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MORE STARS STAY, BUT THE BRIGHTEST ONES STILL LEAVE: JOB HOPPING IN THE SHADOW OF PATENT ENFORCEMENT

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Competitive advantage often rests on the skills and expertise of individuals who may leave for rival organizations. Although institutional factors like non-compete regimes shape intra-industry mobility patterns, far less is known about firm-specific reputations built through patent enforcement. This study formally models and empirically tests how a firm's prior litigiousness over patents (i.e., its reputation for IP toughness) influences employee mobility. Based on inventor data from the U.S. semiconductor industry, we find that litigiousness not only diminishes the proclivity of inventive workers to "job hop" to others in the industry, it also shifts the distribution of talent released to the market. The study contributes new insights linking firm-level reputations as tough legal enforcers to the "stay versus exit" calculus of knowledge workers.

INTRODUCTION

Competitive advantage often rests on the skills and expertise of individuals (Barney, 1991). But the advantages firms derive from human capital can be fleeting: unlike tangible resources such as plants and equipment, employees may walk out the door to join rival organizations (Castanias and Helfat, 2001; Coff, 1997). Among the institutional forces shaping the bargaining power between firms and mobile talent, state laws governing non-compete agreements have received the lion's share of scholarly attention (Fallick *et al.*, 2006; Garmaise, 2009; Marx *et al.*, 2009; Stuart and Sorenson, 2003). Far less is known about the reputations firms build through patent enforcement and their potential influence on employee mobility, despite anecdotal evidence suggesting linkages between this firm-level lever and turnover in the market for skilled labor.[1]

This study investigates how a firm's aggressiveness in patent enforcement casts a shadow over "job hopping" by knowledge workers. Does

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[1] For example, in response to a "siphoning of engineering talent," Intel sued Broadcom for patent infringement (Murphy, 2000). Similarly, Pixar Animation sued former employees Larry Gritz, Matt Pharr, and Craig Kolb over patent violations when they co-founded Exluna (*Business Wire*, 2002), and iRobot litigated against ex-employee Jameel Ahed for patent infringement in the manufacture of defense robots (Shachtman, 2008).

increased litigiousness alter the employee exit calculus? If so, are some employee types more likely to be affected? Many U.S. technology companies are headquartered in California, where the vibrancy of the Silicon Valley region is attributed to weak state-level support for non-competes and trade secrets (Gilson, 1999; Hyde, 2003; Png, 2012). Whether the federal protection provided by patents enables firms in "employee-friendly" states to deter mobility remains unclear. Patent lawsuits also have grown more common in the United States, while their costs have continued to climb (Landes and Posner, 2003). The implications of these twin developments on employer-employee dynamics are underexplored in the literature. Kim and Marschke (2005) report that firms in sectors with higher turnover rates seek patent protection more aggressively, highlighting a patent's role in protecting innovating companies from "insiders." Emphasizing the added reputational gains from costly enforcement, Agarwal *et al.* (2009) find that a firm's prior enforcement of patents reduces the level of knowledge spillovers from employee departures to join or form competing companies. Left unanswered is how a reputation for "IP toughness" alters the antecedent decisions of employees to move and in turn shapes the distribution of talent released to rivals.

We formally model and empirically test the effects of an employer's litigiousness on employee mobility decisions. Consistent with Agarwal *et al.* (2009) and Toh and Kim (2013), we view patent enforcement as a reputation-building strategy rather than a particular tactic launched against a particular target: by engaging in costly and observable litigious action, firms build reputations for being tough in safeguarding their intellectual property (IP). The costliness of litigation plays a two-sided role on value appropriation by the firm and scientist: it reduces the value employees expect from pursuing external commercialization options, but entices firms to offer higher wages to avoid mobility-related disputes. Employing a formal model, we derive explicitly how the mobility threshold is related to the threat of litigation, the competitive loss to the firm due to mobility-related expropriation, and the internal and external value of the ideas. Thus, the model shows how, given frictions in the market for ideas, an increased threat of litigation affects wage bargaining, mobility, and sorting in labor markets in ways difficult to glean through verbal reasoning alone. For instance, without the model, it is unclear whether litigiousness would increase or decrease the appropriation by the inventor (i.e., the retention wages offered by the firm) because logical arguments could be made either way. Further, the model explicates how litigiousness affects the mobility calculus of some employee types more than others, thus affecting not only the retention rate but also the distribution of exits. Finally, the use of the model permits specifications of the boundary conditions for its implications, and the sensitivity of its predictions to simplifying assumptions.

To test our model's predictions regarding effects of threat of litigation on employee mobility, we use a database of patent lawsuits and employee-inventors from the U.S. semiconductor industry, a setting characterized by active job hopping (Fallick *et al.*, 2006) and prolific patenting (Hall and Ziedonis, 2001). To summarize, we predict and find that as firms develop stronger reputations for litigiousness, employee-inventors become less likely to join or form rival companies. Our empirical support for this prediction reflects stringent "within-firm" estimates and controls for the time-varying size, R&D intensity, and patenting activities of the employer. In supplemental analyses, we find no evidence that this finding is spuriously explained by unobserved recruitment effects, where firms attract less mobile workers as they grow more litigious, or omitted factors that yield a simultaneous rise in litigation and retention. Consistent with the model, we further investigate whether litigiousness affects the sorting process by which employees—and the quality of the ideas they carry—are released to labor markets. More specifically, we predict and find that tough reputations are particularly influential in retaining employees whose ideas are valuable internally to the firm although those with the most lucrative prospects for outside advancement are relatively unaffected. Put simply, more stars stay but the brightest ones still leave.

The study contributes to the literature on micro-level dynamics in strategic factor markets (Barney, 1991; Castanias and Helfat, 2001; Coff, 1997; Coff and Kryscynski, 2011). Complementing an extensive literature on incentives-based human resource practices for employee retention (e.g., Horn *et al.*, 2012), we show how tough reputations for patent enforcement can influence the retention of knowledge workers. The study also contributes new insights to the literature on knowledge transfer through mobility (e.g., Anton and Yao, 1995;

Franco and Filson, 2006; Rosenkopf and Almeida, 2003). Much of this work assumes that patents—as legal property rights to exclude others from making, using, or selling protected inventions—fail to shape the underlying mobility process. This study contributes to a nascent stream of research that relaxes this assumption (Agarwal *et al.*, 2009; Hellmann, 2007; Kim and Marschke, 2005), advancing prior work by allowing patent enforcement to endogenously affect employee exit decisions.

BACKGROUND

Employment turnover among engineers and scientists is a key channel through which technological knowledge diffuses among firms (Almeida and Kogut, 1999; Palomeras and Melero, 2010) and regions (Fallick *et al.*, 2006; Saxenian, 1994, 1994).[2] That firms learn by hiring skilled workers from competitors is well documented (e.g., Rosenkopf and Almeida, 2003; Singh and Agrawal, 2011). Parrotta and Pozzoli (2012), for example, report that the recruitment of skilled workers within an industry enhances the productivity of recipient firms.

Job hopping as an expropriation problem

Scholarly work that adopts the "source" firm's perspective, however, highlights the potential harm to innovating firms whose employees leave to join or form rival companies (Campbell *et al.*, 2012; Phillips, 2002; Wezel, Cattani, and Pennings, 2006). Such firms stand to lose human capital while rivals gain technological know-how at their expense. In light of this dilemma, job hopping is cast as an expropriation problem: after hiring and training employees and investing in R&D programs, engineers and scientists may leave to exploit discoveries at rival firms.[3] Attention therefore shifts to the actions firms take to *retain* skilled workers and/or *deter* expropriation.

From a rent appropriation perspective, firms face dual challenges when managing the potential loss of human capital (Coff, 1997). In addition to eroding competitive advantage through inter-firm knowledge transfers (Almeida and Kogut, 1999), mobility threat can alter intra-firm (employer-employee) dynamics and input pricing (Campbell *et al.*, 2012; Castanias and Helfat, 2001). In seminal work, Pakes and Nitzan (1983) model the wage system required to induce optimal levels of innovative effort among employees when firms lack formal property rights to the resulting output. Others emphasize that wage contracts are imperfect solutions to the employer-employee expropriation problem due to private information (Anton and Yao, 1995; Hellmann, 2007; Klepper and Sleeper, 2005), task uncertainties (Cassiman and Ueda, 2006; Franco and Filson, 2006; Hvide and Kristiansen, 2011), and related costs of transacting (Acemoglu and Pischke, 1998).

Among the institutional levers for property rights enforcement, state-level differences in non-compete regimes have received the most systematic study. Gilson (1999) attributed job hopping by engineers in California to the ineffectual enforcement of non-compete contracts, challenging Saxenian's (1994) alternative explanations of cultural and industry-specific factors. Empirical evidence largely supports the thesis that non-compete regimes "matter" as mobility determinants, particularly in technology-intensive settings.[4] Fallick *et al.* (2006) report higher turnover rates in California relative to U.S. states with stronger non-compete regimes, but only in computer-related industries. Exploiting legal shifts within states, others show that stricter non-compete regimes reduce mobility among executives (Garmaise, 2009), employee-inventors (Marx, 2011; Marx *et al.*, 2009), and entrepreneurs (Samila and Sorenson, 2011; Stuart and Sorenson, 2003). Most agree that California's non-compete regime is far more "employee-friendly" than the regimes of other states, with the possible exception of North Dakota (Bishara, 2011).

[2] A related literature on *employee entrepreneurship*—intra-industry mobility events resulting in new firm founding—extols the benefits of individuals moving across firm boundaries for both regional and recipient firm advantage (Agarwal *et al.*, 2004; Bhide, 1994; Klepper and Sleeper, 2005). Such recruitment is also credited with diffusing discoveries across countries and technological domains (Filatotchev *et al.*, 2011; Oettl and Agrawal, 2008; Rosenkopf and Almeida, 2003).

[3] For expropriation to occur, employers must be unable to capture the total value of information leaked through labor markets. This assumption does not imply that all turnover poses expropriation hazards to innovating firms. Rather, it only requires a positive probability that, upon employee exit, employers are not fully compensated for their prior investments in human capital and R&D. See Acemoglu and Pischke (1998) and Moen (2005) for added discussion.

[4] Similar findings are revealed in recent studies on the state penalties for trade secret theft (Png, 2012).

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Patent acquisition and enforcement as a noncontractual solution

A smaller literature investigates whether the federal protection afforded by patents offers firms an alternative safeguard against mobility-driven expropriation (Agarwal *et al.*, 2009; Kim and Marschke, 2005). Patents based on discoveries by employees during work are assigned, with rare exception, to employers (Merges, 1999). Thus, increased patenting can restrict the rights of exiting employees (and their new employers) to use technologies unless permission to do so is provided.

As a deterrent mechanism, patent enforcement offers several advantages beyond mere accumulation of such rights. In essence, a patent is an option to sue (Merges, 1999). The costs to enforce a patent are, however, an order of magnitude larger than those to obtain the right, and hover between \$3 and \$5 million for an average case (Graham *et al.*, 2010). Absent incurring the costs of litigation, it is difficult to establish whether infringement has taken place due to the inherent uncertainty (Moore *et al.*, 1999).[5] Patent lawsuits also tend to attract media attention, thus increasing visibility to third parties. As a costly and observable action, patent enforcement therefore serves a useful sorting function (Spence, 1974). Since passive employers find it costly to imitate tough rivals (Toh and Kim, 2013), prior litigiousness should credibly inform expectations of future action.

Agarwal *et al.* (2009) provide evidence of heterogeneity among firms in the reputations built through patent enforcement, and that firms with strong reputations for IP toughness reduce spillovers to organizations that hire mobile workers. Consistent with the strategic deterrence literature (e.g., Kreps and Wilson, 1982), they find the "reduced spillover effect" holds regardless of whether a firm actively litigates against its ex-employees. As in the learning-by-hiring literature (Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003), however, Agarwal *et al.* (2009) focus on inter-firm knowledge flows, conditional on employees leaving one firm to join another within an industry. Left unanswered is whether and how a firm's litigiousness shapes the antecedent decisions of employees to exit, a matter that we address below.

