

REPUTATIONS FOR TOUGHNESS IN PATENT ENFORCEMENT: IMPLICATIONS FOR KNOWLEDGE SPILLOVERS VIA INVENTOR MOBILITY[†]

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'Job hopping' by engineers and scientists is widely heralded as an important channel for knowledge spillovers within industries. Far less is known, however, about the actions firms take to reduce the outward flow of knowledge through markets for skilled labor. This study investigates the efficacy of a lever that has received little research attention: corporate reputations for toughness in patent enforcement. Drawing on unique data on enforcement activity, intra-industry inventor mobility, and patent citations in the U.S. semiconductor industry, we find that a firm's litigiousness significantly reduces spillovers otherwise anticipated from departures of employee inventors, particularly when the hiring organizations are entrepreneurial ventures. Surprisingly, the deterrent effects of patent enforcement are similar in magnitude for firms located in California, a state characterized by open norms for knowledge trading, and firms headquartered in other U.S. states. The study sheds new light on the strategic actions firms use to prevent rivals from capturing value from their investments in human capital and research and development. Copyright © 2009 John Wiley & Sons, Ltd.

INTRODUCTION

The best way to send information is to wrap it up in a person.

- J. Robert Oppenheimer (quoted in Stephan, 2006: 71)

The mobility of scientists and engineers in labor markets provides a vibrant channel for knowledge dissemination within industries (Arrow, 1962; Stephan, 1996; Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Agarwal, Echambadi,

Franco, and Sarkar, 2004; Klepper and Sleeper, 2005). In a survey of 100 fast-growing private companies, for example, Bhide (1994) finds that 71 percent of the entrepreneurial founders commercialized ideas they had encountered or discovered while working at other companies. In an earlier survey of research and development (R&D) managers, Levin, Klevorick, Nelson and Winter (1987) similarly report that hiring employees from rivals enabled established firms to learn about external technologies more efficiently and, in turn, hastened the speed of imitation. Kerstetter (2000) further documents celebrated employee raids designed to gain access to competitors' technologies, claiming that technology companies often live by the adage, 'If you have trouble with the competition, simply raid its talent' (Kerstetter, 2000: 43).

For firms competing in knowledge-intensive industries, however, departures of key talent can

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deliver a double blow—the firms lose valuable human capital and rivals stand to gain technological know-how at their expense. This study investigates the efficacy of a potential lever for *reducing* knowledge spillovers in markets for skilled labor: building a corporate reputation for being tough in the enforcement of intellectual property (IP) rights.¹ The past few decades have witnessed an explosion of IP-related lawsuits in the United States, particularly over patent-protected technologies (Landes and Posner, 2003; Bessen and Meurer, 2006). The surge in case filings is simultaneously attributed to institutional reforms in the mid-1980s that strengthened the bargaining power of U.S. patent owners (Jaffe, 2000; Gallini, 2002) and intensified efforts by firms to capture value from innovation-related investments (Somaya, 2003). Are there potential reputational effects of these litigious acts, and what are the implications for spillovers via employee departures? Extant literature is silent on this issue, leaving a gap that we propose to fill in this study.

Anecdotal evidence suggests that some firms are indeed willing to aggressively protect their exclusionary rights to technological know-how, often in direct response to unanticipated employee exits. National Semiconductor, for instance, filed a lawsuit in 1984 against Linear Technology, a start-up founded by former employees to commercialize improved chip technologies they had discovered while working at National. In justifying the decision, National's chief executive officer (CEO) at the time noted that 'it might easily cost \$60 million to develop a new semiconductor technology... With investments of such magnitude at stake today, you do get sensitive' (Larson, 1984: 1). To stem a similar tide of employee defections to start-ups in the 1980s, Intel's CEO reportedly issued a blanket order to his general counsel to file two IP lawsuits per quarter to dissuade engineers from 'walking out the door' with proprietary technologies (Jackson, 1997: 214). More recently, Intel sued Broadcom in a tug-of-war over engineering talent, voicing concerns about a 'systematic effort to recruit [Intel] employees' (Hachman, 2000).² As part of the dispute, Intel

accused Broadcom—and a company Broadcom was in the process of acquiring—of infringing on five Intel patents, threatening to halt the manufacture and sale of core products at both companies. The case settled quickly on terms favorable to Intel (AP Newswire, 2000).

To systematically investigate the implications of such litigiousness for mobility-driven spillovers, we draw upon the strategy and economics literature on corporate reputations (Kreps and Wilson, 1982; Milgrom and Roberts, 1982; Weigelt and Camerer, 1988; Shamsie, 2003). Viewing IP enforcement as a general 'reputation-building' strategy (rather than a particular tactic employed against a particular litigant or patent), we develop three hypotheses. First, we predict that a firm's reputation for toughness will significantly reduce the spillovers otherwise anticipated from employee departures to rivals. Second, we predict that tough reputations will be particularly powerful in curbing spillovers to 'entrepreneurial firms' (i.e., organizations that are young, small, or private), given their lesser ability to fund and withstand an IP-related dispute. Similarly, we expect that entrepreneurial firms' threats of litigious action will be perceived as less credible than the threats of established firms, thus eroding the reputation effects associated with IP rights enforcement. Finally, we predict that IP toughness will be less effectual as a spillover-reduction mechanism for California-based companies because of the unusually strong norms of informal knowledge trading and reciprocity characterizing innovative activity in that state (Saxenian, 1994; Gilson, 1999).

We test these predictions in the U.S. semiconductor industry—a canonical setting used in prior studies to illustrate the technological spillovers associated with the firm-to-firm mobility of engineers and scientists (Angel, 1989; Almeida and Kogut, 1999). We integrate hand collected data on patent litigation histories with broader patterns of inventor mobility and patent citation behavior in the industry in the 1973–2003 period. Building cumulatively on prior studies on 'learning-by-hiring' in the semiconductor industry (e.g., Rosenkopf and Almeida, 2003; Almeida, Dokko, and Rosenkopf, 2003; Song, Almeida, and Wu, 2003), we estimate spillovers using patent citations as a proxy. More specifically, we estimate the extent to which a firm's reputation for IP toughness (litigiousness about protecting intellectual property) reduces the extent of spillovers that otherwise

¹ For brevity, we use the term 'IP enforcement' hereafter to refer to enforcement of intellectual property rights.

² This dispute is particularly interesting since Intel provided pre-IPO venture financing and technical assistance to Broadcom in hopes of creating complementarities in their product lines (AP Newswire, 2000).

would be predicted when employees leave to work at other firms within the industry.

This study contributes to three literature streams. The first is research on knowledge spillovers through employee mobility, where Agarwal, Audretsch, and Sarkar (2007) call for examination of the boundary conditions and constraints on interorganizational transfers of knowledge through employee mobility and entrepreneurship. Our study theorizes and provides evidence of the negative impact of reputations for IP toughness on interorganizational knowledge flows due to employee mobility. Second, our study builds on and extends research on reputation effects in corporate strategy. Just as firms can enhance performance by developing reputations for being 'good' (see Roberts and Dowling, 2002), so can they garner strategic advantages by developing reputations for being tough in IP enforcement. Finally, for the literature on IP litigation (Somaya, 2003; Lanjouw and Schankerman, 2004), our study raises the possibility that litigious action confers reputation effects that shape spillovers in markets for skilled labor, thus revealing a source of asymmetry between litigating parties that has received little prior attention. In this context, our study also highlights the differential effects of IP rights enforcement on start-ups, which is relevant for policies aimed at fostering entrepreneurial activity and economic growth.

THEORETICAL FRAMEWORK

Knowledge spillovers via employee mobility

According to the knowledge-based view of the firm, privately held knowledge is an important source of competitive heterogeneity (Grant, 1996; Spender, 1996; Teece, Pisano, and Shuen, 1997). A rich body of research has focused on firms existing for the acquisition and creation of organizational knowledge (Griliches, 1979; Cohen and Levinthal, 1990). Procedures, norms, rules, and forms serve as repositories of such information (Nelson and Winter, 1982; Levitt and March, 1988; March, 1991) and potentially give a firm a competitive advantage, given the difficulty other firms encounter in the replication and imitation of such 'tacit' knowledge.

Importantly, organizational investment in R&D—a primary method of new knowledge creation—often occurs through imparting human capital to employees. Simon (1991) emphasized that learning occurs in the minds of individuals: organizations learn either by their employees learning or by hiring new employees with new knowledge. The symbiotic relationship between organizational and individual knowledge implies that firms that invest in the knowledge-creating activities of their employees also run the risk of losing this value-creating asset. Unlike other value-generating resources, knowledge embedded in employees is a precarious possession—individuals can quit at any time (Coff, 1997). In keeping with Simon's (1991) identification of learning through hiring, scholars have found strong support for knowledge spillovers or transfer via employee mobility (Bhide, 1994; Agrawal, Cockburn, and McHale, 2006., Almeida and Kogut, 1999; Oetl and Agrawal, 2008; Phillips, 2002; Rosenkopf and Almeida, 2003; Agarwal *et al.*, 2004; Klepper and Sleeper, 2005). While the early literature on agglomeration and regional economics focused on localization as a primary mechanism that fosters knowledge spillovers, recent work has drawn attention to the role of employee mobility in overcoming 'local search' (Rosenkopf and Almeida, 2003). Saxenian (1994) and Klepper (2002) attribute the development of regional economies to high levels of knowledge spillovers via employee mobility/entrepreneurship. Indeed, Gilson (1999) argues that the success of firms located in the Silicon Valley of California is largely attributable to the reluctance of California courts to enforce noncompete clauses, which amplified the effects of employee mobility on knowledge diffusion.

The above literature, in general, has focused on the benefits for the *recipient* firm of acquiring knowledge by hiring employees from rivals.³ Almeida and Kogut (1999), Rosenkopf and Almeida (2003), and Song *et al.* (2003), for instance, provide empirical evidence of the benefits for innovation (as measured by patenting activity) for semiconductor firms that hire employees from other firms within the industry. Scholars have also

³ As in prior studies (Rosenkopf and Almeida, 2003), here a *recipient* firm is a potential receiver of technological knowledge from another firm, and a *source* firm is a potential supplier of technological knowledge to others. Firms can assume both roles.

examined whether employee mobility engenders explorative or exploitative search, and how firms should optimally organize themselves for knowledge transfer benefits (Madsen, Mosakowski, and Zaheer, 2003; Tzabbar, Silverman, and Aharonson, 2006). Hiring experienced engineers and scientists from established firms is particularly important for entrepreneurial companies (Angel, 1989; Almeida *et al.*, 2003), and the related research on spin-outs—new ventures founded by mobile employees—also extols the benefits of inherited knowledge (Agarwal *et al.* 2004; Klepper and Sleeper 2005).

