to several strands of literature. A growing literature on "learning-by-hiring" (e.g., Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003) implicitly assumes that employers of mobile talent play a passive role in shaping turnover among knowledge workers. We provide new evidence that corporate "reputations for IP toughness" not only reduce the inter-firm knowledge transfer anticipated from mobility events (as shown in Agarwal et al., 2009), but also may deter employees from leaving. For the literature on patent litigation (Somaya, 2003; Lanjouw and Schankerman, 2001), our study raises the possibility that litigious action confers reputation effects in labor markets, thus revealing a source of asymmetry between litigating parties that has received little prior attention. Finally, our empirics resonate with recent evidence by Marx et al. (2009) that documents higher retention rates of employee-inventors following a state-level shift toward stronger non-compete enforcement. Importantly, our results suggest that the federal protection afforded by patents—and the strategic actions employers take to enforce them—also influence "job hopping" among skilled workers, a finding of practical salience since many US technology companies reside in California, where non-competes are unenforceable (Gilson, 1999).

The study raises a number of questions worthy of more careful study. First, while the model links litigiousness to employee exits through compensation, we do not directly observe employee wages and stock options. Future work could investigate these linkages more directly with access to employee-level compensation data. As per Kim and Marschke (2005), the resulting implications of litigiousness on R&D spending could also be flushed out more fully, both in the model and the empirics. Due primarily to data limitations, our analysis is restricted in other ways that could be improved upon in future work. Most notably, employees with the most promising ideas may disproportionately fail to disclose their discoveries to litigious employers, as Anton and Yao (1995) suggest.

In this event, the differential effects of litigiousness on departures by low versus high-quality employees may be understated based on data compiled from employee-inventors. Finally, in recent work on employee responses to non-compete restrictions in employment contracts, Marx (2010) documents that many skilled workers take "career detours," effectively withdrawing from activities in their main profession, until restrictions in the contract are lifted. In this study, we intentionally restricted attention to movement by employee-inventors to other firms within the industry to capture employment changes in which expropriation hazards are more salient. In the spirit of Marx (2010), it would be interesting to investigate whether litigiousness affects the "distance" mobile workers keep from former employers in the event of departure.

[To be continued…. Obvious questions here regarding policy implications.]

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Table 1: Variable Definitions

Dependent Variables	
Intra-industry Mobility Event	A binary indicator set to 1 if the focal inventor appears on a subsequent patent assigned to a firm from the recipient sample
Post-mobility Patenting Productivity	Number of patents applied for by the mobile inventor at the recipient firm divided by the number of years at the recipient firm.
Explanatory Variables	
Number of Lawsuits Initiated (3-year moving sum)	Moving sum of the patent litigation lawsuits initiated by the source firm over the years *t*-1 to *t*-3.
Controls	
Inventor's Number of Patents	Number of patents the inventor received in a focal year at the source firm.
Inventor's Number of Co-inventors	Average number of patent co-inventors in a given year at the source-firm.
Gender (1=female)	1 if female, 0 otherwise - determined by the first name on the patent document.
Ethnicity (1=Non-white)	1 if Asian, Middle-Eastern or Indian sounding name listed on the patent document, 0 otherwise.
Number of Years Patenting Within Parent	Calculated as the difference between the focal year minus the application year of the first patent at the parent plus one.
Firm Age	Calculated as the current year minus the founding year
Log Number of Employees	Log Number of employees. Missing values and gaps imputed as described in the text.
R&D Intensity	R&D expenditures divided by sales in a focal year. Missing values and gaps imputed as described in the text.
Public Firm	1 if the firm is public, 0 if private.
Instruments	
Number of civil lawsuits	Average number of civil lawsuits litigated in courts used by the focal firm between the years *t*-1 to *t*-3. The instrument is imputed with 0 if the focal firm does not litigate in a given year.
Number of patent lawsuits	Average number of patent lawsuits litigated in courts used by the focal firm between the years *t*-1 to *t*-3. The instrument is imputed with 0 if the focal firm does not litigate in a given year.
Number of patent lawsuits per judge	Average number of civil lawsuits per judge litigated in courts used by the focal firm between the years *t*-1 to *t*-3. The instrument is imputed with 0 if the focal firm does not litigate in a given year.
Number of civil lawsuits per judge	Average number of patent lawsuits per judge litigated in courts used by the focal firm between the years *t*-1 to *t*-3. The instrument is imputed with 0 if the focal firm does not litigate in a given year.