[5] To illustrate, in a recent *Wall Street Journal* article on IP litigation in the smartphones industry, Jones (2013) remarks that "the courts have proven as likely to deliver plaintiffs a rebuke as a win" (p. 1).

IP TOUGHNESS AND EMPLOYEE EXIT: A FORMAL MODEL

The model setup

To investigate how reputations for IP toughness affect employee exit decisions, we draw insights from a formal model. As Adner *et al.* (2009) discuss, formal modeling can make the underlying logic more precise and transparent, while revealing linkages that are more difficult to discern through verbal reasoning alone. At the same time, as noted by Solow (1957), the art of successful theorizing requires assumptions that are simple while realistic. Accordingly, we employ a formal model, discussing key assumptions and features of the model below, and reporting proofs in the APPENDIX. Later, and also as elaborated in the online supporting information S1, we discuss how the predictions are affected when we relax key simplifying assumptions.

Since Kim and Marschke (2005) and Agarwal *et al.* (2009), respectively, evaluate patent acquisition and enforcement as safeguards against mobility-driven expropriation, their work is a useful starting point for our model. We assume that turnover poses expropriation hazards to firms and that contracting frictions prevent firms from perfectly solving the problem through wages or trade in the market for ideas. Kim and Marschke (2005) model the effects of turnover on an employer's decision to patent. We extend the work by investigating how a firm's prior litigiousness over patents affects optimal wage offerings and, in turn, employee incentives to exit. In the model, an employer's prior litigiousness, or reputation for IP toughness, influences the scientist through the expectation of legal conflict, whether against the individual (in event of a spin-out) or the new employer. Consistent with Agarwal *et al.* (2009), we assume that prior patent enforcement credibly shapes expectations of future action and is predetermined at an individual's exit decision.

The model has a two-period setup. In each period, the scientist's opportunity costs of time are $\overline{w}$. The scientist must be paid $\overline{w}$ to invest the time and effort in the creation of innovative ideas even if the project fails. We assume that $\overline{w}$ is set absent market frictions in the valuation of the scientist's input of time, and is the same across all firms.[6] In period 1, the scientist

[6] This assumption allows us to isolate differences in compensation that stem from the differences in the valuation of the ideas—the

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works for wages w_1, which is greater than or equal to $\overline{w}$, to work on one idea, resulting in a one-to-one correspondence between the value of the idea and the scientist.[7]

At the end of period 1, the scientist's effort yields an idea that the firm owns (via patents) and can profit from in period 2 without further effort from the scientist. As in Kim and Marschke (2005), payoffs and probabilities are common knowledge, and the value of the idea is revealed in the form of two random variables: the internal value to the firm ρ_i ($\in R^+$), and external value to the scientist if the idea is capitalized by other firms ρ_e ($\in R^+$). Specifically, ρ_i is the firm's profit if it has a monopoly on the patented idea in period 2, and ρ_e is the scientist's payoff if the idea is capitalized at a competing firm or startup. We assume that ρ_i and ρ_e are defined by $(\overline{\rho}_i, \sigma_i)$ and $(\overline{\rho}_e, \sigma_e)$, respectively, and are distributed according to joint density f.

In period 2, the employer offers wages, w_2, to the scientist who then chooses whether to accept and stay, or leave to potentially profit from the idea elsewhere. If the scientist opts to exit and use the idea elsewhere, competition from the scientist lowers the firm's payoff by $\lambda\rho_i$ with $\lambda \in [0, 1]$. Should the scientist exit and infringe, the employer then has the choice to enforce the patent against the scientist and/or the hiring firm by engaging in costly litigation. With some probability, γ, the employer is expected to litigate. The likelihood γ is known to both parties *ex ante* and is a function of the employer's reputation stock for IP toughness.[8] If the firm sues, it pays attorney and court fees, L ($\in R^+$), and the scientist loses the ability to appropriate knowledge at another firm up to the internal value to the focal firm ρ_i. In other words, the firm can sue for damages associated with the loss of its profits. As suggested above, scientists can face IP litigation risks individually even if employed at another firm. When the target of litigation is a recipient firm, the scientist also may be deleteriously affected. The model does not require, however, that all ideas are infringing or that turnover leads to legal conflict (i.e., it allows for $\rho_e > \rho_i$).

To summarize the model setup, we assume that there is a competitive market for the scientist's time and effort (the input in the labor market). The ensuing market for ideas (the outcome), however, is subject to frictions because the idea is "owned by the firm," and (1) there can be differences in the internal and external valuation of the idea (ρ_i and ρ_e), (2) leakage of the idea outside the firm through employee mobility erodes internal value (λ), and (3) firms can reduce the potential for mobility-related expropriation with the threat of litigation (γ).

Panel A of Table 1 summarizes the model timing above. Panel B reports period 2's payoff matrix for the twin decisions of the scientist (stay or move) and the employer (forgo or choose to litigate). Conditioned on the scientist moving, Panel C reports their probability-weighted average payoffs that take into account the likelihood of litigation:

$$\begin{aligned} &\mathrm{E}\,(\text{Scientist Payoff}\,|\,\text{Move}) \\ &\quad = (1-\gamma)\left(\overline{w}+\rho_e\right)+\gamma\left(\overline{w}+\rho_e-\gamma\rho_i\right) \\ &\quad = \overline{w}+\rho_e-\gamma\rho_i \end{aligned} \tag{1}$$

$$\begin{aligned} &\mathrm{E}\,(\text{Employer Payoff}\,|\,\text{Move}) \\ &\quad = (1-\gamma)(1-\lambda)\;\rho_i+\gamma\left(\rho_i-L\right) \\ &\quad = \rho_i-(1-\gamma)\gamma\rho_i-\gamma L \end{aligned} \tag{2}$$

Impact of litigation: reduction in mobility

In the APPENDIX (Equations A.1–A.6), we formally derive the maximization problem, where the employer sets wages w_1, w_2 to maximize expected profits, subject to the participation constraint of the scientist. In period 2 and from Equation 1, the minimum wage required for the scientist to stay is:

$$w_{2,\text{stay}} = \overline{w}+\rho_e-\gamma\rho_i \tag{3}$$

The first term in Equation 3 is the opportunity cost of the scientist's time. The second term reflects the compensation the scientist will require to forego the realized outside value of the idea ρ_e. However, given the expected loss of outside earning potential due to litigation, $\gamma\rho_i$, the third term captures the

outcome of the effort, rather than differences in valuation of the *input* of effort across firms. Equivalently, we could normalize $\overline{w}$ to 0, thus implying that the scientist is paid only for the knowledge that she created and that can be potentially appropriated outside her focal employer.

[7] Consistent with this one-to-one mapping between the idea and the inventor, we use productivity and quality measures at the inventor level to proxy for (unobserved) idea value in the empirical implementation of the model.

[8] While we assume that γ is a parameter for simplicity, allowing γ to be positively related to the internal value, ρ_i, strengthens the model's predictions. The mobility threshold in Figure 1 becomes steeper and potentially convex.

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Table 1. Model timing and payoffs to employer and scientist

Panel A: Model timing

In period 1	The scientist works for the employer to develop a patentable idea, and is paid $\boldsymbol{w}_1$.
End of period 1	i. The firm patents the idea. ii. The scientist and employer learn the values $\boldsymbol{\rho_i}$, $\boldsymbol{\rho_e}$ of the idea. iii. The employer offers $\boldsymbol{w}_2$ for the scientist to stay in period 2. iv. If $\boldsymbol{w}_2$ exceeds the expected value of exiting, the scientist stays; otherwise, he leaves.
Period 2	Employer produces and sells based on the patented idea. If scientist leaves to capitalize on the same idea elsewhere, employer decides whether to sue.

Panel B: Period 2 payoff matrix (scientist, employer)

		Scientist moves	
		No	Yes
Employer litigates	No	$\boldsymbol{w}_2, \overline{w} + \boldsymbol{\rho_i} - \boldsymbol{w}_2$	$\overline{w} + \boldsymbol{\rho_e}, (1-\lambda)\,\boldsymbol{\rho_i}$
	Yes		$\overline{w} + \boldsymbol{\rho_e} - \boldsymbol{\rho_i}, \boldsymbol{\rho_i} - \boldsymbol{L}$

Panel C: Expected payoffs incorporating likelihood of litigation (γ)

	Scientist moves	
	No	Yes
Scientist expected payoff	$\boldsymbol{w}_2$	$\overline{w} + \boldsymbol{\rho_e} - \gamma\boldsymbol{\rho_i}$
Employer expected payoff	$\overline{w} + \boldsymbol{\rho_i} - \boldsymbol{w}_2$	$\boldsymbol{\rho_i} - (1-\gamma)\lambda\boldsymbol{\rho_i} - \gamma\boldsymbol{L}$

willingness of the scientist to accept a wage that is lower than otherwise.[9]

For the employer, the maximum period 2 wage offer is dictated by the costs associated with mobility, or the amount lost if the scientist moves. Based on Equation 2 above:

$$w_{2,\text{offer}} = \overline{w} + (1-\gamma)\,\lambda\rho_i + \gamma L \tag{4}$$

The first term in Equation 4 again captures the opportunity cost of the scientist's time. Note that $\overline{w}$ from Equation 3 and from Equation 4 are identical, as it is the firm's payment for the scientist's time for the creation of another idea in period 2 (as in period 1). As in Equation 3, the second and third terms are firm-specific components of the wage that the firm is willing to offer. If the firm chooses not to litigate, with the associated probability of $(1-\gamma)$, it incurs a loss in the internal value of the idea due to increased competition $(\lambda\rho_i)$; thus, the second term reflects its willingness to offer the scientist up to that amount to stay. Further, given that the firm is likely to litigate with the probability γ, and incur litigation costs L, the third term captures the increase in wage offer to offset the expected litigation-related costs. Thus, the second and third terms reflect that it is optimal for the firm to offer higher compensation up to the loss associated with mobility. To clarify, consider extreme cases. If litigation risk is zero ($\gamma = 0$), the firm is willing to offer the scientist up to the loss of profits from her departure, $\lambda\rho_i$. If the risk of litigation is one ($\gamma = 1$), the firm is willing to offer the scientist only the expected costs of litigation γL. If the competitive impact on the focal firm and the litigation risk are both zero ($\lambda, \gamma = 0$), the firm will offer the scientist the opportunity cost of her time, $\overline{w}$.

If the period 2 wage offer in Equation 4 exceeds the minimum wage dictated by Equation 3, the employee will stay. Alternatively, the employee will leave if $w_{2,\text{stay}} > w_{2,\text{offer}}$. Put differently,

$$\text{if } \overline{w} + \rho_e - \gamma\rho_i > \overline{w} + (1-\gamma)\,\lambda\rho_i + \gamma L, \text{ the scientist moves.} \tag{5}$$

The left side of Equation 5 reflects the gains to the scientist from pursuing the idea externally. The right side represents the gains from staying. Rearranging terms, the mobility condition is expressed as follows:

$$\rho_e > (\lambda + (1-\lambda)\,\gamma)\,\rho_i + \gamma L \tag{6}$$

Thus, given parameters that reflect the mobility-related losses to the firm λ, the threat

[9] In principle, $w_{2,\text{stay}}$ could fall below the opportunity cost of time, $\overline{w}$, if the scientist's ideas have low external but high internal value and the scientist faces a high litigation risk. Constraining $w_{2,\text{stay}} \geq \overline{w}$ does not change model predictions.