Less attention, however, has been given to the potential adverse effects on *source* firms, particularly when recipient firms are actual or potential competitors in the same industry. Although source firms may receive benefits when former employees join noncompeting firms (Somaya, Williamson, and Lorinkova, 2007), employees' joining rival firms may impose a negative externality: a source firm stands to lose valuable resources when employees leave and further, such departures potentially heighten the capabilities of rivals, to the detriment of the source firm's own competitive advantage. Some scholars have examined contractual solutions to the mobility-induced spillover problem, such as high wages, stock options, and noncompete clauses in employment contracts (Pakes and Nitzan, 1983; Fallick, Fleischman, and Rebitzer, 2006; Marx, Strumsky, and Fleming, 2009). However, labor economists have noted that such mechanisms may not solve the problem entirely, given positive transaction costs in the writing and enforcements of employment contracts (Acemoglu and Pischke, 1998; 1999; Kim and Marschke, 2005). Franco and Filson (2006) show that employees with entrepreneurial aspirations may not value monetary rewards alone, and Anton and Yao (1995) discuss why expropriation hazards in labor markets are imperfectly solved through contracts and incentives. Further, noncompete agreements are difficult to enforce in several states, including California, where many technology-intensive companies are based.

Alternatively, firms may adapt their IP strategies in response to concerns about leakage in labor markets. Kim and Marschke (2005) raise the intriguing possibility that, when confronted with high turnover among skilled employees, firms seek to protect a larger share of their inventions with

patents, which are easier to enforce than trade secrets and noncompete agreements.⁴ Left unanswered by their study, however, is whether firms gain reputation benefits through patent enforcement. Thus, there is a need to pay more attention to the issue of whether firms adopt specific strategies to combat knowledge spillovers via employee mobility, and their efficacy in doing so. We are particularly interested in whether variation in firms' propensity to litigate to protect intellectual property—and their resultant reputations for toughness—affects the spillovers anticipated when employees leave.

Review of the literature on reputations and firm performance

Corporate reputations have long been cast as strategic assets. Scholars in economics, sociology, and strategy have documented the beneficial effects of building a positive reputation, or 'brand capital,' on performance (Shapiro, 1983; Podolny, 1993; Rao, 1994; Roberts and Dowling, 2002; Shamsie, 2003). Being known as a high-quality producer yields a premium (Shapiro, 1983), particularly under conditions of uncertainty, when past reputation and high status can signal continued excellence (Spence, 1974; Podolny, 1993). Similarly, corporations admired by peers 'outperform' less reputable firms (Roberts and Dowling, 2002).

While this recent work focuses on the returns from being 'good,' an older literature in industrial economics highlights the strategic advantages of being 'tough,' particularly in the context of entry deterrence and predatory pricing (Kreps and Wilson, 1982; Milgrom and Roberts, 1982; Weigelt and Camerer, 1988). In reviewing this literature, Carlton and Perloff (2005) discuss the two conditions under which reputation-building investments can yield strategic benefit. First, the investing organization must have an advantage over its rivals.

⁴ Although trade secrets help protect against leakage of business-proprietary information (Cohen, Nelson, and Walsh, 2000; Hannah, 2005), proving theft can be difficult and poses a disclosure paradox: to establish theft, potential plaintiffs must reveal valuable private information, making them reluctant to file suit. In contrast, patent-protected inventions are already public. Patents also confer a strategic advantage over trade secrets when improvements are easy to reverse engineer: while independent invention (through reverse engineering or other means) is a legal defense against trade secret theft allegations, reverse engineering of patented technologies can lead to liability for infringement (Moore, Michel, and Lupo, 1999).

Second, it must demonstrate a credible commitment to following through with the reputational strategy, regardless of a rival's actions.

Asymmetry between firms helps ensure that these two conditions are met. Imperfect information can result in an existing organization successfully engaging in predation or entry deterrence if rivals or potential entrants are uncertain regarding its options, motivation, or behavior (Milgrom and Roberts, 1982). Given imperfect information, rival firms are likely to infer a focal firm's current and future behavior from its past behavior. The focal firm, in such a situation, can credibly commit by investing in building a reputation for toughness—even if the cost of doing so in one particular strategic interaction exceeds the benefits in that instance—since the expected benefits of such a reputation include inhibiting competition by deterring other firms' entry (Scherer, 1980; Kreps and Wilson, 1982; Milgrom and Roberts, 1982).

By engaging in costly actions, such as establishing a history of predatory pricing or raising rival's costs through advertising campaigns, firms can build a reputation for toughness that permits them to earn superior rents (Carlton and Perloff, 2005). The costliness of the action helps ensure a 'separating equilibrium.' If 'passive' actors can easily mimic the behavior of 'tough' actors in the search for performance enhancements, others will find it difficult to predict future action on the basis of past behavior; in turn, a 'pooling equilibrium' arises, and the signaling function of strategic action unravels (Spence, 1974; Weigelt and Camerer, 1988). Finally, to shape the expectations of third parties, an action must also be observable (as are pricing actions, marketing campaigns, and patent lawsuits).

Reputations for IP toughness and knowledge spillovers via employee mobility

Insights from the models cited above extend to strategic actions taken to reduce the risk that technological know-how is expropriated through employee mobility. When employees discover a novel, nonobvious, and useful invention during work, legal rights to patents based on those discoveries are assigned (with rare exception) to their employers (Merges, 1999).⁵ Employees who

leave to join or establish other companies may not have legal rights to make, use, or build upon patented technologies owned by their former employers unless explicit permission to do so has been granted through license agreements. Even if an ex-employee (and his/her new employer) tries to 'design around' prior patents, the success of such solutions can be costly to ascertain. As legal scholars note, it is difficult to determine whether changes to and 'designs-around' a patented device will be deemed infringement unless a case has been adjudicated (Moore *et al.*, 1999). Given these ownership rights and legal ambiguities, patents may help firms not only to safeguard against unauthorized use of knowledge by imitators and rivals, but also to protect against misappropriation by firm insiders (Kim and Marschke, 2005).

Although firms that engage in costly R&D investments often patent their innovations to secure intellectual property rights in the products of these investments (Cohen *et al.*, 2000; Levin *et al.*, 1987), patents confer a right, but not an obligation, to sue others for alleged infringement.⁶ The cost of enforcing patents is several orders of magnitude larger than the cost of acquiring them. Lemley (2001), for example, estimates that the cost of obtaining a typical U.S. patent, inclusive of filing and attorney fees, is approximately \$20,000. Meanwhile, the American Intellectual Property Law Association (AIPLA, 2007) estimate of litigation costs for a patent dispute of average complexity hovers between \$3 and \$5 million. Patent enforcement is therefore a particularly useful lever for firms seeking to build reputations for being tough about the unauthorized use of their proprietary technologies. The costliness of the

employers) to a pre-invention assignment regime (employees signed over invention rights *ex ante* as an employment contract condition). According to Fisk, 'Once employer lawyers disabused judges of the inventor-hero image in favor of the modern vision of inventive employees working in a big, employer-financed laboratory, the law began to change' (Fisk, 1998: 1198). Modern U.S. courts continue to uphold an employer's interest in 'protecting confidential information, trade secrets, and, more generally, its time and expenditures in training and imparting skills and knowledge to its paid work force' (Fisk, 1998: 1196n281).

⁶ We refer readers to Moore *et al.* (1999) and Lanjouw and Schankerman (2004) for detailed discussions regarding patent rights and enforcement procedures. It is important to recognize, however, that patent rights are exclusionary, not affirmative: a patent, (if valid) grants a patentee a time-limited right to *exclude* others from use of the patented invention; it does not grant the patentee the right to *use* the patented invention if such use infringes upon others' rights.

⁵ Fisk (1998) describes the shift in the early 1900s from a shop rights regime (employees owned patents that were licensed to

activity has an important sorting function. Moreover, the press frequently monitors patent lawsuits, which makes them widely observable. Employees and their potential hirers can therefore gauge which firms are likely to adopt a more protective stance against unauthorized uses of proprietary technologies.

Thus, corporate reputations for patent litigiousness should moderate the extent to which proprietary technology disseminates through employee exits. Consistently with the first condition for a reputation-building strategy (Carlton and Perloff, 2005), the source firm has an advantage over its rival by virtue of its ownership of patents on the innovation—with the ownership of IP being analogous to cost advantage in the predation/entry deterrence models. If the source firm has additionally invested in the costly and observable activity of engaging in IP litigation, departed employees and a recipient (hiring) firm will perceive a credible threat, so the second condition for the strategy to be successful is met (Carlton and Perloff, 2005). Absent full information on the source firm's actions, its ex-employees and the hiring organization will use its past behavior to make inferences about future actions to curb unauthorized use of proprietary know-how and technologies. In turn, incentives to misappropriate technologies from firms perceived as tough will be diminished.

We note that it is not necessary for a firm to actively pursue IP litigation against all, or even many, of its ex-employees. Again reflecting market-entry deterrence models (Scherer, 1980), the IP toughness model does not focus on what patents a firm defends or which firms it targets, but rather focuses on whether it builds an overall reputation for toughness. Even if the costs of being litigious in a particular dispute outweigh the benefits, the deterrence of future knowledge spillovers can justify the investment. This logic also suggests that reputations can be built through litigious actions that are not specifically directed against mobility-driven leakage. If a former employer has invested in prior litigation to bar direct product market rivals from unauthorized use of its patent-protected technologies, hiring organizations and employees may perceive that the firm is tough rather than passive in protecting its IP.⁷ In line

with the strategic deterrence literature, these reputations can shape others' behavior irrespective of whether action is realized in a particular instance. Accordingly, we make the following prediction:

Hypothesis 1: Reputations for IP toughness will reduce the spillovers otherwise anticipated from intra-industry inventor mobility.

Our second set of predictions concerns whether IP toughness is a more efficacious mechanism for deterring employee mobility-related spillovers for entrepreneurial or established firms, given differences between them regarding access to financial or managerial resources. Extant research typically differentiates between entrepreneurial and established firms on the basis of three related, yet conceptually distinct, firm-level characteristics: (a) access to public equity markets (i.e., private ownership status), (b) size, and (c) age. Each of these characteristics can affect the organizational and financial burdens associated with IP litigation, thus shaping firm behavior toward potential conflict. Since these attributes tend to be highly correlated with one another, we refer to private/small/young firms collectively as 'entrepreneurial' and distinguish them from their more 'established' counterparts.