Table 2 Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Intra-industry Mobility	54804	0.016	0.127	0	1
Post-mobility Patenting Productivity	902	1.402	1.044	0	14
Number of Lawsuits Initiated (3-year moving sum)	54804	2.888	4.286	0	17
Inventor's Number of Patents in a Focal Year	54804	1.173	2.078	0	163
Inventor's Average Number of Co-inventors	54804	1.422	1.779	0	20
Gender (1=female)	54804	0.023	0.150	0	1
Ethnicity (1=Non-white)	54804	0.234	0.423	0	1
Number of Years Patenting Within Parent	54804	3.680	3.635	1	27
Firm Age	54804	26.03	12.007	0	52
Log Number of Employees	54804	9.572	1.608	2.833	11.406
R&D Intensity	54804	0.028	0.025	0	0.298
Public Firm	54804	0.992	0.086	0	1

Table 3 Correlations

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Intra-industry Mobility	1										
2. Post-mobility Patenting Productivity (Cond. on mobility)	.	1									
3. Number of Lawsuits Initiated (3-year moving sum)	-0.0479	0.0793	1								
4. Inventor's Number of Patents in a Focal Year	0.0068	0.1173	-0.0531	1							
5. Inventor's Average Number of Co-inventors	0.0076	-0.0211	-0.0199	0.2236	1						
6. Gender (1=female)	-0.0103	-0.0057	0.0073	-0.0108	0.0419	1					
7. Ethnicity (1=Non-white)	0.0288	0.0406	-0.025	0.0234	0.0585	-0.0499	1				
8. Number of Years Patenting Within Parent	-0.0268	-0.0004	0.1799	-0.0078	-0.1316	-0.0534	-0.0824	1			
9. Firm Age	-0.0526	0.0504	0.4753	-0.042	-0.007	0.0129	-0.0091	0.2588	1		
10. Log Number of Employees	-0.0686	0.0129	0.4559	-0.051	-0.0354	0.0017	-0.044	0.1624	0.7376	1	
11. R&D Intensity	0.0234	0.0112	-0.2672	0.0727	0.1405	0.0152	0.1124	-0.1236	-0.3746	-0.5314	1
12. Public Firm	-0.0236	0.0498	0.0572	0.011	0.0003	-0.0006	0.0128	0.0231	0.1157	0.0309	0.0472

Table 4 Litigiousness and inventor mobility

Model	Model 1 Logit Main Model	Model 2 Logit Employees joining non-litigious firms only	Model 3 OLS Instrumental variable estimation	Model 4 OLS Instrumental variable estimation with sample as in Model 2
Dependent Variable	Mobility			
Number of Lawsuits Initiated (3-year moving sum)	**-0.050*** **	**-0.085** **	**-0.002** **	**-0.001***
Control Variables				
Inventor's Number of Patents in a Focal Year	0.020*	0.058**	0.001**	0.001**
Inventor's Average Number of Co-inventors	0.043*	0.063**	0.001***	0.001***
Gender (1=female)	-0.643**	-1.212**	-0.006***	-0.014***
Ethnicity (1=Non-white)	0.351***	0.243	0.006***	0.005*
Number of Years Patenting Within Parent	-0.028*	-0.038*	-0.0002*	-0.0006**
Firm Age	-0.049	-0.05	-0.0005*	-0.0005
Log Number of Employees	-0.313	-0.117	-0.005**	-0.003
R&D Intensity	-8.482	-7.361*	-0.17***	-0.141*
Public Firm	-0.82	-0.208	-0.017**	-0.01
Firm Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Constant	-15.622	-16.576	0.047**	0.034
Pseudo R2/R2	0.104	0.113	0.05	0.06
Log Likelihood	-4113	-2514		
Sargan overidentification test (p-value)			0.13	0.23
N	54,804	25,942	57,512	28,367

* p<.1, ** p<.05, *** p<.01, single-sided test

Instruments used: Number of civil lawsuits per judge, Number of patent lawsuits per judge, Total civil lawsuits, Total patent lawsuits (all averages in courts used by the focal firm).

Table 5: Litigiousness and the patent productivity of departing employee-inventors (OLS)

Model	Model 1 Main model	Model 2 Employees joining non-litigious firms only	Model 3 Instrumental variable estimation	Model 4 Split sample (lower 50% of DV)	Model 5 Split sample (upper 50% of DV)
Dependent Variable		Post-mobility Patenting Productivity			
Number of Lawsuits Initiated (3-year moving sum)	**0.025***	**0.038***	**0.147****	**0.008****	**0.016**
Control Variables					
Inventor's Number of Patents in a Focal Year	0.127**	0.157*	0.131***	0.012	0.17*
Inventor's Average Number of Co-inventors	-0.022	-0.005	-0.024	-0.0001	-0.059*
Gender (1=female)	0.021	-0.17	-0.077	-0.018	0.128
Ethnicity (1=Non-white)	0.022	-0.013	-0.003	0.028	0.054
Number of Years Patenting Within Parent	-0.005	-0.007	0.035	0.003*	0.011
Firm Age	0.042**	0.008	0.004*	-0.012	0.009
Log Number of Employees	0.142**	0.009	0.066	-0.036	0.26
R&D Intensity	-5.605	-8.826**	-4.79	0.747	-9.19
Public Firm	0.706**	0.389	0.455	0.12	0.537
Firm Effects	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes
Constant	-0.132	1.059	0.747	1.042***	-0.574
R2	0.07	0.08	0.09	0.29	0.18
Sargan overidentification test (p-value)			0.31		
N	902	597	902	454	454

* p<.1, ** p<.05, *** p<.01, single-sided test

Instruments used: Number of civil lawsuits per judge, Number of patent lawsuits per judge, Total civil lawsuits, Total patent lawsuits (all averages in courts used by the focal firm).