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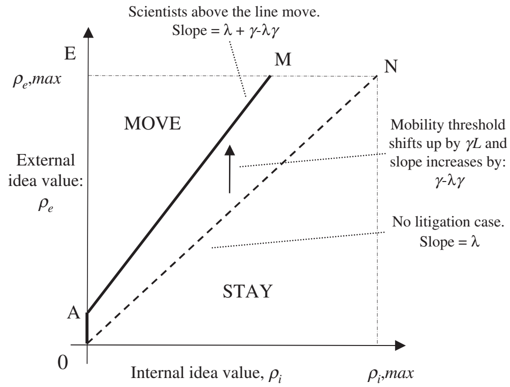

Figure 1. Increase in litigiousness and mobility

of litigation γ and L, Equation 5 allows us to model the mobility condition based on the realized internal and external value of the ideas. These values, in turn, depend on distributional assumptions regarding the random variables ρ_e and ρ_i. We assume independently distributed random components of ρ_e and ρ_i (such as the uniform or jointly normal distributions) to formally derive the effect of litigiousness on the probability that an employee will exit in the APPENDIX, and to aid graphical analysis.[10] Based on Equation 6 above and derivations in the APPENDIX, Figure 1 depicts the mobility condition and maps the internal-external value space of the patented idea. The x and y axes are realized internal (to the firm) and external values, respectively. Under no fear of litigation, $\gamma = 0$, the scientist moves if the external value of the idea exceeds $\lambda \rho_i$, the competition-adjusted internal value of the idea to the firm depicted by line 0 N. In the region left of 0 N, the scientist will leave under no threat of litigation. In the region to the right of 0 N, the scientist will stay.

When employees perceive that the firm enforces patents with a probability of γ, the mobility line shifts upward to AM, with an intercept of γL, and an increase in the slope by $\gamma(1 - \lambda)$. The intercept shift due to the increase in litigiousness results from the firm's willingness to increase its wage offer to avoid *ex post* litigation costs L. The slope increases due to the complementarity between the litigiousness and the internal value of the idea on the left-hand side of Equation 6: the threat of litigation reduces the scientist's payoff if she moves, up to the internal value of the idea at risk of being lost by the firm, as represented by $\gamma(1 - \lambda)$. In combination, Figure 1 shows that an increase in litigiousness decreases the region above the mobility line, thus lowering the likelihood of mobility. Accordingly, and from Equation A.10 in the APPENDIX, we have the following testable implication:

> *Implication 1: The likelihood of mobility decreases with the anticipated likelihood of litigation, γ.*

Impact of litigation: type of mobility and value of ideas

The model yields additional insights regarding the effect of litigiousness on the value of ideas undertaken externally and internally to the focal firm and, in turn, the distribution of employee exits. The derivations are shown in Equations A.11–A.18 in the APPENDIX. We focus first on changes in the average external value of ideas of scientists that exit the firm. As shown in Figure 1, the average external value of the ideas of exiting scientists with no threat of litigation is an average of ρ_e values given by the area 0NE. An increase in litigiousness (upward shift of the mobility line to AM) does not prevent all scientists from exiting. Scientists with the higher external value of the ideas ρ_e for any given internal value of the idea, ρ_i, —"brighter stars"—will exit even as litigiousness increases, since their wage offers fall below their external value, ρ_e. Among the pool of mobile scientists, increased litigiousness nonetheless retains scientists with lower values of ρ_e for each ρ_i.[11] When litigiousness increases, the average external value of ideas associated with exiting employees is shown by region AME in Figure 1, and represents a higher average external value relative to the no-litigation-threat region 0 NE. As shown in the APPENDIX, Equation A.18, a second implication follows:

> *Implication 2: The average external value of ideas of scientists that exit the focal firm increases with the anticipated likelihood of litigation, γ.*

At the same time, an increase in litigiousness boosts the retention of those scientists from the

[10] The supporting information S1 details alternative distributional assumptions of correlated ρ_e and ρ_i. Implications 1 and 2 always hold, and Implication 3 holds under reasonable (but not all) conditions.

[11] Given the assumption of independent random components of ρ_e and ρ_i, the same holds for the entire conditional distribution. See the mathematical analysis in the APPENDIX for more clarity on this point.

mobility pool whose ideas have higher internal value to the firm, as derived in the APPENDIX, Equations A.19–A.25. Intuitively and from Figure 1, the average internal value of ideas associated with exiting scientists is an average of ρ_i values given by the area 0 NE. An increase in litigiousness and an upward shift of the mobility line to AM helps retain scientists with higher internal value ρ_i relative to other mobile inventors for any given external value of that idea, ρ_e. The scientists that exit the firm when litigiousness increases thus represent lower values of internal value ρ_i for each external value ρ_e. The average internal value delineated by the triangle AME, which represents scientists who leave to market the ideas outside the firm with a higher litigation likelihood, is thus lower than the average of the internal value of the triangle 0 NE, which represents scientists who leave to market the ideas outside the nonlitigious firm. From the APPENDIX, Equation A.25, the model therefore predicts that litigiousness will sort scientists among those that stay and leave such that the firm retains more scientists with ideas that are valuable internally. In the event of departure, the average internal value of ideas "released" to the market therefore falls as litigiousness increases:

> *Implication 3: The average internal value of ideas of scientists that exit the focal firm decreases with the anticipated likelihood of litigation, γ.*

In summary, Implication 1 predicts that an increase in litigiousness decreases mobility because the expected value of mobility is reduced and the firm has a greater incentive to retain scientists to avoid the costs associated with the post-mobility litigation. Implications 2 and 3 predict a sorting in which the scientists with the lowest external and the highest internal idea values (from the pool of otherwise mobile scientists) will be retained in response to increased enforcement. These scientists are closest to the mobility threshold and are thus most sensitive to the changes.

DATA AND EMPIRICAL ANALYSIS

We test Implications 1–3 with data from the U.S. semiconductor industry, a setting well known for active job hopping and prolific patenting. Our analysis captures the intra-industry mobility of employee-inventors from 129 public U.S. semiconductor firms. Consistent with prior studies (Rosenkopf and Almeida, 2003), we refer to these employers as "source firms." The source-firm sample comprises all publicly traded U.S. firms that compete primarily in semiconductor markets and are founded prior to 1995, thus allowing a sufficiently long window through which to view possible litigiousness and mobility events. Of the 129 employers, 80 are headquartered in California. The remainder reside in states with smaller semiconductor clusters and stronger non-compete regimes, including Texas, Arizona, Massachusetts, and New York.

As in Ziedonis (2003), for each source firm, we observe initiations of patent infringement lawsuits filed in U.S. courts between 1973 and 2001 by merging case filings reported in legal databases (LitAlert, produced by Thomson Derwent) with supplemental information from archival 10-K filings, news articles, and press releases. We deliberately exclude instances where the firm is defending against legal challenges or no longer owns the disputed patents. These data thus enable us to determine the extent to which, if at all, a firm initiates a patent infringement lawsuit against others in a time-varying manner and can be used for discerning reputation effects from such enforcement.

We trace employee-inventor departures from a focal source firm to either (1) another source firm, or (2) another U.S. semiconductor company that owns patents. The latter category includes 266 venture-backed start-ups, identified from VentureOne, and 52 firms that went public after 1995, identified from Compustat. Because semiconductor engineers often leave established companies to join or form entrepreneurial ventures, we enlarge the pool of so-called recipient firms to capture such movement. For the combined set of 447 firms, we integrate financial and founding year data from Compustat, Hoover's *Business Directories*, and VentureOne, patent data from Delphion and the National University of Singapore, and source-firm patent litigation histories from Ziedonis (2003). Between 1973 and 2003, sample firms collectively received 50,491 patents, of which 38,689 were awarded to firms with observed patent enforcement histories.

Methodology

Establishing a causal link between litigiousness and mobility poses numerous identification challenges.

It is possible, for example, that "better" firms have superior technologies to protect and are more litigious. Such firms could retain more (and more valuable) knowledge workers for reasons unrelated to reputations built through patent enforcement. Our base specification, therefore, uses firm-specific fixed effects specifications that test whether *changes* in an employer's litigiousness lead to *changes* in employee exits. As discussed below, we add numerous time-varying observables at the employee-, firm-, and macro-levels and employ a variety of methods, including use of court-based instruments and a falsification test, to further probe whether mobility is causally shaped by litigiousness in ways predicted by the model. To better compare coefficient estimates across models, we report results using ordinary least squares (OLS) (including linear probability models) and two-stage least squares (2SLS) estimators.

Further, our empirical test of the effects of litigiousness on employee mobility and sorting are likely conservative. The mobility of inventors who do not intend to use any of the knowledge or ideas related to their work at the source firm should not be affected by the firm's litigiousness. Tracking patenting patterns within the industry, we find that 60 percent of individual inventor's self-citations are retained post-mobility. Similarly, an average match in the number of International Patenting Classification 4 (IPC4) patent classes pre- versus post-mobility is 43 percent. In comparison, the same match for comparable inventors who stay at the parent firm is 53 percent. These patterns in our data conform to extant literature (Almeida and Kogut, 1999; Singh and Agrawal, 2011), which finds that inventors commonly continue to work in the same technological domain and build on ideas created at the source firms.

Dependent variables

Mobility

The first dependent variable is a binary indicator set to 1 if our matching algorithm identifies the focal inventor on a subsequent patent assigned to a recipient firm other than the focal employer (another semiconductor firm in the sample). To identify instances when employee-inventors change jobs between source and recipient firms, we used a multi-filter algorithm described in Raffo and Lhuillery (2009). The algorithm refines Trajtenberg *et al.* (2006) and is equivalent to that used in Agarwal *et al.* (2009). Like other patent-based studies of mobility (Marx *et al.*, 2009; Singh and Agrawal, 2011), this approach captures the intra-industry movement of inventively productive employees. To focus on mobility events likely to pose expropriation hazards, we exclude instances where employees move to recipient firms owned by the focal source firm through acquisition or corporate venture capital investments. We also omit observations for failing firms in the year prior to and including liquidation to better capture voluntary exits rather than layoff-driven departures. For 28,123 unique inventor names listed in patents awarded to firms in the sample, 1,166 mobility events met these criteria. The mobility rate in our sample (for 51,615 dyads over a 30-year time window) is approximately 0.08 percent per dyad-year, slightly exceeding the 0.05 percent rate reported for semiconductor dyads in Rosenkopf and Almeida (2003). Due to the source-firm fixed effects and the need to constrain our analysis only to public source firms, our effective sample includes 662 events.

External value of ideas of mobile scientists

Lacking a direct measure of idea values, we follow Hoisl (2007) and Palomeras and Melero (2010) to create indirect measures that rely on the number and quality of the scientist's patents. We use two proxies to capture the value realized after an inventor moves. *Post-mobility patent productivity* is the number of patents the inventor produces at the recipient firm divided by the years the individual is inventively active at that firm. *Post-mobility patent quality* measures the average annual number of citations to those patents in a five-year window, divided by the number of patents he or she produced at the firm. As Hall *et al.* (2001) discuss, patents that are more highly cited in other patents tend to be more valuable inventions.

Internal idea value

Analogous to external idea value, we use *pre-exit inventor patenting productivity* and *pre-exit inventor patenting quality* to proxy for the internal value of the idea to the source firm. Correspondingly, *pre-exit inventor patenting productivity* tallies the annual number of inventor patents at the firm, while *pre-exit inventor patenting quality* measures the average number of citations to those patents in a five-year window. Our results are robust to alternative specifications based on the three- and five-year windows pre- and post-mobility.

Explanatory and control variables

Litigiousness, our proxy for IP toughness, is a time-varying measure based on the observed behavior of a focal employer in enforcing its exclusionary rights to patent-protected technologies. More specifically, it is a lagged three-year moving sum (over *t*-1 to *t*-3) of the number of unique patent infringement lawsuits launched by the firm. Results reported below are robust to use of alternative litigiousness measures, including separate lags. Use of a three-year lagged explanatory variable improves the precision of our estimates and allows reputation stocks to evolve slowly while still being prone to some decay. The measure also allows a firm's reputation for IP toughness to be predetermined when the scientist makes a mobility decision, as assumed in the formal model.