If recipient firms are differentially affected by the potential costs and disruptions of an IP-related dispute, we should expect heterogeneous responses to reputations for IP toughness. The law and economics literature (e.g., Lerner 1995; Lanjouw and Lerner, 2001) suggests that, vis-à-vis established firms, entrepreneurial firms are at a disadvantage in funding or withstanding lawsuits and will take care to avoid conflict when hiring employees from firms with reputations for IP toughness. Lerner (1995) finds evidence supportive of this prediction by examining the patent filings of new biotechnology firms with various levels of litigation costs: he shows that firms with high litigation costs (firms with fewer financial resources and low litigation experience) are more likely to avoid patenting in subclasses in which there have been other court-ordered awards to patent holders, particularly when

⁷ For example, in the 1980s, Intel invested heavily in patent enforcement against its main product market rival, Advanced

Micro Devices (AMD) (Jackson, 1997). Even though the lawsuits against AMD did not pertain to employee exits, these actions informed perceptions about the toughness of Intel.

low-litigation-cost firms have secured prior ownership stakes in those areas.⁸

Turning to specific characteristics associated with entrepreneurial firms, we note that imperfections in capital markets can disproportionately affect the ability of firms to finance costly litigation (Lanjouw and Lerner, 2001). Relative to public companies, private firms are at a disadvantage when raising funds to defend against claims of infringement by either issuing additional equity to investors or securing loans. As Nesheim (2000) notes, 'Venture capitalists hate investing in a start-up that gets bogged down in lawsuits that drain precious time and cash resources' (Nesheim, 2000: 33).

Further, IP legal disputes can be particularly deleterious for small firms. Small firms are more likely than large ones to forgo certain research opportunities because of the potential disruption and legal disputes (Koen, 1991) associated with them. Lanjouw and Schankerman (2004) suggest that small firms are disproportionately handicapped when settling IP-related disputes because their patent portfolios are smaller than those of larger firms, which puts them at a bargaining disadvantage when 'trading' IP rights. Small firms also are less likely than larger firms to have in-house legal counsel (Lerner, 1995; Lanjouw and Schankerman, 2004), which puts them at a cost disadvantage when managing IP disputes.

Finally, the opportunity costs of becoming embroiled in an IP-related lawsuit should loom particularly large for nascent organizations. Little prior research and quantitative evidence support this claim, yet the conjecture resonates with qualitative accounts of IP attorneys and entrepreneurs. Following an IP lawsuit filed by IBM, the vice president of a start-up founded by ex-IBM employees (Cybernex Corp) reported that the lawsuit 'scare[d] off new recruits, customers, suppliers, and, most important, investors' (Larson, 1984: 2).

⁸ Related work in law and economics examines how costly regulations or legal expenses differentially affect firms. In an influential early study, Bartel and Thomas (1987) argue that 'if the cost burden of certain regulations falls heavily on one group of firms and lightly on a second group, then an indirect effect of these regulations is to provide cost advantage to the second group of firms' (Bartel and Thomas, 1987: 239). The authors find that 'compliance asymmetries' in the costs of meeting occupational safety and environmental regulations favor large firms over smaller ones. This work, which is not commonly cited in strategy research, is informative as to how costly activities may have heterogeneous effects on firm behavior and thus, on competitive advantage.

In interviews with Silicon Valley attorneys, Larson cites heightened concerns that entrepreneurs 'will be absorbed at the most crucial time in the start-up's history'—the early stages of the firm's development—and concludes that the 'founders' time is one of the clearest and most costly victims of [IP] suits' (1984: 2). Further, younger firms may lack the organizational experience and capabilities to deal with IP litigation.

In combination, these arguments suggest that entrepreneurial—private, small, or young firms—are disadvantaged in funding and withstanding IP-related disputes relative to public, large, or older firms. Assuming that entrepreneurial firms take added precautions to avoid legal conflict when hiring employees from litigious firms, we offer the following prediction:

Hypothesis 2a: Reputations for IP toughness will reduce the spillovers anticipated from intra-industry inventor mobility more for entrepreneurial recipient firms than for established recipient firms.

The characteristics of entrepreneurial firms that disadvantage them as hiring organizations in IP-related conflicts may similarly undermine their ability to *establish* credible reputations for IP toughness. As discussed above, for a reputation to be built, others must perceive prior action as informative about future behavior. Even if an entrepreneurial firm initiates a patent lawsuit (i.e., it engages in costly and observable action), its relative lack of resources may lead others to discount the probability that it will do so again in the future. Thus, building on the arguments set forth in Hypothesis 2a above,

Hypothesis 2b: Reputations for IP toughness will reduce the spillovers anticipated from intra-industry inventor mobility less for entrepreneurial source firms than for established source firms.

The prevailing business environment may also influence the effects of a tough IP reputation on rival firm behavior. Saxenian (1994) attributes the greater continuing success of California's Silicon Valley firms relative to New England's Route 128 firms to a unique configuration of West Coast culture, detachment from traditional hierarchical business practices, and norms established

by early major players such as Hewlett-Packard. Saxenian (1994) argues that firms like Hewlett-Packard encouraged employees to pursue outside entrepreneurial activities, while their East Coast counterparts, such as Digital Equipment, took a defensive approach. Additionally, institutional factors in California also encourage knowledge spillovers in labor markets, as the state typically does not enforce noncompete covenants in employment (Gilson, 1999; Stuart and Sorenson, 2003). These factors are credited with creating a unique environment in the state that is characterized by extensive job-hopping and fluid communication of technical information and 'best practices' across firm boundaries (Rogers and Larsen, 1984; von Hippel, 1987; Appleyard, 1996; Saxenian, 1994).

A 'stylized fact' emerging from these studies is that information technology firms based in Silicon Valley and elsewhere in California simultaneously face rapid absorption by other firms of information and know-how pertaining to inventions and unusually high turnover among skilled employees (Almeida and Kogut, 1999; Kim and Marschke, 2005; Fallick *et al.*, 2006). In such an institutional and business environment, the efficacy of firm-level strategies targeted at reducing spillovers is likely to be weak. Consequently, California-based employers may find signaling toughness via reputations built on prior litigious activity difficult, even if they engage in such behavior. Accordingly, we predict:

Hypothesis 3: Reputations for IP toughness will reduce the spillovers anticipated from intra-industry inventor mobility less for California-based source firms than for those based in other U.S. states.

EMPIRICAL CONTEXT AND METHODOLOGY

Industry context and data description

The context of our study is the U.S. semiconductor industry. The industry exhibits high employee mobility, and prior studies document that such mobility facilitates interfirm transfer of technological knowledge (e.g., Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003). We use these prior empirical studies, which trace patterns of citations revealed in patent documents, to construct a baseline model and to benchmark our results. Firms

in this industry also have a high propensity to file patents (Hall and Ziedonis, 2001) and appear to be increasingly active in enforcing those patents (Ziedonis, 2003; Bessen and Meurer, 2006).

Empirically, we trace the innovative activities of 447 U.S. semiconductor firms over the 1973–2003 period. We track firm founding and litigation events over the period 1973–2001, and patenting activities and citations over the period 1973–2003. We distinguish between when a firm is a potential *source* of knowledge spillovers and when it is a potential *recipient* of such knowledge. For simplicity, we refer to the firms in their role as 'source' (or 'cited') and 'recipient' (or 'citing') firms, respectively. As noted earlier, our dyad-level analysis allows source firms to play dual roles as recipients of talent from other industry incumbents.

The source firm sample ($n = 136$) is drawn from a comprehensive list of U.S. firms that (a) compete primarily in the semiconductor industry and (b) were publicly traded for at least one year during the period 1973–1995. Importantly, the sample does not include 'patent predators,' which merely buy patents and practice extortion by threatening litigation; none of the source firms listed Standard Industrial Classification (SIC) code 6797 (patent owners and lessors) as their primary line of business. In 2000, the source firms in our sample collectively generated over \$88 billion in annual revenues and spent \$12 billion on R&D. For each source firm, we observe any initiation of patent infringement lawsuits in U.S. courts during 1973–2001 using data in Ziedonis (2003). These data merge case filings reported in legal databases (e.g., Litalert by Derwent) with supplemental information reported in archival 10-K filings, news articles, and press releases. As a result, we are able to determine when a firm actually files a patent infringement lawsuit against a third party, not just whether patents awarded to that firm are involved in litigation, as is common practice (e.g., Lanjouw and Schankerman, 2001; Somaya, 2003).⁹ Importantly, the time-varying data for each firm's IP toughness permit us to observe patent litigation histories over the entire lifespan of these companies (i.e., post-founding), thus enabling us to test Hypothesis 2b (on the differential effects of

⁹ The involvement of patents assigned to a given firm in a litigated dispute does not necessarily mean that the original assignee (firm) is taking action to enforce its legal rights; others could be challenging the validity of those patents, or the patents could have been sold to third parties (Ziedonis, 2003).

IP toughness among entrepreneurial vs. established source firms).

To assemble a larger pool of potential recipient firms, we add to source firms (a) 454 venture-backed semiconductor firms founded during 1980–2001, using data provided by VentureOne, and (b) 59 firms in the industry (SIC 3674) that went public after 1995, identified from Compustat. Including recent entrants and start-ups in the recipient pool is particularly useful for our tests of Hypothesis 2a (regarding heterogeneous effects of IP toughness among entrepreneurial vs. established recipient firms).

Since knowledge flows and mobility events are identified in our study with patent data, we require that source and recipient firms receive at least one U.S. patent. This restriction eliminates seven source firms, 188 start-ups, and seven recent public entrants. The disproportionate omission of start-ups is not surprising. Many start-ups in the larger sample fail or are acquired at very young ages, thus reducing the likelihood of observing patent awards for these firms.¹⁰ The final sample therefore includes 129 source firms, 266 private start-ups, and 52 recent public entrants. 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; information on alliances and cross-licensing activities from SDC Platinum and searches of news articles and press releases in Lexis-Nexis and Factiva; and patent litigation histories (for source firms) from Ziedonis (2003). Between 1973 and 2003, sample firms collectively received 50,491 patents, of which 38,689 were awarded to the subset of source firms for which we observe litigation behavior.

Variable definition

Dependent variable: citation count

The dependent variable is the count of citations made by patents of a recipient firm to patents of a source firm in a given year. More (fewer) such citations are interpreted as evidence of higher (lower) knowledge spillovers. In keeping with prior research, we acknowledge that while patent

citations are the best available option for large-scale studies, they are nonetheless a noisy proxy for knowledge diffusion (Jaffe, Trajtenberg, and Henderson, 1993; Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Alcacer and Gittleman, 2006; Deng, 2008). Alcacer and Gittleman (2006) show that government examiners also add citations to patent documents, thus calling into question whether applicants truly 'know' about technologies embedded in other patents they cite. However, Lampe (2007) argues and shows that firms in the semiconductor industry (and their inventors) may have strategic motives for omitting citations to patents that are technologically close.¹¹ In such instances, citations added by examiners usefully reveal otherwise unobservable technological linkages. In light of these unresolved controversies, we report robustness checks that both include and omit examiner-added citations.

Although knowledge diffusion is possible after a firm leaves a market (Hoetker and Agarwal, 2007), we assume that reputation effects cease to exist when a source firm exits and remove exited source firms from future dyad-year observations. We make additional adjustments for acquisitions. If one firm in the sample acquires another, the acquired firm exits the sample in the year of acquisition, and its patents are added to the acquirer's portfolio from that point forward. Our final database is an unbalanced panel with 506,374 unique dyad years and 74,624 citations to source firms. Self-citations and citations made by firms outside the focal sample are not included.

Main independent variables

Four explanatory variables are of central interest in our study. The first variable, *mobility*, captures

¹⁰ Of the patents in our sample, 92 percent are generated by established firms.

¹¹ Legal requirements aside, a firm faces conflicting strategic incentives when citing other patents in an application. By failing to cite, the firm risks losing its *own* patent if subsequently challenged with omitting 'prior art' that establishes obviousness or lack of novelty. The effects of citations on the risk that *others* will sue the patentee for infringement are more ambiguous. On the one hand, prior art citations may represent an attempt to 'invent around' an earlier patent to avoid infringement. As noted earlier, however, it can be difficult and costly to determine whether such a solution is noninfringing (Moore *et al.*, 1999). On the other hand, in the event of an infringement suit, such citations could be used as evidence that the citing party knew about the patented invention but continued without a license, thus fueling concerns that damages could be enhanced through a verdict of willful infringement. Lampe (2007) discusses these trade-offs in more detail.

the movement of inventively productive employees from a source firm to a potential recipient. The second variable, *litigiousness*, is our proxy for a reputation for toughness in patent enforcement. For the last two hypotheses, we constructed indicator variables—*entrepreneurial firm* and *CA firm*—to capture salient firm-level characteristics.

Mobility is defined as the cumulative count of inventors hired from a given source firm by a recipient firm over the preceding five years, as measured by the application year of a mobile inventor's first patent at the recipient organization. To determine mobility events, we implement the matching algorithm described in the Appendix to create inventor patenting and employment histories at focal firms within our sample. For 28,123 unique inventor names listed in patents awarded to sample firms, the algorithm yields 1,166 mobility events, of which 841 originate at California-based firms.¹² Inventors are present in the data for 2.2 years on average, measured as the difference between the first and last patent application date. For 51,615 dyads over a 30-year time window, the mobility rate is approximately 0.08 percent per dyad-year. This estimate is slightly higher than the 0.05 percent mobility rate reported in Rosenkopf and Almeida (2003); the difference could be due to our inclusion of more recent data, given an increasing trend in turnover among college-educated electrical engineers (Kim and Marschke, 2005). Other recent studies report mobility rates in the range of one to two percent per inventor-year (Fallick *et al.*, 2006; Tzabbar *et al.*, 2006). On an inventor-year basis, our estimates are similar, at 1.88 percent.

Litigiousness is a time-varying measure based on the observed enforcement of a source firm's exclusionary rights to patent-protected technologies. We measure *litigiousness* using a five-year cumulative count of the number of unique patent infringement lawsuits launched by a source firm between 1973 and a focal observation year.¹³ Legal

disputes over patents often involve multiple suits and countersuits between parties, and a given dispute may appear multiple times in the data because of simple changes in venue. To provide a more conservative estimate, we screen out such duplicative listings. For example, if three lawsuits involving Intel suing Broadcom for patent infringement are reported in 2000, the dispute is counted only once as a litigious action that year by Intel. Since we are interested in devising a firm-specific proxy for taking litigious action, we also exclude instances in which a firm is defending against lawsuits filed by others. To capture reputation effects at the corporate level, we measure the litigious activity of a source firm against all defendants rather than against a particular recipient.

A firm (whether recipient or source) is considered to be *entrepreneurial* if it is public, small, or young in a focal citation year; otherwise it is considered to be *established*. If a firm is listed on the New York or NASDAQ stock exchanges, we code it as public (else, private). While we control for size using a continuous measurement, we define a firm as small if it has less than 100 employees in a given year, which corresponds to the 60th percentile of the size distribution (else, large). A firm is defined as young for the first five years after founding (else, old). The results are robust to alternative cutoffs at 500 employees and 12 years for size and age.

Finally, the dummy *CA source firm* is set to one if a firm has headquarters in California. Information about headquarters location was compiled from several sources, including Hoovers, Compu-stat, and VentureOne. Of the 129 source firms in the estimation sample, 80 are headquartered in California. The majority of firms' inventive activities occur in their headquarters' states. For the median California-based company, almost 90 percent of inventors list California as the state of primary residence. The percentage is somewhat lower (~70%)

¹² Labor markets in California appear to be unusually localized relative to those in other states. Seventy-three percent of mobile inventors from California firms accept reemployment at another semiconductor firm within the same consolidated statistical area (CSA). This pattern reflects the work of Angel (1989), who traces career histories of semiconductor engineers and finds that 78 percent of mobile engineers remained in Silicon Valley. In contrast, only 12 percent of inventors in our sample from firms outside of California stay within their CSA, with 55 percent accepting reemployment at semiconductor firms with headquarters in California.

¹³ Our results are robust to several alternative measures for *litigiousness*; we choose to report the five-year measure for

several reasons. A simple indicator variable identifying whether a source firm had initiated a patent infringement suit by a focal year of citation implicitly treats firms filing one and numerous lawsuits as equally tough. A cumulative count of patent infringement lawsuits initiated by the firm in the sample period gives the same weight to very early and more recent lawsuits and permits no potential erosion of the reputational signaling value of old lawsuits over time. Any assignment of weights over time may seem *ad hoc*. Restricting attention to a five-year window preceding a focal year of citation not only improves the predictive power of our models, but also provides a measure that allows reputation stocks to evolve slowly while still being prone to some decay.

for firms headquartered in other states, which presumably reflects the fact that semiconductor firms from other states often locate some R&D activity in California, in part to gain access to engineering talent and know-how.

Control variables

As do prior researchers, we include controls for firm- and dyad-level factors shown to affect citation behavior in general (Jaffe and Trajtenberg, 2002) and in the semiconductor industry in particular (Rosenkopf and Almeida, 2003; Song *et al.* 2003). For each source and recipient firm, we include the following time-varying variables: *age* is defined as year *t* minus the founding year; *log patent stock* is a count of patents awarded to a firm in a year *t*, measured as a log because of skewness; *log employee* is the number of employees in year *t*, also measured as a log;¹⁴ *log citability* is the number of citations a firm receives from all other sample firms in a year *t*; and, following Rosenkopf and Almeida (2003), we used the *citability* measure to control for the overall quality of a firm's patent portfolio.

We also include the following dyad-level characteristics: *alliances* measures the moving sum of the alliances formed between the firms in a dyad over the last five years, including the focal year (using other forms of cumulative counts had no effect on the results). Absent this control, citations could reflect flows of knowledge mediated by market transactions rather than residual spillovers between firms (Zucker, Darby, and Armstrong, 1998). Like prior researchers, we record the entire range of alliances, including marketing, licensing, design, manufacturing, and equity. When an alliance involved more than two firms, we record each alliance separately within dyads. In total, we identified 1,168 collaborative agreements between firms, including 199 from SDC Platinum and an additional 969 reported in news articles and press

releases obtained from Factiva and Lexis-Nexis. Following Jaffe (1989), we measure *technological proximity* as the angular separation between normalized vectors based on the distribution of patents awarded to source and recipient firms across U.S. patent classes. *Geographic match* is set to one when both firms in a dyad have headquarters in the same CSA, according to the 2000 U.S. Census classification. Finally, we include period dummies for the following intervals: pre-1980, 1980-1984, 1985-1989, 1990-1994, and 1995-1999. The omitted category is 2000-2003. The period dummies allow the baseline citation rate to increase over time (Jaffe and Trajtenberg, 2002) and also control for macroeconomic conditions that could affect the patenting and citation levels in the industry.¹⁵

Summary statistics

Tables 1 and 2 provide summary and correlation statistics for our variables for dyad-year observations. The number of observations varies considerably among the dyads; pairs of long-standing firms have more observations than pairs involving a long-standing firm and a start-up. Figure 1 plots the annual numbers of patents awarded to and patent infringement lawsuits initiated by source firms. Figure 1 shows a spike in litigious activity in the mid-1980s, followed by a more gradual upswing in patenting activity, which is consistent with claims that 'pro-patent' U.S. institutional environment shifts triggered a more aggressive stance toward the acquisition and enforcement of patents (Hall and Ziedonis, 2001; Bessen and Meurer, 2006). We nonetheless observe considerable heterogeneity among firms in their propensities to enforce patents: while 45 percent had initiated at least one patent infringement lawsuit by 2001, the remainder had not. The two top litigants, Intel and Texas Instruments, are large, established firms, but age and size vary significantly among the top 20 litigants. Approximately 60 percent of all litigious firms are based in California. In total, we identify 270 unique U.S. patent infringement suits filed by source firms during 1973-2001.

¹⁴ For public firms, the few missing annual employee counts are imputed from the data reported for the most proximate year. For private firms, employee counts are available only for the last financing rounds reported in VentureOne. Though time-invariant, employee counts for private firms are generally an order of magnitude smaller than those for public firms. In unreported regressions, we obtain similar results when (a) removing observations with imputed employee counts from the sample and (b) measuring firm size in the baseline model as log(assets) rather than log(employees). The latter restriction drops dyad-year observations for missing asset values.

¹⁵ The results are robust to two alternative measures for business cycle effects—an annual Tobin's *q* within the semiconductor industry (from Compustat) and annual VC investments in IT firms (from VenturXpert).