Controls

Unless otherwise indicated, all specifications include a full set of year and source-firm fixed effects in addition to time-varying controls at the employee, source-firm, and macro levels. At the employee-inventor level, *gender* (1 = female) and *ethnicity* (1 = non-White) allow for influence of demographic factors. *Inventor's number of co-inventors* allows for team-size effects. *Tenure* measures the number of years the employee is inventively active at the source firm, thus allowing mobility decisions to be shaped by seniority or a deepening of firm-specific skills over time.

At the source-firm level,[12] firm patent awards let the simple ownership of patents shape employee exit decisions (Kim and Marschke, 2005). Following Hall *et al.* (2001), it is measured as the annual *number of U.S. patents awarded to the source firm* dated by year of filing. Since larger firms file more patents (Hall and Ziedonis, 2001), this variable provides an indirect proxy for firm size as well, thus alleviating concerns that *litigiousness*, our explanatory variable of interest, spuriously reflects the cost advantages of larger firms in patent enforcement (Lanjouw and Schankerman, 2004). Use of a direct size measure based on employment counts produces similar findings. We also control for the annual *R&D intensity* and *patenting quality* (average annual citations per patent in a five-year window) of each source firm to allow R&D commitments and the quality of the firm's overall innovative output to affect retention. Since larger firms tend to spend more on research, R&D spending is normalized by employee counts to disentangle the effects. Separately, finance scholars show that broad-based stock options are pervasive in technology-intensive industries such as semiconductors (Ittner *et al.*, 2003). Although our inclusion of source-firm fixed effects captures time-invariant differences among firms in granting of stock options to R&D employees, a firm's employee retention rate could increase in periods when its stock price is climbing (Bettis *et al.*, 2005; Core and Guay, 2001; McKeon, 2013). Lacking data on options granted to inventors, we control for the annual stock return of the source firm using data compiled by McKeon (2013).

A final set of controls captures time-varying state and regional factors that could influence turnover in ways insufficiently captured by year dummies. The *Garmaise noncompete index* is based on the non-competition enforceability index compiled by Garmaise (2009) for U.S. states. Across states, the index ranges from zero to nine, with higher scores indicating stronger regimes of non-compete enforcement and California's score listed as zero. As listed in Table 1, the index is time varying for three states: Texas, Florida, and Louisiana. At the regional level, shifts in the supply of knowledge workers can affect wage rates as well as the proclivity of firms to grant stock options to rank-and-file employees (Kedia and Rajgopal, 2009). We therefore control for the *number of inventors in the region*, measured as the annual number of inventors in other semiconductor firms' patents (minus the source-firm's) for inventors located in the same region as the focal firm. Regions are defined using 125 combined statistical areas (CSA) of the U.S. Census.

Table 2 provides summary information about the variables and their construction. Tables 3 and 4 list summary statistics and bivariate correlations.

RESULTS

Tables 5–8 report results related to the three testable implications of the model.

[12] While the results are robust to the inclusion of comparable controls at the recipient-firm level, we do not include these since recipient-firm characteristics may be endogenous to the employee mobility decision, our main variable of interest.

Table 2. Variable definitions

Dependent variables	
Intra-industry mobility event	A binary indicator set to 1 if source-firm inventor appears on a subsequent patent assigned to another firm in recipient sample
Post-mobility patent productivity	Number of patents produced by ex-employee at recipient firm divided by the number of years at the recipient firm.
Post-mobility patenting quality	Number of forward citations over a five-year window made to patents by ex-employee at the recipient firm divided by the number of patents at the recipient firm.
Pre-exit inventor patenting quality	Annual number of employee's citations per patent at source-firm
Pre-exit inventor patenting productivity	Annual number of employee's patents at source-firm
Main explanatory variable	
Litigiousness (three-year moving sum)	Moving sum of the number of unique patent infringement lawsuits initiated by the source firm from year *t*-1 to year *t*-3.
Controls	
Inventor number of co-inventors	Annual mean number of co-inventors at source-firm
Inventor tenure	Last minus first year of source-firm inventive activity for employee
Gender (1 = female)	1 if female, else 0 based on first name of inventor
Ethnicity (1 = non-White)	1 if Asian, Middle-Eastern, or Indian sounding name on patent document, 0 otherwise
Firm patenting productivity	Annual number of firm's patents
Firm patenting quality	Annual number of firm's citations per patent
R&D intensity	Source-firm R&D expenditures divided by employee counts in focal year (in millions per employee (year 2000 dollars)
Annual stock returns	Annual return on source-firm stock from McKeon (2013)
Number of inventors in the region	Log of the number of inventors in the inventor's combined statistical area (CSA) excluding the focal firm
Garmaise noncompete index	Noncompete enforceability index for U.S. states listed in Garmaise (2009; see supporting information S1, Table A1); time-varying for Texas, Florida, and Louisiana
Instruments[a]	
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
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
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
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

[a] All instruments are imputed with 0 if the focal firm does not litigate in *t*-1 to *t*-3. As an alternative, we have imputed the average value of the measure across all litigating firms over *t*-1 to *t*-3 as a way of capturing the "expected" value of the measure. The results remained unchanged to either specification of the instruments.

Effect of litigiousness on mobility likelihood

Turning first to Table 5, Model 1 estimates the effects of control variables on the mobility likelihood using an OLS linear probability model. The unit of analysis is an inventor-year. Robust standard errors, clustered by firms, are reported. Among the controls, inventors with more highly cited patents have higher propensities to exit, as do those who are male, non-White, and more recently hired. Not surprisingly, inventors are more likely to leave firms with declining patenting quality, R&D intensity, and stock prices. As in Marx *et al.* (2009) and Garmaise (2009), mobility rates decline as the strength of non-compete enforcement increases: a one-point increase in the Garmaise enforceability index lowers the annual mobility likelihood by 11.3 percent among these inventors.

Model 2 in Table 5 adds *litigiousness*, the main explanatory variable of interest. Consistent with Implication 1, *litigiousness* is negative and statistically significant. More specifically, the filing of an additional patent lawsuit reduces the annual turnover rate predicted for the focal employer by almost 3 percent. At an average of three lawsuits in the preceding three years for litigating firms, this

Table 3. Summary statistics and correlations, all inventors, $N = 49{,}334$

		Mean	Std. dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)	Mobility	0.015	0.120	0	1	1.000												
(2)	Litigiousness (three-year moving sum)	3.065	4.401	0	17	−0.043	1.000											
(3)	Pre-exit inventor patenting quality (citations per patent)	5.232	9.198	0	203	0.025	−0.004	1.000										
(4)	Pre-exit inventor patenting productivity (patents per year)	1.111	1.926	0	163	0.010	−0.044	0.174	1.000									
(5)	Average number of co-inventors	1.426	1.791	0	20	0.001	−0.022	0.280	0.238	1.000								
(6)	Gender (1 = female)	0.024	0.153	0	1	−0.013	0.005	0.015	−0.005	0.044	1.000							
(7)	Ethnicity (1 = non-White)	0.244	0.430	0	1	0.030	−0.039	0.028	0.025	0.062	−0.051	1.000						
(8)	Tenure within firm	3.744	3.717	1	27	−0.024	0.175	−0.119	−0.022	−0.132	−0.052	−0.089	1.000					
(9)	Firm patenting quality (citations per patent)	0.421	1.819	0.014	29.5	−0.015	−0.081	−0.088	0.011	0.062	0.000	0.033	−0.004	1.000				
(10)	Firm patenting productivity (patents per year)	301.39	261.47	0	989	−0.051	0.340	0.098	0.091	0.105	0.026	0.024	0.112	−0.124	1.000			
(11)	R&D intensity	0.029	0.025	0	0.212	0.007	−0.307	0.038	0.100	0.162	0.016	0.119	−0.126	0.298	−0.073	1.000		
(12)	Annual stock returns	1.286	0.632	0.090	9.733	−0.009	−0.049	0.048	−0.007	0.020	0.008	0.013	−0.007	−0.089	0.054	0.003	1.000	
(13)	Number of inventors in region (excluding focal firm, log)	5.704	2.091	0	8.255	0.024	−0.315	0.151	0.125	0.139	0.028	0.139	−0.179	0.031	−0.024	0.576	0.130	1.000
(14)	Garmaise noncompete index	2.583	2.473	0	9	−0.057	0.358	−0.019	−0.035	−0.008	−0.016	−0.167	0.111	−0.073	0.282	−0.388	−0.061	−0.597

Table 4. Summary statistics and correlations, mobile inventors, $N = 662$

		Mean	Std. dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	Post-exit inventor patenting quality (citations per patent)	24.64	28.58	0	361.8	1.000													
(2)	Post-exit inventor patenting productivity (patents per year)	1.432	1.045	0.18	14	0.040	1.000												
(3)	Litigiousness (three-year moving sum)	1.351	2.799	0	16	0.037	0.064	1.000											
(4)	Pre-exit inventor patenting quality (citations per patent)	7.085	8.126	0	63	0.071	0.009	−0.022	1.000										
(5)	Pre-exit inventor patenting productivity (patents per year)	1.314	0.999	0	15	−0.011	0.159	−0.047	0.015	1.000									
(6)	Average number of co-inventors	1.479	1.375	0	9	0.027	−0.026	0.075	0.122	0.071	1.000								
(7)	Gender (1 = female)	0.006	0.077	0	1	0.019	−0.008	0.019	0.060	−0.009	0.033	1.000							
(8)	Ethnicity (1 = non-White)	0.342	0.475	0	1	0.051	0.031	0.002	0.028	−0.038	0.006	−0.028	1.000						
(9)	Tenure within firm	2.871	2.920	1	23	0.018	−0.016	0.057	−0.049	0.055	−0.015	−0.029	−0.120	1.000					
(10)	Firm patenting quality (citations per patent)	0.202	0.295	0.03	7	−0.065	−0.081	−0.110	−0.229	−0.047	−0.064	−0.006	−0.005	−0.019	1.000				
(11)	Firm patenting productivity (patents per year)	168.51	234.94	1	1176	−0.044	−0.015	0.422	−0.012	0.112	0.070	0.052	0.028	0.160	−0.156	1.000			
(12)	R&D intensity	0.030	0.029	0	0.187	−0.038	0.007	−0.124	0.081	0.021	0.068	−0.020	0.187	−0.076	0.164	−0.083	1.000		
(13)	Annual stock returns	1.221	0.620	0.27	5.079	−0.005	0.058	0.010	−0.046	0.090	0.090	0.017	−0.030	0.046	−0.029	0.042	0.017	1.000	
(14)	Number of inventors in region (excluding focal firm, log)	6.031	2.025	0	8.255	−0.035	0.077	−0.232	0.086	0.139	−0.025	0.008	0.119	−0.021	−0.069	−0.033	0.315	−0.003	1.000
(15)	Garmaise noncompete index	1.534	2.200	0	9	−0.042	−0.004	0.306	−0.019	0.002	0.036	−0.009	−0.150	0.033	−0.037	0.268	−0.151	0.005	−0.426

Table 5. Litigiousness and the probability of employee-inventor exits (inventor-year observations)