Table 1. Variable definitions and summary statistics

Variable	Definition	Mean	St. dev.
Dependent variables			
<i>Total citations</i>	Annual number of citations made by the recipient to the source firm's patents.	0.116	3.061
Main independent variables			
<i>Litigiousness</i>	Moving sum of patent litigation lawsuits over the last five years including the given year by the cited firm.	0.579	1.987
<i>Mobility</i>	Moving sum of mobility events from the citing to the cited firm over the last five years including the focal year as measured by the application year of the citing firm patent.	0.007	0.119
Dyad-level controls			
<i>Technological proximity</i>	Technological proximity between the source and recipient firms. Calculated as angular separation between the normalized vectors representing proportions of patents in each patent class, as per Jaffe (1989).	0.153	0.259
<i>Same region</i>	Dummy = 1 if cited and citing firms have headquarters in the same consolidated statistical area (CSA).	0.251	0.434
<i>Alliances</i>	Moving sum of alliances over the last five years including the given year between the firms in a dyad.	0.01	0.122
<i>Direct target</i>	Dummy = 1 if recipient firm directly targeted by lawsuit initiated by the source firm in the focal year or in the past; 0 otherwise.	0.0015	0.039
Firm-level controls			
<i>Age (recipient)</i>	Recipient firm age: focal year-founding year.	10.202	10.709
<i>Log employees (recipient)</i>	Log of the number of employees in a focal year. Time invariant for firms from the VentureOne database. Missing data filled in using the first and last record available (see text).	4.993	1.675
<i>Log patent stock (recipient)</i>	Log of the number of patents the recipient firm received in a focal year, as measured by the application year. Patents of acquired firms are counted starting with acquisition year +1.	0.805	1.160
<i>Log patent stock (source)</i>	Analogous to log patent stock (recipient).	1.089	1.420
<i>Log citability (source)</i>	Log of the number of citations the source firm received from all sample firms within the preceding five years, as measured by the application year.	0.966	1.541
<i>Age (source)</i>	Source firm age: focal year-founding year.	16.313	12.205
<i>Log employees (source)</i>	Analogous to log size (recipient)	5.913	1.682
Subgroups			
<i>Entrepreneurial recipient</i>	Dummy = 1 if, in focal year, recipient firm is privately owned OR has 100 or fewer employees OR is less than five years old (based on founding year); 0 otherwise	0.69	0.462
<i>Entrepreneurial source</i>	Dummy = 1 if, in focal year, source firm is privately owned OR has 100 or fewer employees OR is less than five years old (based on founding year); 0 otherwise	0.36	0.481
<i>CA source firm</i>	Dummy = 1 if headquarter location of source firm is in California; else = 0.	0.602	0.489

Estimation method

Since the dependent variable is the number of citations that a recipient firm makes to patents owned by a focal source firm in a given year, we use count data models. Following Rosenkopf and Almeida (2003), we first estimate negative binomial regressions, which are used when conditional variance exceeds the conditional mean. A likelihood-ratio test refutes the hypothesis of no overdispersion

($p < 0.001$) in our sample. We allow for nonindependence of dyad-year observations and use error terms that are robust to heteroskedasticity.¹⁶ Alternative models (zero-inflated negative binomial models and Poisson models with robust variance matrix) generated qualitatively similar results.

¹⁶ Clustering errors by dyads yields identical results.

Table 2. Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1) Citations	1															
(2) Litigiousness	0.0536	1														
(3) Mobility	0.219	0.0589	1													
(4) Technological proximity	0.0868	0.1388	0.1037	1												
(5) Same region	0.0125	0.0311	0.0388	0.0794	1											
(6) Alliances	0.1537	0.0555	0.1398	0.1363	0.0565	1										
(7) Direct target	0.1857	0.0689	0.1227	0.0857	0.0146	0.0796	1									
(8) Age (recipient)	0.0268	0.0009	0.0244	0.0953	-0.1099	0.071	0.036	1								
(9) Log employees (recipient)	0.0649	-0.021	0.0672	0.1859	-0.002	0.1193	0.0592	0.4904	1							
(10) Log patent stock (recipient)	0.1207	0.0018	0.0995	0.3024	0.0447	0.1266	0.0588	0.1661	0.5337	1						
(11) Log patent stock (source)	0.0861	0.3339	0.0733	0.2191	0.0925	0.0973	0.0571	0.0002	-0.0122	0.0429	1					
(12) Log citability (source)	0.078	0.2817	0.0635	0.1869	0.1005	0.0906	0.0523	-0.0005	-0.0061	0.0485	0.8579	1				
(13) Age (source)	0.0331	0.1551	0.0536	0.0651	-0.1282	0.0291	0.0229	0.0072	-0.0396	0.0039	0.0578	-0.0102	1			
(14) Log employees (source)	0.0685	0.392	0.0899	0.2095	0.0158	0.0902	0.0601	0.0033	-0.0155	-0.0086	0.5485	0.4236	0.3927	1		
(15) Entrepreneurial recipient	-0.0421	0.0116	-0.0437	-0.1648	0.018	-0.0911	-0.0454	-0.5797	-0.7186	-0.3671	0.0007	-0.0058	0.0237	0.0113	1	
(16) Entrepreneurial source	-0.0264	-0.1837	-0.0361	-0.1728	-0.031	-0.0464	-0.0274	-0.0055	0.0277	-0.0091	-0.3255	-0.2361	-0.3727	-0.6788	-0.0174	1
(17) CA source	0.0034	0.0615	0.0141	0.0779	0.394	0.044	0.0075	0.0002	-0.0138	0.0043	0.1113	0.147	-0.3013	0.0343	0.0083	-0.0231

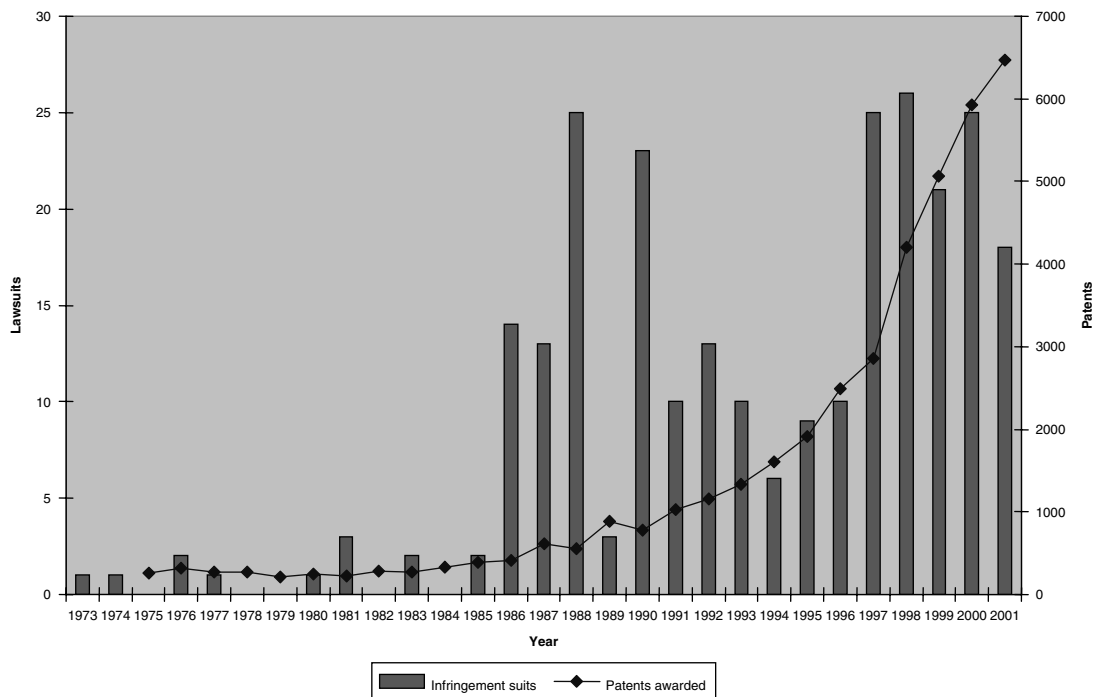


Figure 1. Annual # of U.S. patent infringement suits initiated by source firms vs. the annual # of U.S. patents they received, 1973–2001

By using control variables and estimation methods common in prior citation-based studies of knowledge spillovers, we first establish a baseline estimate of the propensity of one firm to cite patents owned by another. We then introduce IP toughness and its interaction with inventor mobility, the key variables of interest in our study, and further test for heterogeneous effects on different types of firms. Importantly, we conduct robustness tests related to (a) our use of patent citations as a proxy for knowledge diffusion, and (b) the assumption of strict exogeneity of the key explanatory variables of interest, as discussed in detail below.

RESULTS

To test Hypothesis 1, we examine whether the interaction effect of *mobility* and *litigiousness* is negative and significant (Table 3). To test Hypotheses 2 and 3, we use a Wald test for differences in coefficients among the relevant subgroups within a seemingly unrelated regression framework (Table 4). Results of the baseline specification, reported in Column 1, Table 3, are consistent with

prior work. The baseline citation rate is higher between firms that are technologically and geographically proximate; it also is higher between alliance partners and firms that hire away employees. Larger firms and firms with larger portfolios of patents tend to receive a higher baseline number of citations from a given recipient, as do firms with patents that receive higher citations more generally (thus suggesting that the baseline number of citations received by firms with more ‘important’ patents is higher than that of firms with less influential patents). Column 2 of Table 3 introduces the litigiousness variable, which is positive and significant, while Column 3 adds the interaction term of focal interest (*litigiousness* × *mobility*). As predicted in Hypothesis 1, the coefficient on *litigiousness* × *mobility* is negative and significant. The average marginal effect of the interaction is -0.18 , and this effect is significant at the 0.05 level for 99 percent of the observations in the sample. These results suggest that even though litigious firms have patents that are highly cited, they are built upon less extensively by firms that hire their employees than otherwise would be predicted. For each additional lawsuit filed by a source firm, the citation count is lower by 0.18 for a firm

Table 3. Impact of IP litigiousness on mobility-driven spillovers

Model	Main results			Robustness checks			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Main variables							
<i>Litigiousness * mobility</i>			-0.057***	-0.052***	-0.171***	-0.061**	-0.057***
<i>Litigiousness (source)</i>		0.023***	0.027***	0.01	0.142***	0.037**	0.027***
Dyad-level controls							
<i>Technological proximity</i>	3.571***	3.568***	3.569***	3.864***	2.147***	1.576***	3.461***
<i>Same region</i>	0.346***	0.348***	0.347***	0.314***	—	—	0.368***
<i>Alliances</i>	0.156**	0.159**	0.164**	0.249	0.5	0.458	0.017
<i>Mobility</i>	0.607***	0.613***	0.752***	0.625***	2.342***	0.662	0.818***
Firm-level controls							
<i>Age (recipient)</i>	-0.027***	-0.027***	-0.027***	-0.046***	0.007	0.004	-0.026***
<i>Log employees (recipient)</i>	-0.165***	-0.165***	-0.166***	-0.426***	-0.554***	-0.483***	-0.191***
<i>Log patent stock (recipient)</i>	1.257***	1.256***	1.258***	1.745***	1.295***	1.255***	1.276***
<i>Log patent stock (source)</i>	0.101***	0.099***	0.099***	0.066	0.129**	0.136**	0.068***
<i>Log citability (source)</i>	0.273***	0.271***	0.271***	0.330***	0.108**	0.052	0.297***
<i>Age (source)</i>	0.009***	0.009***	0.009***	0.013***	0.033***	0.0066	0.012***
<i>Log employees (source)</i>	0.406***	0.387***	0.387***	0.519***	0.183***	0.264***	0.379***
<i>Direct target (recipient sued by source)</i>							2.718***
<i>Direct target * mobility</i>							-1.095***
Constant	-9.234***	-9.132***	-9.134***	-10.936***	dyad fixed eff.	dyad fixed eff.	-9.007***
Log likelihood	-44,764	-44,749	-44,734	-10,358	—	—	-44,334
Unit of analysis	dyad-year	dyad-year	dyad-year	dyad-year	dyad-year	dyad-year	dyad-year
# observations	506,374	506,374	506,374	172,889	38,691	38,691	506,374

* p<0.1, ** p<0.05, *** p<0.01

Notes: All models include time period dummies as defined in text, except for Model 4, which instead is based on a subsample of recent data and uses annual year dummies.

† GMM fixed effects are at the dyad level, with one- and two-year lags of *mobility*, *litigiousness*, and *alliances* used as instruments.

†† GMM fixed effects are at the dyad level, with one-year lag of firm-level proportion of female inventors used as an instrument for *mobility*. *Litigiousness* and *alliances* instrumented as in Model 5.

Table 4. Subgroup analyses for entrepreneurial and California-based firms† (Y=annual # citations made by recipient to source-firm patents)

	Established recipient	Entrepreneurial recipient	Established source firm	Entrepreneurial source firm	California source firm	Non-California source firm
Model	(1)	(2)	(3)	(4)	(5)	(6)
Main variables						
<i>Litigiousness * mobility</i>	-0.051***	-0.104***	-0.054***	-0.063	-0.051***	-0.062***
<i>Litigiousness (source)</i>	0.047***	0.016**	0.024***	0.203***	0.060***	0.001
Dyad-level controls						
<i>Technological proximity</i>	3.526***	3.473***	3.580***	3.290***	3.466***	3.716***
<i>Same region</i>	0.172***	0.612***	0.271***	1.036***	0.426***	0.442**
<i>Alliances</i>	0.163***	0.398**	0.134*	0.560***	0.2***	-0.093
<i>Mobility</i>	0.520***	1.581***	0.713***	1.107***	0.785***	0.654***
Firm-level controls						
<i>Age (recipient)</i>	-0.019***	-0.066***	-0.028***	-0.014*	-0.024***	-0.030***
<i>Log employees (recipient)</i>	-0.294***	-0.223***	-0.153***	-0.311***	-0.140***	-0.212***
<i>Log patent stock (recipient)</i>	1.130***	1.617***	1.262***	1.311***	1.221***	1.329***
<i>Log patent stock (source)</i>	0.163***	0.054	0.099**	0.219*	0.142***	0.111**
<i>Log citability (source)</i>	0.225***	0.310***	0.264***	0.334***	0.3***	0.194***
<i>Age (source)</i>	0.0003	0.017***	0.007**	0.024***	0.017***	-0.002
<i>Log employees (source)</i>	0.345***	0.420***	0.402***	0.05	0.250***	0.540***
Constant	-7.208***	-9.891***	-9.222***	-7.793***	-8.597***	-9.920***
Log likelihood	-27,755	-16,165	-40,307	-4,242	-29,865	-14,730
Unit of analysis	dyad-year	dyad-year	dyad-year	dyad-year	dyad-year	dyad-year
# observations	156,671	349,703	321,616	184,758	305009	201365
Wald test statistic $\chi^2(1)$		7***		0.02		0.42

* p<0.1, ** p<0.05, *** p<0.01

Note: All models include time period dummies as defined in the text.

† Entrepreneurial firms are defined as firms that have less than 100 employees, or are less than five years old, or are private in a focal year of observation; else, firms are considered to be more established. California firms are headquartered in California; 'non-California' firms are headquartered in other U.S. states.

that has hired an inventor relative to a firm that has not.

In Columns 4–7 of Table 3, we test the robustness of this core finding in our study in several ways. First, we reestimate the model after excluding examiner-added citations for patents awarded since 2001 for which such data are available. As shown in Column 4, there is little evidence that biases introduced from examiner-added citations spuriously drive our results. The *litigiousness* × *mobility* coefficient remains negative and highly significant irrespective of whether examiner-added citations are included or removed from the dependent variable.

Next, we investigate a more fundamental issue regarding model specification. While the negative binomial model specification allows us to build cumulatively upon and replicate the results in prior

work on learning-by-hiring (e.g., Rosenkopf and Almeida, 2003; Almeida *et al.*, 2003), the underlying assumption of strict exogeneity of key variables of interest may be particularly strong in the context of our study. Importantly, a firm's prior litigiousness as well as other unobserved characteristics could affect not only citations conditional on job changes among inventors, but also the underlying distribution of employees who decide to switch jobs. Further, the use of variables based on cumulative counts violates the strict exogeneity assumption of the standard count estimation methods (Wooldridge, 1997). To test if our results are sensitive to these potential issues, we employ an instrumental variable approach recommended by Wooldridge (1997), and use the generalized method of moments (GMM) estimation method, which permits the inclusion of

explanatory variables correlated with past and current values of the error term. We estimate the GMM models using the GAUSS routine ‘ExpEnd’ of Windmeijer (2002) and moment conditions based on quasi-differencing (Wooldridge, 1997).¹⁷ To correct for time-invariant heterogeneity in each dyad, we define the panel using the dyad-level fixed effects. Since within-unit changes must be observed over time for effects to be estimated, the number of observations drops accordingly. First, we correct for violation of the strict exogeneity assumption resulting from use of cumulative counts by using lagged variables as instruments. In Column 5 of Table 3, we instrumented *mobility*, *litigiousness*, and *alliances* (and the relevant interaction terms) using their one- and two-year lagged values. As Wooldridge (1997) discusses, this approach relaxes the strict exogeneity assumption of a negative binomial model by relying on weaker sequential moment restriction. Importantly, the coefficient on *litigiousness* × *mobility* in Column 5 remains negative and highly significant. Indeed, the estimated magnitude of the coefficient is larger when we use lagged values as instruments to relax the strict exogeneity assumption.

Second, in Column 6 of Table 3, we employ an even more stringent specification by fully instrumenting *mobility* with an exogenous inventor-level differences variable rather than lagged values. Following Kim and Marsche (2005), we instrument *mobility* using the annual percentage of each source firm’s inventors who are female (*percentage female*).¹⁸ The logic behind this instrument is straightforward: the ratio of women inventors is likely to be correlated with exit decisions (women tend to be less mobile) and is also likely to be uncorrelated with unobserved quality differences.

¹⁷ The nonlinear GMM estimates (based on Wooldridge’s (1997) quasi-differencing) are obtained by the minimization of

$$\left(\frac{1}{N} \sum_{i=1}^N s_i' Z_i \right) W_N \left(\frac{1}{N} \sum_{i=1}^N Z_i' s_i \right)$$

from Windmeijer (2000), where *W* is the weighting matrix, *Z* is the instrument matrix, and *s* is Wooldridge’s quasi-difference. Unfortunately, as Stock, Wright, and Yogo (2002) discuss, there is no ‘weakness test for instruments’ available for nonlinear GMM.

¹⁸ To compile this variable, we created a dummy variable manually coded one for ‘female’ on the basis of the first names of inventors listed on patents in our sample. For each source firm, we then divided the total number of female inventors by the total number of inventors at the source firm in a focal year, thus allowing the percentage to change over time.

As seen in Column 6 in Table 3, the fully instrumented *litigiousness* × *mobility* remains negative and highly significant.

Finally, we note that in our theory, reputation for toughness is a corporate-level construct. In the final column of Table 3, we investigate an alternative explanation for our Hypothesis 1 findings. If IP toughness reduces the spillover associated with employee mobility only between firms directly involved in legal conflict, our results could be explained by dyad-level dynamics rather than broader reputation effects within the industry. If this alternative explanation is correct, *litigiousness* × *mobility* should become statistically indistinguishable from zero, or drop sharply in magnitude once we control for dyad-level litigation. To test this possibility, we constructed a new variable, *direct target*, which is set to one if a given recipient firm has been sued for patent infringement by a given source firm by a focal year of citation.¹⁹ We also created the interaction term *direct target* × *mobility* to permit assessment of differences in the effect of litigiousness on mobility-driven spillovers between litigating and nonlitigating dyads. Column 7, Table 3, reports results that add these two variables to our main model in Column 3. Importantly, the coefficient on *litigiousness* × *mobility* remains highly significant and similar in magnitude even after we take into account the dynamics introduced by actual legal conflict between dyads. These results provide corroborating evidence that litigation acts shape the behavior of hiring organizations more broadly within the industry, even absent the filing of an actual lawsuit, as reputation-based theories would predict.