DV = mobility	Controls only Model 1 (OLS)	Main model Model 2 (OLS)	No firm FE, Model 3 (OLS)	"Switchers" only Model 4 (OLS)	IV estimates Model 5 (2SLS)	Falsification test Model 6 (OLS)
Litigiousness (three-year moving sum)		−0.0003**	−0.0005*	−0.0009**	−0.0013**	0.0023
		(0.0001)	(0.0003)	(0.0004)	(0.0006)	(0.0016)
Inventor-level controls						
Inventor patenting quality	0.0003***	0.0003***	0.0003***	0.0006**	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Average number of co-inventors	0.0002	0.0002	0.0002	0.0008	0.0001	0.0002
	(0.0004)	(0.0004)	(0.0003)	(0.0006)	(0.0004)	(0.0004)
Tenure within firm	−0.0002**	−0.0002**	−0.0003***	−0.0009**	−0.0002**	−0.0002**
	(0.0001)	(0.0001)	(0.0001)	(0.0005)	(0.0001)	(0.0001)
Gender (1 = female)	−0.0082***	−0.0081***	−0.0086***	−0.0169***	−0.0081***	−0.0080***
	(0.0014)	(0.0014)	(0.0016)	(0.0030)	(0.0014)	(0.0015)
Ethnicity (1 = non-White)	0.0058***	0.0058***	0.0066***	0.0061	0.0057***	0.0060***
	(0.0019)	(0.0019)	(0.0019)	(0.0044)	(0.0020)	(0.0019)
Firm-level controls						
Firm patenting quality	−0.0010***	−0.0009***	−0.0005**	−0.0004	−0.0008***	−0.0006*
	(0.0003)	(0.0003)	(0.0002)	(0.0004)	(0.0002)	(0.0003)
Firm patenting productivity	−0.00004	−0.00004	−0.00002***	−0.00002	−0.00002	0.000005
	(0.0001)	(0.0001)	(0.00001)	(0.00001)	(0.0001)	(0.00001)
R&D intensity	−0.2292**	−0.2358**	0.0218	−0.2732**	−0.2870**	−0.1530**
	(0.0912)	(0.0948)	(0.0919)	(0.1367)	(0.1125)	(0.0684)
Annual stock returns	−0.0015**	−0.0015**	−0.0020*	−0.0012	−0.0019**	−0.0023***
	(0.0007)	(0.0007)	(0.0010)	(0.0010)	(0.0009)	(0.0009)
Region-level controls						
Number of inventors in region	−0.0079**	−0.0080**	−0.0008	−0.0105***	−0.0083***	−0.0063
(excl. focal firm, log)	(0.0035)	(0.0035)	(0.0010)	(0.0037)	(0.0031)	(0.0038)
Garmaise noncompete index	−0.0016*	−0.0016*	−0.0023***	−0.0019*	−0.0015*	−0.0015**
	(0.0009)	(0.0009)	(0.0009)	(0.0011)	(0.0008)	(0.0008)
First-stage instruments in Model 5						
Number of patent cases					0.0034*** (0.0012)	
Number of civil cases					−0.0001* (0.0001)	
Number of patent cases per judge					0.1156 (0.3606)	
Number of civil cases per judge					0.0101 (0.0132)	
Hansen over-ID test (p-value)					0.304	
$R2$	0.003	0.004	0.008	0.005	0.003	0.004
N	49,334	49,334	49,338	22,415	49,334	47,130

Robust standard errors, clustered by firms, are reported. Constants are not reported. Year dummies are included, as are firm-fixed effects except in Model 3.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 6. Litigiousness and the patent productivity of employee-inventors post-exit (mobile inventors only)

DV = post-exit patenting productivity	Controls only, OLS Model 1	Main model, OLS Model 2	"Switchers" only Model 3	IV, 2SLS Model 4	Falsification test Model 5
Litigiousness (three-year moving sum)		0.0320**	0.0223**	0.163*	−0.163
		(0.0152)	(0.0104)	(0.1000)	(0.1510)
Inventor-level controls					
Pre-exit inventor patenting productivity	0.2052***	0.2093***	0.2846**	0.2258***	0.2276***
(patents per year)	(0.0727)	(0.0694)	(0.1181)	(0.0575)	(0.0695)
Average number of co-inventors	−0.0307	−0.032	−0.0305	−0.037	−0.0276
	(0.0328)	(0.0324)	(0.0346)	(0.0318)	(0.0343)
Tenure within firm	−0.0081	−0.0064	−0.0087	0.0008	−0.0046
	(0.0140)	(0.0155)	(0.0143)	(0.0202)	(0.0128)
Gender (1 = female)	0.1159	0.1023	0.4310**	0.0466	0.0414
	(0.1567)	(0.1613)	(0.1750)	(0.1969)	(0.1601)
Ethnicity (1 = non-White)	0.0252	0.0298	0.0072	0.0487	0.0313
	(0.1044)	(0.1026)	(0.0809)	(0.1001)	(0.1000)
Firm-level controls					
Firm patenting quality	−0.4567	−0.4841	0.0286	−0.5958	0.4126
	(0.5355)	(0.5420)	(0.3709)	(0.5476)	(0.3098)
Firm patenting productivity	−0.0003**	−0.0004***	−0.00002	−0.0007***	−0.0005***
	(0.0001)	(0.0001)	(0.0005)	(0.0002)	(0.0002)
R&D intensity	−5.3189	−4.818	−4.1632	−2.7766	−1.5893
	(5.0824)	(5.2570)	(4.1975)	(6.5371)	(4.0261)
Annual stock returns	−0.048	−0.0391	0.0958	−0.0029	0.0215
	(0.0726)	(0.0746)	(0.0654)	(0.0950)	(0.0640)
Region-level controls					
Number of inventors in region	−0.1106	−0.1003	−0.1711**	−0.0584	−0.1514**
(excl. focal firm, log)	(0.1340)	(0.1334)	(0.0759)	(0.1110)	(0.0602)
Garmaise noncompete index	0.0208	0.0174	−0.003	0.0034	0.0109
	(0.0212)	(0.0196)	(0.0292)	(0.0164)	(0.0211)
Constant	0.8726***	0.8893***	2.3066***		1.5890***
	(0.2850)	(0.2576)	(0.6942)		(0.4448)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
Hansen over-ID test (*p*-value)				0.28	
R^2	0.08	0.08	0.08	0.015	0.06
N	662	662	413	662	662

Robust standard errors, clustered by firms, are reported.
$*p < 0.1$; $**p < 0.05$; $***p < 0.01$

translates into a 9 percent reduction in estimated departures by knowledge workers each year.

As a robustness check, Model 3 omits firm-fixed effects from the specification. Although the results are qualitatively unchanged, the magnitude of the *litigiousness* effect grows larger, to an estimated 5 percent decline in annual departures. In combination, Models 2 and 3 suggest that the estimated effect of *litigiousness* is biased upward absent controls for time-invariant differences among employers. In unreported output (all of which are available upon request), we excluded inventors in the lowest quartile of a source-firm's patent producers to assuage concerns that our results are spuriously driven by layoffs of less productive workers, and obtained similar findings. Finally, our findings are also robust to the non-instrumented specifications in Table 5 using conditional logit, probit, and Cox hazard-rate models.

Alternative explanations for findings related to Implication 1

Models 4–6 in Table 5 investigate three main concerns to identifying a causal relationship between a firm's litigiousness and the employee

Table 7. Litigiousness and the patent quality of employee-inventors post-exit (mobile inventors only)

DV = post-exit patenting quality (citations per patent)	Controls only, OLS Model 1	Main model, OLS Model 2	"Switchers" only Model 3	IV, 2SLS Model 4	Falsification test Model 5
Litigiousness (three-year moving sum)		0.8029*	2.2221**	8.3200**	2.3487
		(0.4671)	(0.9009)	(3.6069)	(6.8589)
Inventor-level controls					
Pre-exit inventor patenting quality	0.2263***	0.2352***	0.2785	0.3191**	0.2130**
(citations per patent)	(0.0828)	(0.0799)	(0.1664)	(0.1441)	(0.0840)
Average number of co-inventors	0.434	0.3692	−0.5496	−0.2367	0.3304
	(1.3126)	(1.3231)	(0.8549)	(1.3567)	(1.2956)
Tenure within firm	0.6755*	0.7067*	0.3974	0.9985*	0.6171*
	(0.3446)	(0.3660)	(0.2675)	(0.5133)	(0.3490)
Gender (1 = female)	8.136	7.5836	12.8978**	2.4121	5.2949
	(5.6105)	(5.7182)	(5.0167)	(6.6691)	(4.9115)
Ethnicity (1 = non-White)	3.151	3.1903	−0.9275	3.5584	2.8345
	(2.8849)	(2.9498)	(3.1458)	(3.3919)	(2.8405)
Firm-level controls					
Firm patenting quality	−1.3184	−1.7548	−12.5733	−5.8409	−10.5254
	(12.5659)	(12.3238)	(16.4397)	(13.4202)	(12.5324)
Firm patenting productivity	0.0118	0.0099	0.0025	−0.0081	0.0121
	(0.0073)	(0.0077)	(0.0129)	(0.0102)	(0.0112)
R&D intensity	149.941	160.9615	273.8925	264.1357	203.099
	(200.5057)	(198.0647)	(255.8483)	(215.1463)	(205.5457)
Annual stock returns	0.3729	0.3712	−0.6707	0.3552	1.2861
	(1.3349)	(1.3320)	(1.8051)	(1.4218)	(1.7179)
Region-level controls					
Number of inventors in region	−2.2227	−2.3742	−4.3892	−3.7925	−0.9467
(excl. focal firm, log)	(2.6918)	(2.5336)	(2.6220)	(2.6849)	(2.4759)
Garmaise noncompete index	−0.5665	−0.6434	−0.3954	−1.3635	−0.7046
	(0.5560)	(0.6035)	(0.7383)	(0.8907)	(0.6192)
Constant	1.3162	1.4761	20.907		30.7717*
	(25.3045)	(24.4715)	(21.7780)		(17.0303)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
Hansen over-ID test (p-value)				0.18	
R^2	0.04	0.04	0.1	0.03	0.06
N	662	662	413	662	662

Robust standard errors, clustered by firms, are reported.
$*p < 0.1$; $**p < 0.05$; $***p < 0.01$

exit calculus suggested by our model. Prominent among them is that, as firms grow more litigious, they could attract less mobile workers. If true, a negative *litigiousness* coefficient could reflect an underlying shift in individual types that "select in" via recruitment, rather than a change in employee departure incentives due to litigious action. To investigate this possibility, Model 4 restricts the sample to employee-inventors hired by firms that switch *post-hiring* from passive to aggressive in enforcing patents, thus isolating attention to employees that joined companies when they were nonlitigious. At odds with a recruitment-driven explanation, *litigiousness* remains negative and significant, with a more pronounced effect.