Perhaps not surprisingly, the estimates reported in Column 7 suggest that the effects of IP toughness are amplified for firms directly involved in legal conflict. The positive and significant coefficient on *direct target* indicates that recipient firms have a higher propensity to cite patents owned by source firms that have directly sued them for patent infringement. Legal conflict could result in settlements that give recipient firms greater access to patent-protected technologies owned by focal source firms in our sample, thus increasing citation counts at the dyad level. Alternatively,

¹⁹ We are grateful to a reviewer for this valuable suggestion. Of the 270 unique patent infringement suits initiated by source firms, 113 (42%) are against recipient firms in the sample. Most out-of-sample disputes are filed against non-U.S. firms or firms in other industries.

source firms may be more likely to sue recipient firms that are disproportionate beneficiaries of knowledge spillovers emanating from their organizations, thus resulting in a positive correlation between observed legal conflict and recipient firm citations to source firm patents. For the purposes of our study, it is more relevant to observe that between litigating dyads, IP toughness reduces the spillovers associated with inventor mobility events. In fact, comparing coefficient estimates on *litigiousness* \times *mobility* and *direct target* \times *mobility* (-0.057 and -1.095 , respectively), the deterrent effect of IP rights enforcement on spillovers in labor markets is greater when the costly filing of an actual lawsuit accompanies it.²⁰

In summary, Table 3 provides evidence that IP litigiousness moderates the extent to which recipient firms learn by hiring inventors from industry rivals. We find little evidence that biases introduced by examiner-added citations or endogeneity concerns about our variables of interest spuriously affect our results. Finally, our results are consistent with the view that IP toughness casts a shadow over behavior in the semiconductor industry as a whole rather than merely behavior confined to pairs of firms directly involved in legal conflict.

We now turn to Table 4, reporting our subgroup analyses and corresponding tests for Hypotheses 2a and 2b (on heterogeneity among firms) and Hypothesis 3 (on California-specific effects). Columns 1 and 2 in Table 4 present evidence consistent with Hypothesis 2a: IP toughness will deter spillovers to a greater degree for hiring organizations that are entrepreneurial rather than established. While *litigiousness* \times *mobility* is negative and significant for both established (Column 1) and entrepreneurial (Column 2) recipients, the magnitude of the effect for entrepreneurial recipients is about double that for their more established counterparts. More specifically, the impact of the interaction effect on citations is a decrease by about five percent for established recipients and 10 percent for entrepreneurial recipients with each litigation and mobility event. The Wald test

²⁰ Robustness checks not formally reported here test a second alternative explanation: hiring inventors from more litigious firms induces recipient firms to keep a greater share of their subsequent innovations secret as opposed to seeking patents. We find little evidence of a decline in the propensity of recipient firms to patent after a mobility event, which is reflective of strong pressures to file patents in this industry (Hall and Ziedonis, 2001; Ziedonis, 2003)

refutes the hypothesis that the coefficients are equivalent in the respective subgroups, thereby supporting Hypothesis 2a. Similarly, Columns 3 and 4 of Table 4 provide evidence consistent with Hypothesis 2b: the deterrent effects of IP toughness will be lower for entrepreneurial source firms than for established ones; indeed, the finding is stronger than the prediction. Moreover, the results suggest that IP toughness reduces the spillovers associated with inventor hiring *only* for relatively well-established firms. In contrast, for less well-established source firms, the coefficient on *litigiousness* \times *mobility* is indistinguishable from zero. An absence of litigation initiated by entrepreneurial source firms does not appear to drive the latter finding; roughly 10 percent of the total patent infringement lawsuits are initiated by small, young, or private firms.²¹

Finally, we predict in Hypothesis 3 that IP toughness will have a less deterrent effect on employee mobility-related spillovers for source firms based in California than for firms based in other U.S. states. The subgroup analysis for Hypothesis 3 is reported in Columns 5 and 6 of Table 4. Overall, the coefficient on *litigiousness* \times *mobility* remains negative and significant at the one percent level for source firms irrespective of state. While the magnitude of the coefficient is slightly smaller for California-based firms (at -0.05) than for others (at -0.06), the Wald test fails to refute the null hypothesis that the effects are statistically equivalent in size. At odds with our Hypothesis 3 prediction, we therefore fail to find that coefficient of *litigiousness* \times *mobility* is significantly different for California and non-California firms. As a robustness check, we divided

²¹ In an unreported analysis (available upon request), we explore finer-grained asymmetries between source and recipient firms. The results largely mirror those reported in Columns 1 and 2 of Table 4. IP toughness reduces employee mobility-related spillovers to a greater extent when the relative difference in resource constraints is large: established source firms are more effective against entrepreneurial recipients than are established recipients, while entrepreneurial source firms are ineffective against established recipients but effective against entrepreneurial recipients. Further, we tested for differential effects of IP toughness for employee entrepreneurship. We included a dummy variable *spin-out* if the mobility event represented the founding of a new firm by the employee, as well as its interaction with *litigiousness*. The results are similar to those for the *direct target* analysis: the coefficient of *spin-out* is positive and significant (spin-outs cite the source firm to a greater extent), and the coefficient of *litigiousness* \times *spin-out* is negative and significant (spin-outs cite litigious firms less than other hiring recipients).

the source firm sample into ‘Silicon Valley’ and ‘non-Silicon Valley’ and obtained similar results.

DISCUSSION AND CONCLUSION

Don’t let your employees do to you what you did to your former boss!

—Roger Borovoy, former general counsel, Intel (Jackson, 1997: 214).

Although job hopping by engineers and scientists is widely heralded as a vibrant channel for knowledge transfer, little is known about the actions firms take to *reduce* knowledge outflows through markets for skilled labor. Assuming that employee moves to rival firms impose a negative externality on source firms and that contractual and other legal mechanisms provide imperfect solutions, this study investigates the effectiveness of a lever that has received little attention in prior research—a reputation for tough enforcement of intellectual property rights. In doing so, we shed new light on the strategies firms use to capture value from their innovation-related investments.

Drawing on a uniquely rich database of patent lawsuits, inventor mobility events, and patent citations in the U.S. semiconductor industry over three decades, we find (in support of Hypothesis 1) that a firm’s patent litigiousness significantly curtails the outward dissemination of technological knowledge that otherwise would be expected from employee departures. These findings are consistent with the view that filing a patent lawsuit—a costly and observable action—serves a sorting function whereby tough employers can be credibly separated from their passive counterparts. Such evidence of past litigiousness sends a strong signal to third parties (whether employees or their potential hirers), thus shaping their behavior. Building on earlier work on strategic deterrence and predation, this study shows how corporate reputations for toughness can be valuable to firms seeking to deter unauthorized transfers of proprietary knowledge through employee exits.

Our results further suggest that the costs and distractions associated with IP enforcement may affect both the precautions firms take to ‘avoid the shadows’ of litigious firms and the credence others in the industry place in threats of litigious action. Consistently with Hypothesis 2a, our estimates suggest that corporate reputations for toughness are

particularly powerful in curbing knowledge outflows to entrepreneurial firms. An important implication of this finding is that entrepreneurial firms, which prior studies have shown stand to gain most from hiring skilled workers from established firms (Almeida *et al.*, 2003; Agarwal *et al.*, 2004), are disproportionately affected by tough reputations of industry incumbents. We also find, consistently with Hypothesis 2b, that IP toughness reduces mobility-driven spillovers less when source firms are young, small, or private than when they are more established. While entrepreneurial firms are widely viewed as an important source of ‘creative destruction’ (Schumpeter, 1942) because of their innovations, these findings collectively underscore the hurdles that these firms may face when introducing technologies that may disrupt market leaders. These findings contribute new evidence to that offered by a handful of studies exploring how the high costs of patent enforcement may tilt advantage toward firms with superior resource endowments (Lerner, 1995; Lanjouw and Lerner, 2001; Lanjouw and Schankerman, 2001). From a policy perspective, these results suggest that current initiatives to lower the costs of adjudicating patent rights in the United States may warrant serious consideration, as Lemley and Shapiro (2005) and others discuss. Otherwise, the costs and uncertainties of IP-related conflicts may redirect innovative activity toward more established, resource-rich organizations.

Finally, we hypothesized that an environment that fosters entrepreneurial activity in technology-based industries, such as that of Silicon Valley and California overall, reduces the impact of IP litigiousness on knowledge spillover via employee mobility. Empirically, we find little evidence that reputations for patent litigiousness are less effective as a spillover-reduction mechanism for semiconductor firms headquartered in California than they are for firms headquartered in other states. The lack of supporting evidence for this prediction has important implications, both for firm strategy and for government policy. From a strategic perspective, the nonfinding highlights the intriguing possibility that, when seeking to reduce leakage of proprietary know-how from employee departures, firms may be able to partially compensate for poor environmental support by enacting aggressive strategies that build on firm-level capabilities. When firms confront weak state laws governing employment contracts, they can leverage

federal policies governing IP protection, which have strengthened considerably over the past few decades (Jaffe, 2000). The public policy implications are not obvious. To the extent that aggressive IP enforcement helps reduce knowledge spillovers via employee mobility, firms may have greater incentives to invest in human capital and R&D. By increasing the market power of employers over mobile workers, the pro-patent shift in U.S. policies helped stimulate investments in on-the-job training and R&D projects of value to other firms in an industry. In this view, our study suggests that broader research on human capital investments (e.g., Acemoglu and Pischke, 1998, 1999) may be fruitfully informed by paying greater attention to the role of firm-level IP strategies. At the same time, however, the vitality of innovative regions such as Silicon Valley is widely attributed to active job hopping by skilled workers and the corresponding diffusion of technological know-how and discoveries across firm boundaries (Saxenian, 1994; Gilson, 1999). If reputations for IP toughness curb the interfirm dissemination of technological knowledge, particularly to start-ups, regional dynamics could be threatened.

Limitations and future research

Both the limitations and the findings of the study present avenues for future research. First, while the semiconductor industry is a canonical context for examining research questions such as ours, the present findings may be limited in generalizability by our single-industry focus. In theory, we expect reputations for IP toughness to deter spillovers in strong legal regimes and in sectors where uncompensated leakage via employee exits can erode significant investments in innovation. Following this logic, our findings should generalize to other pro-patent legal regimes and to other knowledge-intensive sectors, such as biotechnology and medical devices. Future research that examines other industry contexts will be useful, particularly to identify boundary conditions for the effectiveness of IP toughness strategies.²² Also, there may be

²² While they do not examine reputation effects associated with patent enforcement, Kim and Marschke (2005) provide evidence that may be instructive for future cross-industry studies. They find that an increase in employee turnover stimulates more aggressive patenting by firms in high-technology industries than in less R&D-intensive ones. Given recent developments of cross-industry patent litigation databases (e.g., Lanjouw and

conditions under which interorganizational transfers of knowledge *benefit* firms (e.g., see Oettl and Agrawal, 2008), in which case a reputation for IP toughness should hold little deterrent value. Future studies could investigate this issue by investigating the role of IP toughness in sectors such as software, where success often hinges on rapid adoption and use by others.

Second, although we use 'IP rights enforcement' and 'patent enforcement' interchangeably in the study, our focus on patents does not account for the alternative mechanisms (i.e., trade secrets, nondisclosure agreements, noncompete agreements in employment contracts, copyrights, trademarks) available to firms for protecting their technological know-how. For instance, von Graevenitz (2007) finds that past aggressive protection of trademarks increases the likelihood of current disputes being settled speedily. An interesting avenue for future research is whether litigiousness over other legal forms of IP rights reinforces corporate reputations for toughness gained through patent enforcement. If that were true, the magnitude of effects reported in this study would be understated. Similarly, our study focuses only on the effects of IP toughness on a single channel of knowledge transfer—employee mobility. Future research that examines alternative strategies for building reputations for IP toughness and compares the efficacy of such strategies in multiple channels of knowledge transfer (i.e., alliances, vicarious learning, reverse engineering) will greatly enhance our understanding of the boundary conditions on value appropriation (Agarwal *et al.*, 2007).

Third, since our empirical analysis hinged on the use of patent data to identify mobility events, our observations are necessarily restricted to instances in which an inventor was identified on patents assigned to more than one firm in our sample. Missing from the sample, therefore, are instances in which the mobile employee had minor involvement or only general awareness of a technology. Similarly, our study does not capture actions related to technologies that were in the initial stages of development but not patented prior to the employee departure. However, there is no *a priori* reason to expect that a reputation for IP

Schankerman, 2001, 2004; Bessen and Meurer, 2006), future studies could investigate the differences in the magnitude of effects among sectors.

toughness would affect knowledge transfer associated with *noninventor* mobility differently from how it affects transfer via inventor mobility.

Fourth, while our results are robust to alternative measures of litigiousness, our study naturally invites further investigation of the following questions: How should a firm *build* a reputation of toughness? For instance, as mentioned in our introduction, Intel's CEO initiated a strategy of filing two IP suits per quarter. Is such repetition particularly powerful? Or is one strong and highly visible aggressive action sufficient? Similarly, do reputations for toughness need to be *maintained* once they are built? Our robustness checks indicated some erosion of IP toughness reputation over time, in that the five-year litigiousness measure outperforms the proxy based on total cumulative counts. More generally, little is known about whether or how much the time required to build (or lose) corporate reputation is domain-specific or similar across activities. Are reputations for toughness about IP rights quicker to build (and slower to erode) than reputations for goodness in product markets or in the environmental and other social responsibility arenas? Future research examining the cost-benefit trade-offs for building alternative forms of reputation can help shed light on these questions.

Fifth, our findings for the moderating effect of IP toughness on knowledge spillover through employee mobility have important implications for issues relating to individuals' decisions to join or leave organizations and their behavior during employment. Examining this interwoven set of issues is beyond the current scope. A resulting limitation of the study is that we do not explicitly model the potential effects of IP toughness on employee decisions to enter or exit an organization (and the corresponding incentives and motives of potential hiring organizations). Understanding the longer-term consequences of reputation for IP toughness for employee recruitment, incentives, and retention is an important avenue for future research. For instance, the immediate effect of a tough reputation may be to reduce employee exit, thus reducing transfer of knowledge. However, such a reputation may also influence the decisions of employees to disclose novel ideas to their employers (Anton and Yao, 1995), thus adversely affecting the development of new knowledge within organizational boundaries. In the longer term, aggressive IP enforcement may alter

the ability of an organization to hire skilled labor. Moen (2005) and Franco and Filson (2006) find that individuals with entrepreneurial aspirations often accept a pay cut to apprentice for the 'best' firms. Given our findings that entrepreneurial firms are relatively disadvantaged in the realm of litigious behavior, such individuals may be reluctant to join a firm reputed to be tough if doing so appears to curtail opportunity for future advancement outside the firm's boundaries. Thus, if a tough reputation makes it more difficult or costly to attract key talent, or triggers an exodus of star inventors, a firm may 'win the battle, but lose the war' by adopting a litigious stance toward proprietary knowledge. Similarly, the trade-offs between IP 'toughness' and rewards-based systems (e.g., use of bonuses, stock options, and/or vestment periods) remain unaddressed in this study. This naturally invites continued research with a more 'general equilibrium' approach examining the effect of various strategies that firms may employ to attract and retain inventive employees while at the same time restricting leakage of knowledge through employee exit.

Finally, our study opens up interesting avenues for continued research on 'learning by hiring' and more generally, 'make-or buy' decisions for inventive talent: Why do firms risk litigation through 'learning-by-hiring' when they could conceivably develop knowledge in-house? What are the costs and benefits of the 'learning-by-risking litigation' strategy? We hope that our study will trigger additional research that examines the costs and trade-offs faced by recipient firms as well.

Contributions

These limitations notwithstanding, our study makes several important contributions. Prior studies of knowledge spillovers through employee mobility (e.g., Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Song *et al.*, 2003) implicitly assume a passive role for source firms in the process by which knowledge diffuses across firm boundaries. By relaxing this implicit assumption, we contribute to a nascent stream of research on the mechanisms firms use to safeguard against the inadvertent leakage of know-how and proprietary technologies. In addition to 'keeping a distance' from key rivals when entering foreign countries

(Alcacer and Chung, 2007), altering the composition of inventive teams (Zhao, 2006), and enforcing noncompete agreements in employment contracts (Gilson, 1999; Stuart and Sorenson, 2003; Marx *et al.*, 2009), we show that firms engage in reputation building by enforcing legal rights to intellectual property.

The study also builds on and extends the literature on reputation effects in corporate strategy. Although much recent work emphasizes the benefits of being 'good'—either as a socially responsible corporate citizen or as a high-quality producer (see Roberts and Dowling, 2002)—earlier studies highlight the reputational benefits of being tough or aggressive (Kreps and Wilson, 1982; Milgrom and Roberts, 1982). Our study shows that insights from such strategic interaction models of competitive dynamics in product markets can also inform the interplay between an employer's IP litigiousness and employee-driven expropriation risk. Just as a reputation for predatory pricing may enhance monopoly advantage by curtailing entry, so may a reputation for aggressive initiation of patent infringement lawsuits limit knowledge transfer through a key conduit: mobile employees. To the best of our knowledge, our study is the first to provide systematic evidence on this issue, reinforcing impressions drawn from anecdotal evidence.

Finally, in the literature on IP litigation, prior studies show that firms are more likely to enforce economically valuable patents (e.g., Lanjouw and Schankerman, 2004; Allison *et al.*, 2004) and to be litigious when the strategic stakes are higher (Somaya, 2003). By casting IP enforcement as a broader reputation-building strategy that is salient to employer-employee dynamics, we add new insights to this literature. In this respect, our study is perhaps most similar in spirit to recent work by Kim and Marschke (2005) emphasizing patents as protecting firms from expropriation by insiders who leave to join rival firms or to start new companies. While Kim and Marschke (2005) find that firms file for patent protection more aggressively when faced with increased employee turnover, they do not consider the added reputation effects that accrue through patent enforcement. Spillover deterrence through labor market channels can be viewed as an added benefit of being litigious more generally. By credibly signaling that it is aggressive, a firm may reap indirect reputational benefits even from disputes propelled by broader

motives. Our study also provides new evidence on how the high costs associated with IP litigation can differentially affect the behavior of entrepreneurial and established firms, thus contributing to prior research on this important topic (Lerner, 1995; Lanjouw and Lerner, 2001; Lanjouw and Schankerman, 2001).

In conclusion, we theorize and demonstrate that corporate reputations for tough enforcement of intellectual property rights significantly influence the knowledge spillovers that occur when employees leave to join rivals or form new companies of their own. Such reputations have a stronger effect on knowledge transfers to entrepreneurial firms than on those to established firms, and are equally effective for firms located inside and those located outside an institutional domain known to foster interfirm knowledge exchanges. The study sheds new light on the strategic levers firms use to prevent rivals from capturing value from their investments in human capital and R&D, and reveals promising pathways for continued research.

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APPENDIX: METHODOLOGY FOR MATCHING INVENTOR NAMES

We match the patent inventor records using the following procedure. First, we aggregate inventors on the patents assigned to the firms using exact match on the first and last name within each firm.²³ Next, we generate two subsets: the first uses the last patent associated with that inventor at the source firm; the second uses the first patent associated with that inventor at each recipient. We then match the two sets against each other using exact match on the first and last names. All matches that occur following an acquisition by one firm of another are omitted, which removes about 15 percent of the observations. Put differently, if inventor X patents at firm A in 1997 and at firm B in 1998 and B acquires A in 1997, the observation is not treated as a mobility event.

If middle initials are the same, a match is recorded; if they are different, the event is discarded. Thus, the letter 'M' and the name 'Michael' would be treated as a match on middle initial whereas the letter 'M' and the name 'John' would not. If one or both of the records have missing middle initials, the record is flagged and matched

manually using other criteria like geographical proximity, metropolitan density, and common name frequency. For instance, John Smith is less likely to be a match to any other John Smith than Vladimir Rumennik to Vladimir Rumennik. As discussed by Trajtenberg, Shiff, and Melamed (2006), the likelihood of a match is amplified in small metropolitan areas and over small distances.

Finally, we impose the rule that the application date of the last patent for a given inventor in a source firm must precede the application date of that inventor's first patent in a recipient firm. To correctly recreate the movement history, each event is matched against the first possible move.²⁴ The events are then manually cleaned for patent coassignments (patent may be assigned to both source and target firm at the same time; we have 50 such occurrences in our sample) and concurrent patenting at more than one assignee (appearing as moving back and forth between the firms). Any instances where the same inventor appears at more than one assignee at the same time or any questionable patterns (all patents at different employers in the same year) are excluded as mobility events and are assumed to represent two inventors with the same name.

²³ Using the exact match appears as a robust and parsimonious way to generate matches. Complete manual match on a subset of the data revealed that misspellings and different name versions on first and last names account for less than two percent of the actual mobility events—type I error. The differences in the middle initial account for about three percent of the events, but such events are correctly recorded by our procedure. We also discovered that using fuzzy match on the first and last names would dramatically increase the amount of false matches—type II error—excessively increasing the burden on the manual cleaning.

²⁴ For instance, the result of the matching algorithm would be as follows:

Inventor AB events:

Event	Source Firm	Last Patent Date	Target Firm	First Patent Date
1	X	1/1/1999	Y	12/4/2000
2	X	1/1/1999	Z	4/22/2002
3	Y	3/5/2001	Z	4/22/2002

Only events 1 and 3 are recorded as mobility events.