Alternatively, the negative effect of litigiousness on employee departures could reflect unobserved, time varying "shocks" within firms. To elaborate, assume that a given source firm has a breakthrough discovery insufficiently captured by our controls. This opportunity shock could yield a simultaneous increase in legal action, since the firm has valuable technologies to protect, and greater employee retention, if the value of internal projects relative to outside options shifts upward. In this event, litigiousness and retention could be correlated but not causally related. To investigate this second possibility, we use the court characteristics that likely affect a firm's decision to sue but unlikely to coincide with a firm-specific shock in unobserved

Table 8. Litigiousness and the patent productivity and quality of employees pre-exit (mobile inventors only)

DV	A. Pre-exit patent productivity				B. Pre-exit patent quality			
Model	Main, OLS Model A1	"Switchers" only Model A2	IV, 2SLS Model A3	Falsification test Model A4	Main, OLS Model B1	"Switchers" only Model B2	IV, 2SLS Model B3	Falsification test Model B4
Litigiousness	−0.0245**	−0.0616***	−0.082**	0.0692	−0.2381**	−0.3838***	0.6308	0.739
(three-year moving sum)	(0.0110)	(0.0177)	(0.0420)	(0.1870)	(0.1167)	(0.1140)	(0.8581)	(1.9762)
Inventor-level controls								
Average # co-inventors	0.0595***	0.0456	0.0556***	0.0545***	0.6753**	0.8291**	0.6800**	0.6951**
	(0.0206)	(0.0319)	(0.0185)	(0.0200)	(0.2780)	(0.3761)	(0.2672)	(0.3115)
Tenure within firm	0.0023	−0.0201	−0.0019	0.0024	−0.0976	−0.0241	−0.0857	−0.1144
	(0.0076)	(0.0148)	(0.0099)	(0.0082)	(0.0797)	(0.1073)	(0.1079)	(0.0882)
Gender (1 = female)	−0.202	−0.9909***	−0.1608	−0.1942	5.0441	−0.7474	5.4831	4.9002
	(0.3427)	(0.2173)	(0.3187)	(0.3476)	(7.8557)	(2.5726)	(8.2021)	(8.3552)
Ethnicity (1 = non-White)	−0.0527	−0.0923	−0.0679	−0.0561	0.1733	−0.0071	0.4133	0.2847
	(0.0945)	(0.1336)	(0.0794)	(0.0937)	(0.7986)	(0.9336)	(0.7857)	(0.8151)
Firm-level controls								
Firm patenting quality	−1.0232**	−0.9786***	−0.9423**	−1.0667**	−8.1789*	−11.1518**	−14.5897***	−9.8477***
	(0.4110)	(0.3607)	(0.4600)	(0.4466)	(4.1085)	(4.1868)	(4.9016)	(2.7108)
Firm patenting productivity	0.0005***	−0.0003	0.0006**	0.0005**	−0.0059**	−0.0077**	−0.0043	−0.0050***
	(0.0002)	(0.0004)	(0.0003)	(0.0002)	(0.0025)	(0.0038)	(0.0030)	(0.0018)
R&D intensity	−6.5239*	−9.2374	−7.0299*	−6.0166	45.8703	62.0553	23.0169	25.3243
	(3.6464)	(5.5969)	(4.1877)	(4.2509)	(39.3135)	(54.4102)	(47.8445)	(38.1280)
Annual stock returns	0.032	0.0843	0.0261	0.0372	−0.2797	−1.1904	−0.323	−0.4891
	(0.1438)	(0.1646)	(0.1093)	(0.1166)	(0.6284)	(1.1096)	(0.5114)	(0.5213)
Region-level controls								
# inventors in region	0.2194***	0.1106*	0.1193**	0.1584***	−0.6553	−0.6684	1.0293**	−1.2155
(excl. focal firm, log)	(0.0499)	(0.0633)	(0.0551)	(0.0559)	(0.9343)	(1.2070)	(0.5240)	(0.9315)
Garmaise noncompete index	0.0095	0.0085	0.0184	0.0056	0.2126	0.2458	0.042	0.1617
	(0.0174)	(0.0227)	(0.0192)	(0.0152)	(0.1715)	(0.2720)	(0.2066)	(0.2002)
Constant	1.5796**	2.8144***		−0.2826	15.1682*	18.6433		4.8737
	(0.7213)	(1.0425)		(0.2206)	(8.6424)	(11.1379)		(4.9831)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hansen over-ID test (p-value)			0.34				0.92	
R^2	0.1	0.11	0.07	0.09	0.13	0.18	0.04	0.09
N	663	413	663	663	663	413	663	663

Robust standard errors, clustered by firms, are reported.
$*p < 0.1$; $**p < 0.05$; $***p < 0.01$

technological value to develop the instrumental variables for litigiousness. Kesan and Ball (2006, 2010) show that district court effectiveness and experience—both in civil disputes overall and in patent-related matters—alter litigation outcomes and, in turn, directly affect decisions to file patent infringement lawsuits. These court-level characteristics are driven by numerous factors, including budget constraints and judicial expertise, which are reasonably exogenous to a time-varying technological shock within a focal source firm. Using annual statistics reported in Kesan and Ball (2006, 2010), we therefore utilize the characteristics of the U.S. District Courts in which source firms litigate patents, based on civil and patent caseloads and caseloads heard on a per-judge basis,[13] to calculate the instrumental variables for *litigiousness*.

Model 5 in Table 5 reports 2SLS estimates with the court-based instruments shown at the bottom of the column. The instruments are jointly significant at the 0.1 percent level in the first-stage regression, and pass the Hansen over-identification test with p value of 0.3. As before, firm-fixed effects are included and robust standard errors, clustered by firms, are reported. Assuming that court-level characteristics influence litigation choices for reasons exogenous to a time-specific shock within a particular firm, the estimates in Model 5 are again consistent with Implication 1: the *litigiousness* coefficient remains negative and statistically significant.

A third, related concern is that our *litigiousness* measure is picking up positive opportunity shocks at the region level that are insufficiently captured by our controls. Similar to the prior discussion, a region-wide opportunity shock could ignite more legal conflict due to the higher value of technological discoveries (possibility creating bottlenecks in judicial outlets), while also resulting in higher retention rates in local labor markets. If true, we should find a similar effect if our firm-specific *litigiousness* variable is replaced with a "false" measure based on lawsuits filed by other semiconductor firms within the region. Model 6 of Table 5 conducts this falsification test by replacing the firm-level *litigiousness* variable with an equivalent measure based on the patent infringement lawsuits launched by other semiconductor firms in the region based on the CSA of the headquarter location, excluding the focal source firm. Consistent with the view that the *litigiousness* effect stems from firm-specific reputational factors, the false measure fails to predict employee exits at statistically significant levels.

Effect of litigiousness on external value of ideas

The remaining analyses investigate whether a firm's reputation for IP toughness yields differential sorting, thus altering the mobility calculus of some employee types more than others. Implication 2 predicts that, as employers grow more litigious, the average value of ideas carried by mobile scientists to rival companies will shift upward. We test Implication 2 based on the post-exit patenting productivity (Table 6) and post-exit patenting quality (Table 7) of mobile inventors. Tables 6 and 7 are therefore conditioned on employee-inventor movement from a source firm to another U.S. semiconductor company, with a mobile inventor as the unit of analysis.

Consistent with Implication 2, Tables 6 and 7 reveal a clear empirical pattern: regardless of whether external idea value is captured by the inventor productivity or quality measure, *litigiousness* shifts the value distribution of mobile inventors outward. Turning first to Table 6, Model 2 estimates that the additional filing of a patent infringement lawsuit will lead to 2.1 percent increase in average patent productivity of mobile employees post-exit. At an average of five lawsuits in the last three years, a 10.5 percent increase in post-mobility productivity is predicted for the average litigant. Model 2 in Table 7 shows a similar pattern, with the additional filing of a patent infringement lawsuit yielding a 3.2 percent increase in the predicted number of patent citations of a mobile employee post-exit, a 16 percent increase for the average litigant.

Alternative explanations for findings related to Implication 2

Similar to the alternative explanation tests for Implication 1, Tables 6 and 7 provide little indication that our results are spuriously driven by shifts in recruitment (Model 3), latent opportunity shocks within employers (Model 4), or regional dynamics insufficiently controlled for in our regressions (Model 5). As an additional robustness check, we

[13] As described in Table 1, the variable is based on all district courts in which the focal source firm has litigated patents in the prior three years. Although plaintiffs in patent infringement lawsuits have some latitude for selection of legal venues (Moore, 2001), we assume nontrivial adjustment costs in switching venues.

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re-ran the noninstrumented models using a Poisson quasi-maximum likelihood estimator more suitable for skewed counts (Gourieroux *et al.*, 1984) and obtained similar results. In combination, Tables 6 and 7 reveal the pattern depicted in Figure 1—that litigiousness increases the value threshold required for knowledge workers to leave in pursuit of outside opportunities. This evidence is consistent with the view that more ideas near the mobility constraint would have been carried to other firms through employee exits absent the intensified threat of legal action.

Effect of litigiousness on internal value of ideas

If litigiousness boosts the retention of scientists with ideas of higher value internally, the average internal value of ideas carried by mobile workers should fall (Implication 3). Table 8 tests this final implication of the model. Analogous to Tables 6 and 7, internal idea value is proxied by the pre-exit patent productivity and quality of mobile inventors in Panels A and B, respectively. For brevity, we report parallel results in one table.

The evidence in Table 8 is further indicative of differential sorting. Consistent with Implication 3, an increase in litigiousness shifts the distribution of employee/idea types that leave toward those with lower internal value pre-exit. Specifically, estimates in Model A1 reveal that one additional patent infringement lawsuit lowers the pre-exit patent productivity of mobile inventors by 2.1 percent. Model B1 similarly suggests a drop in pre-exit patenting quality by 4.5 percent.

Alternative explanations for findings related to Implication 3

As above, the results hold in subsamples of mobile inventors from firms that switched to litigious post-hiring (Models A2 and B2), and do not appear to be driven by latent regional dynamics (Models A4 and B4). Although the court-based instruments pass the Hansen over-identification test in Models A3 and B3 with p-values of 0.71 and 0.52, the statistical significance of *litigiousness* on internal idea value is sensitive to the value proxy, falling below conventional significance levels for the quality-based measure in Model B3 yet remaining negative and significant in Model A3.

To view the differential effects of litigiousness on employee sorting suggested by Implication 3 from another vantage point, we conducted supplemental analyses using the unconditioned sample of employee-inventors and interaction terms between litigiousness and the pre-exit patent productivity and quality of employee-inventors, respectively. While the use of two endogenous variables (the main effect and each interaction) undermines the strength of the instruments in 2SLS regressions, the OLS estimates nonetheless mirror the pattern revealed in Table 8: the retention effect of litigiousness is stronger among employee-inventors who are more productive or highly cited pre-exit. Evidence from this analysis is available upon request.

Additional robustness tests

A final set of supplemental analyses probe the overall robustness of our findings, and are reported in the supporting information S1. Table A1 in S1 uses information about the extent to which a focal inventor's patents are cited by the source firm or outsiders to construct alternative proxies for internal and external idea value. The results are again consistent with Implications 2 and 3. Since citations to a mobile inventor's patents could be endogenously shaped by concerns of infringement (Lampe, 2012), we prefer use of the more aggregate value proxies reported in Tables 6–8.

It is also possible that litigiousness alters the inventive activities of employees that remain at the source firm in ways insufficiently captured by Tables 6–8, where the sample is restricted to mobile inventors. To investigate this possibility, we match mobile inventors to ones remaining at the source firm using a coarsened exact matching (CEM) method. As shown earlier in Tables 2–4, the productivity and quality of movers post-mobility is greater than that of the stayers. If Implications 2 and 3 hold, we therefore should find that the performance gap between movers and stayers *widens* when a firm grows more litigious. This pattern is indeed visible and statistically significant in the supplemental matched sample analysis reported in Table A2 in S1.

DISCUSSION AND CONCLUSION

This study reveals new linkages between the reputations firms build through patent enforcement and employee mobility decisions. Our findings, drawn from the U.S. semiconductor industry, are consistent with the view that reputations for IP toughness reduce the payoffs employees anticipate from switching jobs within an industry, thus deterring voluntary exits (Implication 1). We also find that litigiousness alters the *distribution* of employee exits, and is particularly helpful in retaining those pursuing ideas of high internal value (Implications 2 and 3). In contrast, the brightest inventors (with ideas most highly valued externally) are relatively unaffected.

The formal model shows how a firm's litigiousness over patents could alter the dynamics between employers and a potentially mobile workforce for reasons difficult to discern from extant theory and verbal reasoning alone. Although costly investment in legal action reduces the value employees expect to reap externally, it entices firms to offer higher wages to retain scientists and avoid mobility-related disputes. Legal costs, therefore, play a two-sided role in employer-employee wage dynamics. The model also crystallizes our understanding of how, by shifting the mobility threshold, litigiousness affects both the overall rate of employee mobility and the distribution of who stays versus exits. As depicted in Figure 1, an increase in litigiousness shifts the retention threshold upward. Thus, disproportionately higher external values are needed to justify exit. This second effect is meaningful, however, only if mobility threatens the profits of the focal firm—a boundary condition of Implication 3 that future studies could explore. Overall, the model suggests that the effect of litigiousness on mobility is driven by inter-relationships among the costliness of legal action, the relative value of patented discoveries to the employer versus outsiders, and the competitive losses anticipated from employee departures.

Empirically, our findings suggest that job changes among skilled workers are driven not only by state laws governing non-compete enforcement (Fallick *et al.*, 2006; Marx *et al.*, 2009), but also by firm-specific reputations built through patent enforcement. While actions taken to enforce patents undoubtedly shape product market rivalry (Lanjouw and Schankerman, 2004; Somaya, 2003), our evidence suggests that intra-firm dynamics are also affected. In addition to establishing intellectual property rights in sectors with higher turnover rates (Kim and Marschke, 2005), we find that firms owning patents can strategically alter both the job-hopping proclivity of inventors as well as the distribution of talent released to rivals' actions taken to enforce those patents.

The model and empirical findings of this study reveal several pathways for future work. Employees with the most promising ideas could disproportionately fail to disclose discoveries to litigious employers (Anton and Yao, 1995), which could be captured by adding private information to the model. Whether IP toughness differentially affects employee effort pre- versus post-departure is also worthwhile to consider. In a broad sense, however, our model allows for an effort-induced effect; thus, the predictions should hold either due to the relative value of knowledge of new employers and/or the added stimulus to productivity post-departure.

Assuming that reputation stocks are given at the time of an individual employee's mobility decision limits our ability to inform how employers should determine optimal levels of toughness. Firms file patent infringement lawsuits for numerous reasons, including but not limited to potential expropriation through employee turnover. Clearly, larger forces are at play. Somaya (2003), for example, finds that rivals are more likely to sue one another as the stakes grow larger. Lerner (1995) reports that a credible threat to enforce patents can deter entry. To the extent that firms compete in both product and resource markets, our study highlights the need to investigate how actions in one market space affect the other. By bolstering the retention of skilled workers, litigious action in product markets could reinforce the safeguarding of technologies and know-how in both channels. If such litigiousness undermines a firm's efforts to recruit talent in resource markets or to transfer technological discoveries from other firms, longer-term sources of advantage could be threatened (Coff, 1997). Additional research on how firms balance these potential trade-offs is needed.

Empirically, future studies could test the implications from the model more directly through use of confidential wage data like that used in Moen (2005) and Campbell *et al.* (2012). Such data would also alleviate concerns of bias due to use of patent data, and be used to explore several questions left unanswered in this study. Little is known, for example, about how patent enforcement—as a deterrent against mobility-related expropriation—interacts with incentives-based mechanisms such as stock options. Similarly, its effects on individual-level behavior could be probed more deeply with surveys or qualitative research methods. Hannah (2005), for example, provides a fascinating glimpse into how trade secrets shape employee behavior, reporting that employees entrusted with such secrets respond favorably to the enforcement actions. Qualitative evidence by Marx (2011) provides a less sanguine view of employee reactions to non-compete agreements, reporting anger and dismay over limitations inked in employment contracts. Whether IP toughness results in increased loyalty and commitment as per Hannah (2005) or alienation and resentment as per Marx (2011) is a critical question to address, both from a scholarly and managerial perspective.

Limitations notwithstanding, this study contributes to three related streams of research. First, by revealing an understudied mechanism affecting employee retention—corporate reputations for IP toughness, we contribute to extant models examining mechanisms within existing firms that result in employee mobility and entrepreneurship (Anton and Yao, 1995; Franco and Filson, 2006; Hellmann, 2007; Klepper and Sleeper, 2005). Building on Kim and Marschke (2005), we relax the assumption that patents are ineffectual safeguards against expropriation by insiders. Importantly, we advance prior work by modeling and empirically showing that an employer's aggressiveness in patent enforcement alters the antecedent proclivity of employees to exit.

Our findings are also salient to the strategic management literature on micro-level dynamics in strategic factor markets (Barney, 1991; Castanias and Helfat, 2001; Coff, 1997) and the bargaining power between firms and employees (Campbell *et al.*, 2012). While most of the literature focuses on the efficacy of human resource practices on employee retention (Horn *et al.*, 2012), we show that employee exit decisions are significantly altered by corporate reputations for IP toughness. We therefore add to a growing literature on the legal instruments used to bind employees to incumbent firms, including non-compete clauses (Marx *et al.*, 2009) and work visas (Mithas and Lucas, 2010).

Finally, the study makes an important contribution to the learning-by-hiring literature (e.g., Almeida and Kogut, 1999; Palomeras and Melero, 2010; Rosenkopf and Almeida, 2003). Prior studies typically trace knowledge flows and mobility events using patents and their citations, yet implicitly assume that the enforcement of those patents fails to shape the mobility process. We advance this literature by allowing patent enforcement to endogenously affect employee exits. Our evidence suggests that such enforcement not only curtails the inter-firm knowledge transfers anticipated from mobility events (Agarwal *et al.*, 2009), but also reduces the baseline probability that skilled workers will leave in pursuit of outside options.

In terms of managerial implications, our study provides several practical insights. By establishing reputations for IP enforcement, managers can retain key knowledge workers. This federal lever may be a particularly important alternative to state-level non-compete clauses, which have varying levels of enforceability. However, an effective retention strategy has to include higher compensation to offset the employee's foregone external options. By sharing some of the value created by the idea with the employee, the firm can also save on potential litigation costs that will be incurred should the employee choose to leave. Further, managers need to be cognizant that reputations for IP toughness are not equally effective across employees, and will not help retain those individuals who perceive the outside options to be very high. Accordingly, rather than using "one size fits all" retention strategies, managers should weigh the differences in the idea's internal value to the firm and the external value to their employees when customizing retention packages.

In summary, this study models and empirically demonstrates that a firm's aggressiveness in patent enforcement affects the job-hopping activities of its skilled workers. We find that litigiousness not only reduces the likelihood of employee exits but also serves a sorting function—altering the exit calculus of some employee types more than others. The study thus sheds new light on the strategic levers firms use to capture value from R&D and human capital investments.

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APPENDIX: EMPLOYER'S MAXIMIZATION PROBLEM

The employer maximizes the expected profit from hiring a scientist (Kim and Marschke, 2005):

$$E(\pi) = -w_1 + \iint_S \left[\rho_i - w_2 + \overline{w}\right] \times f\left(\rho_e, \rho_i\right) d\rho_e d\rho_i + \iint_M \left[\rho_i - (1-\gamma)\lambda\rho_i - \gamma L\right] \times f\left(\rho_e, \rho_i\right) d\rho_e d\rho_i \quad \text{(A.1)}$$

where S is a set of ρ_i, ρ_e such that the scientist stays and M is a set where he moves. The employer hires a scientist when the expected profit is positive. The scientist accepts the offer at the beginning of the first period if the marginal product for two periods is $\overline{w}$:

$$2\overline{w} \leq w_1 + \iint_S w_2 f\left(\rho_e, \rho_i\right) d\rho_e d\rho_i + \iint_M \left[\rho_e - \gamma\rho_i + \overline{w}\right] f\left(\rho_e, \rho_i\right) d\rho_e d\rho_i \quad \text{(A.2)}$$

The employer's problem is to choose w_1, w_2 to maximize Equation A.1 subject to the participation constraint of the scientist (Equation A.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_1 so that the participation constraint holds with equality. Substituting for w_1 in Equation A.1 and simplifying, we obtain:

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

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

To obtain w_2, we only need to realize that to induce the scientist to stay, the employer has to offer at least $\rho_e - \gamma\rho_i + \overline{w}$.

$$w_2 = \rho_e - \gamma\rho_i + \overline{w} \text{ for } \rho_i, \rho_e \text{ such that the scientist stays} \quad \text{(A.4)}$$

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_1:

$$w_1 = 2\overline{w} - \iint \left[\rho_e - \gamma\rho_i + \overline{w}\right] f\left(\rho_e, \rho_i\right) d\rho_e d\rho_i \quad \text{(A.5)}$$

Following Kim and Marschke (2005), we assume that $\rho_e = \overline{\rho}_e + \varepsilon_e$ and $\rho_i = \overline{\rho}_i + \varepsilon_i$, where $(\varepsilon_e \in \mathrm{R}, \varepsilon_e > -\rho_i)$. ε_e, ε_i are mean 0 random variables with joint density q and $\overline{\rho}_e, \overline{\rho}_i$ are constant means of ρ_e and ρ_i.

For w_1, integrating Equation A.5, we get:

$$w_1 = \overline{w} - \overline{\rho}_e + \gamma\overline{\rho}_i \quad \text{(A.6)}$$

Note that the w_1 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.

Formal Proofs of Implications

Proof of Implication 1

We now express ρ_i and ρ_e as $\rho_e = \overline{\rho}_e + \varepsilon_e$ and $\rho_i = \overline{\rho}_i + \varepsilon_i$, where ε_e and ε_i are mean 0 random variables with joint density q, and $\overline{\rho}_e, \overline{\rho}_i$ are constant means. To focus on meaningful (positive) values of the external option, we further assume that $(\varepsilon_e > -\rho_i)$. After substituting in and expressing Equation 6 from the main text as an inequality between the random component of the external idea value, ε_e, and a function of the random component of the internal idea value, ε_i, Equation 6 becomes:

$$\varepsilon_e > \varepsilon_i\ (\lambda + \gamma - \lambda\gamma) + \overline{\rho}_i\ (\lambda + \gamma - \lambda\gamma) - \overline{\rho}_e + \gamma L \tag{A.7}$$

Equation A.7 implies that the *ex ante* likelihood of mobility falls as the right-hand side of the inequality grows larger. The external value of the idea must be larger to entice the scientist to move.

To explicitly derive the unconditional probability of exit, we assume that ε_e and ε_i are independent normally distributed random variables. Since the marginal densities of ε_e and ε_i are also normal, and the two random variables are independent, we have:

$$\varepsilon_e - \varepsilon_i\ (\lambda + \gamma - \lambda\gamma) \sim \mathrm{N}\left(0, \sigma_{\mathrm{e}}^2 + (\lambda + \gamma - \lambda\gamma)^2\, \sigma_{\mathrm{i}}^2\right) \tag{A.8}$$

In the event that the scientist moves (D = 1), Equation A.8 leads to the following expression:

$$\begin{aligned}
\Pr(D = 1) &= \Pr\big(\varepsilon_e - \varepsilon_i\ (\lambda + \gamma - \lambda\gamma) \\
&\quad > \overline{\rho}_i\ (\lambda + \gamma - \lambda\gamma) - \overline{\rho}_e + \gamma L\big) \\
&= \Pr\Big(\frac{1}{\sqrt{\sigma_{\mathrm{e}}^2 + (\lambda + \gamma - \lambda\gamma)^2\, \sigma_{\mathrm{i}}^2}} \left[\varepsilon_e - \varepsilon_i\ (\lambda + \gamma - \lambda\gamma)\right] \\
&\quad > \frac{1}{\sqrt{\sigma_{\mathrm{e}}^2 + (\lambda + \gamma - \lambda\gamma)^2\, \sigma_{\mathrm{i}}^2}} \\
&\quad\quad \times \left[\overline{\rho}_i\ (\lambda + \gamma - \lambda\gamma) - \overline{\rho}_e + \gamma L\right]\Big) \\
&= \Phi\Big(-\frac{1}{\sqrt{\sigma_{\mathrm{e}}^2 + (\lambda + \gamma - \lambda\gamma)^2\, \sigma_{\mathrm{i}}^2}} \\
&\quad\quad \times \left[\overline{\rho}_i\ (\lambda + \gamma - \lambda\gamma) - \overline{\rho}_e + \gamma L\right]\Big)
\end{aligned} \tag{A.9}$$

To evaluate the effect of litigiousness on the likelihood of mobility, we need to evaluate the sign of $\partial \Pr(D = 1)/\partial\gamma$. Differentiating Equation A.9 with respect to γ, simplifying and rearranging terms, we obtain the following:

$$\begin{aligned}
&\frac{\partial \Pr(D = 1)}{\partial\gamma} \\
&= \phi(.) \left[\frac{\begin{array}{c}\left(\sigma_{\mathrm{i}}^2 \lambda \overline{\rho}_{\mathrm{e}} \gamma - \sigma_{\mathrm{i}}^2 \lambda \overline{\rho}_{\mathrm{e}}\right) + \left(L\sigma_{\mathrm{i}}^2 \lambda\gamma^2 - L\sigma_{\mathrm{i}}^2 \lambda\gamma\right) \\ + \left(L\sigma_{\mathrm{i}}^2 \lambda^2\gamma - L\sigma_{\mathrm{i}}^2 \lambda^2\right) + \left(L\sigma_{\mathrm{i}}^2 \lambda^2\gamma - L\sigma_{\mathrm{i}}^2 \lambda^2\gamma^2\right) \\ -\sigma_{\mathrm{i}}^2 \gamma \overline{\rho}_{\mathrm{e}} - \overline{\rho}_{\mathrm{i}} \sigma_{\mathrm{e}}^2 - L\sigma_{\mathrm{e}}^2\end{array}}{\left(\sigma_{\mathrm{e}}^2 + (\lambda + \gamma - \lambda\gamma)^2\, \sigma_{\mathrm{i}}^2\right)^{3/2}}\right] \\
&= -\phi(.) \left[\frac{\begin{array}{c}(1 - \gamma)\left[\sigma_{\mathrm{i}}^2 \lambda \overline{\rho}_{\mathrm{e}} + L\sigma_{\mathrm{i}}^2 \lambda\gamma + L\sigma_{\mathrm{i}}^2 \lambda^2\gamma\right] \\ + L\sigma_{\mathrm{i}}^2 \lambda^2 + \sigma_{\mathrm{i}}^2 \gamma \overline{\rho}_{\mathrm{e}} + \overline{\rho}_{\mathrm{i}} \sigma_{\mathrm{e}}^2 + L\sigma_{\mathrm{e}}^2\end{array}}{\left(\sigma_{\mathrm{e}}^2 + (\lambda + \gamma - \lambda\gamma)^2\, \sigma_{\mathrm{i}}^2\right)^{3/2}}\right]
\end{aligned} \tag{A.10}$$

The sign of $\partial \Pr(D = 1)/\partial\gamma$ is given by the numerator of the fraction in Equation A.10. As it is obvious from Equation A.10, all terms in the fraction are positive and, consequently, $\partial \Pr(D = 1)/\partial\gamma < 0$, which concludes the proof of Implication 1.

Proof of Implication 2

To show that Implication 2 holds, we revisit Equation A.7 and derive the threshold value of $\varepsilon_e = \varepsilon_e^*$. All inventors with draws above ε_e^* will move. From Equation A.7, the mobility threshold of the external value is:

$$\varepsilon_e^* = \varepsilon_i\ (\lambda + \gamma - \lambda\gamma) + \overline{\rho}_i\ (\lambda + \gamma - \lambda\gamma) - \overline{\rho}_e + \gamma L \tag{A.11}$$

For the expected value of external ideas of mobile inventors, we obtain:

$$\begin{aligned}
E\left[\varepsilon_e \mid \varepsilon_e > \varepsilon_e^*\right] = \iint &\big[\varepsilon_e \mid \varepsilon_e > \varepsilon_i\ (\lambda + \gamma - \lambda\gamma) \\
&+ \overline{\rho}_i\ (\lambda + \gamma - \lambda\gamma) - \overline{\rho}_e + \gamma L\big] \\
&\times f\left(\varepsilon_e, \varepsilon_i\right) d\varepsilon_e d\varepsilon_i
\end{aligned} \tag{A.12}$$

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We need to show that $\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\right]/\partial\gamma$ is positive. Let's assume $\varepsilon_i = \tilde{\varepsilon}_i$. We will temporarily treat ε_i as a fixed number. Then, we have:

$$E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right] = \frac{\displaystyle\int_{\varepsilon_e^*(\tilde{\varepsilon}_i)}^{\varepsilon_{e,\max}} \varepsilon_e f\left(\varepsilon_e\right) d\varepsilon_e}{\displaystyle\int_{\varepsilon_e^*}^{\varepsilon_{e,\max}} f\left(\varepsilon_e\right) d\varepsilon_e} \tag{A.13}$$

where $f(\varepsilon_e)$ is the marginal density of ε_e. Because ε_i and ε_e are independent, the density function of ε_e does not depend on $\tilde{\varepsilon}_i$. Note that the following holds:

$$\frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right]}{\partial\gamma} = \frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right]}{\partial\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)}\frac{\partial\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)}{\partial\gamma} \tag{A.14}$$

$$\frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right]}{\partial\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)} = \frac{f\left(\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right)}{1 - F\left(\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right)} \times \left[E\left(\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right) - \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right] \tag{A.15}$$

Under the assumption Equation A.8 of normality and independence, one can easily show that Equation A.15 is positive. This implies that the sign of $\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right]/\partial\gamma$ will be the same as the sign of $\partial\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)/\partial\gamma$. Differentiating the threshold ε_e^* with respect to litigiousness, γ, we obtain the following:

$$\frac{\partial\varepsilon_e^*\left(\tilde{\varepsilon}_i\right)}{\partial\gamma} = \left(\tilde{\varepsilon}_i + \overline{\rho}_i\right)(1-\lambda) + L \tag{A.16}$$

where $\tilde{\varepsilon}_i$ is ε_i being treated as a fixed number. Constraining the internal ideas only to meaningful positive values of ρ_i, ($\varepsilon_i > -\rho_i$), we see that the term Equation A.16 is positive, which implies the following:

$$\frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\tilde{\varepsilon}_i\right)\right]}{\partial\gamma} > 0, \text{for any } \tilde{\varepsilon}_i \tag{A.17}$$

Now, we can treat ε_i as a random variable. The inequality follows directly from Equation A.17, completing the proof:

$$\frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\right]}{\partial\gamma} = E\left[\frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\varepsilon_i\right)\right]}{\partial\gamma}\right] = \int \frac{\partial E\left[\varepsilon_e|\ \varepsilon_e > \varepsilon_e^*\left(\varepsilon_i\right)\right]}{\partial\gamma} f\left(\varepsilon_i\right) d\varepsilon_i > 0 \tag{A.18}$$

Proof of Implication 3

To show that Implication 3 holds, we start by expressing the mobility threshold in terms of the internal idea value (scientists with internal ideas below this value will move):

$$\varepsilon_i^* = \frac{\left(\tilde{\varepsilon}_e + \overline{\rho}_e - \gamma L\right)}{(\lambda + \gamma - \lambda\gamma)} - \overline{\rho}_i, \quad \text{if } \tilde{\varepsilon}_e > \gamma L - \overline{\rho}_e, \text{and}$$
$$\varepsilon_i^* = -\overline{\rho}_i, \rho_i = 0 \quad \text{if } -\overline{\rho}_e < \tilde{\varepsilon}_e \le \gamma L - \overline{\rho}_e \tag{A.19}$$

If the value of external ideas is very low (i.e., if $-\overline{\rho}_e < \varepsilon_e < \gamma L - \overline{\rho}_e$), all scientists stay. The conditional expectation of the internal idea values of mobile scientists has the form:

$$E\left[\varepsilon_i|\ \varepsilon_i \le \varepsilon_i^*\right] = \iint\left[\varepsilon_i|\ \varepsilon_i < \frac{\left(\varepsilon_e + \overline{\rho}_e - \gamma L\right)}{(\lambda + \gamma - \lambda\gamma)} - \overline{\rho}_i\right] f\left(\varepsilon_e, \varepsilon_i\right) d\varepsilon_e d\varepsilon_i, \text{ if } \varepsilon_e > \gamma L - \overline{\rho}_e, \text{and}$$
$$E\left[\varepsilon_i|\ \varepsilon_i \le 0\right] = -\overline{\rho}_i, \rho_i = 0, \text{ if } -\overline{\rho}_e < \varepsilon_e \le \gamma L - \overline{\rho}_e \tag{A.20}$$

To show how the value of internal ideas changes with respect to litigiousness, we need to evaluate the term $\partial E\left[\varepsilon_i|\ \varepsilon_i < \varepsilon_i^*\right]/\partial\gamma$. The proof of Implication 3 is symmetric to the proof of Implication 2. To complement the above, Equations A.14 and A.15 now become:

$$\frac{\partial E\left[\varepsilon_i|\ \varepsilon_i < \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right]}{\partial\gamma} = \frac{\partial E\left[\varepsilon_i|\ \varepsilon_i < \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right]}{\partial\varepsilon_i^*\left(\tilde{\varepsilon}_i\right)}\frac{\partial\varepsilon_i^*\left(\tilde{\varepsilon}_e\right)}{\partial\gamma} \tag{A.21}$$

$$\frac{\partial E\left[\varepsilon_i \mid \varepsilon_i < \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right]}{\partial \varepsilon_i^*\left(\tilde{\varepsilon}_i\right)} = \frac{f\left(\varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right)}{F\left(\varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right)} \times \left[\varepsilon_i^*\left(\tilde{\varepsilon}_e\right) - E\left(\left[\varepsilon_i \mid \varepsilon_i < \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right)\right)\right] \quad \text{(A.22)}$$

Under the assumption of Equation A.8, A.22 is positive. This implies that the sign of $\partial E\left[\varepsilon_i \mid \varepsilon_i < \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right]/\partial\gamma$ will be the same as the sign of $\partial\varepsilon_i^*\left(\tilde{\varepsilon}_e\right)/\partial\gamma$. The sign of this threshold differentiated with respect to litigiousness, γ:

$$\frac{\partial \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)}{\partial\gamma} = -\frac{(1-\lambda)\left(\tilde{\varepsilon}_e + \overline{\rho}_e - \gamma L\right)}{(\lambda+\gamma-\lambda\gamma)^2} - \frac{L}{(\lambda+\gamma-\lambda\gamma)} \text{ if } \tilde{\varepsilon}_e > \gamma L - \overline{\rho}_e \quad \text{(A.23)}$$

where $\tilde{\varepsilon}_e$ is ε_e being treated as a fixed number. If $\tilde{\varepsilon}_e > \gamma L - \overline{\rho}_e$, both terms in Equation A.23 are negative, and thus $\partial\varepsilon_i^*\left(\tilde{\varepsilon}_e\right)/\partial\gamma \le 0$, which implies the following:

$$\frac{\partial E\left[\varepsilon_i \mid \varepsilon_i > \varepsilon_i^*\left(\tilde{\varepsilon}_e\right)\right]}{\partial\gamma} < 0, \text{for any } \tilde{\varepsilon}_e \quad \text{(A.24)}$$

Now, we can treat ε_e as a random variable. The inequality follows directly from Equation A.24, which completes the proof:

$$\frac{\partial E\left[\varepsilon_i \mid \varepsilon_i < \varepsilon_i^*\right]}{\partial\gamma} = E\left[\frac{\partial E\left[\varepsilon_i \mid \varepsilon_i < \varepsilon_i^*\left(\varepsilon_e\right)\right]}{\partial\gamma}\right] = \int \frac{\partial E\left[\varepsilon_i \mid \varepsilon_i < \varepsilon_i^*\left(\varepsilon_e\right)\right]}{\partial\gamma} f\left(\varepsilon_e\right) d\varepsilon_e < 0 \quad \text{(A.25)}$$

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix S1: More stars stay, but the brightest ones still leave: job hopping in the shadow of patent enforcement

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