An Organizational Perspective on Patenting and Open Innovation

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change in U.S. patent law in the early 1980s increased the value of patents, particularly for firms in the electronics and semiconductors industry, yet many of the industry’s leading firms did not embrace patenting after the change. We show through an in-depth study of International Business Machines (IBM), the world’s largest patentee, that the company’s practices during much of the 1980s discouraged patenting. IBM adopted pro-patent management practices in 1989 after the installation of a new research and development head and in the face of faltering financial performance. IBM’s increased patenting and licensing activities improved its financial bottom lines but curtailed its industry-wide knowledge spillovers. These causes and consequences of pro-patent practices are visible in several other large U.S. corporations. Thus, in the context of the “patent explosion” of the 1980s, we show that intraorganizational forces such as inertia, financial pressures, and new leadership shaped established firms’ uptake of pro-patent management practices and their success. Our findings also suggest that pro-patent practices associated with “open innovation” may stem the free flow of knowledge across organizational boundaries.

Keywords: technology and innovation management; patents and intellectual property rights; diffusion of innovation; strategy implementation; management processes; strategy and policy; strategy and firm performance; external environment; organization and management theory; organizational processes

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1. Introduction
A key task of managers is to deal with change (Mintzberg 1990). Ecological and evolutionary theorists contend that managers in large and established firms are slow to respond to change. This inertia in organizations leads to poor financial performance and, sometimes, their death (Hannan and Freeman 1977, Henderson and Clark 1990, Rumelt 1995, Christensen 1997, Tripsas and Gavetti 2000). Yet anecdotal observations from several industries suggest that some established organizations were slow to respond to change but managed to renew themselves and thrive in their dynamic environments (see Tushman and Romanelli 1985, Agarwal and Helfat 2009). What loosened the grip of inertial forces on these organizations and stimulated their response to change? Can delayed response recover profitability? Does firm-specific response have industry-wide consequences? We take up these questions in the context of the U.S. “patent explosion” of the 1980s.

Figure 1 shows the dramatic growth in U.S. patenting after 1983. According to patent scholars, the creation of the Court of Appeals of the Federal Circuit (CAFC) in 1982, and its subsequent pro-patent decisions, strengthened patent rights and led to increased patenting (Kortum and Lerner 1999, Hall 2005). This growth was pronounced in electronics and semiconductors—industries in which patents were traditionally not considered important for protecting firms’ research and development (R&D) investments (Hall and Ziedonis 2001). Still, not all firms within the electronics and semiconductors industry increased their patenting immediately in response to the institutional change that made patents more valuable. Figure 2 reveals the heterogeneity in the post-1983 patenting of top U.S. electronics and semiconductors corporations. In the five-year span after 1983, Hewlett-Packard (HP) increased its patent applications by 275%, Intel by 213%, Kodak by 187%, and Texas Instruments (TI) by 168%. More modestly, Motorola increased its applications by 43%, Xerox by 23%, and IBM by 10%. AT&T’s patenting decreased by 32%.

We explore the reasons behind this heterogeneity through an in-depth case study of the intellectual property (IP) management practices at one firm, IBM, between 1979 and 1998. We focus on IBM because, as Figure 3 shows, the company lagged its rivals in responding to the increased value of patents despite being the industry’s largest R&D performer. IBM’s share of patents in the electronics and semiconductors industry started declining after 1983, but the firm turned this trend around in 1989 and emerged as the world’s largest patentee in 1993.

Our qualitative research documents the role played by James McGroddy, who was appointed IBM’s director of
research in 1989, in implementing pro-patent management practices at the company. We quantitatively isolate the consequences of IBM’s adoption of pro-patent practices by employing a differences-in-differences approach that compares IBM’s patenting propensity, and its effects, to that of 114 control-group firms in its industry before and after 1989. We show that the adoption of pro-patent practices increased IBM’s patent propensity, led to an increase in its licensing revenues, and enhanced profitability. But aggressive patenting and patent enforcement appears to have stifled IBM’s industry-wide knowledge spillovers.

The objective of our study is to provide a nuanced understanding of the ways in which established firms responded to an exogenous change in their IP environment and the consequences of their response. Accordingly, our in-depth study of one firm allows us to complement our quantitative analysis with a qualitative description of both the circumstances that led to the adoption of pro-patent management practices and the mechanisms through which the practices affected private returns and knowledge spillovers. We also extend our study to eight other large U.S. corporations, which, along with IBM, owned 57% of the patents assigned to publicly listed U.S. firms in the electronics and semiconductors industry. We find that these firms, similar to IBM, adopted pro-patent practices typically following changes in leadership and in the shadow of declining financial performance. The adoption of the practices by these firms had a striking impact, as in IBM’s case, on increasing their private returns but decreasing knowledge spillovers.

Our findings offer several insights for the development of theory on organizational change and the management of innovation. Neoclassical economic theories imply that profit-maximizing firms seamlessly adapt to changes in their environment to maximize profits; deviations from this norm are argued to be due to informational frictions (see Bloom et al. 2013). Here, we show that established U.S. corporations delayed the adoption of pro-patent management practices in the aftermath of a well-known legal change that increased the value of patents. It is unlikely that this delayed adoption was a consequence of informational constraints. Instead, our case study of IBM suggests that inertial forces, reinforced by the “open-science” norms at the company and entrenched leadership, played a role in resisting adoption—a finding consistent with the literature on the ossifying effects of organizational inertia (Hannan and Freeman 1977, Tripsas and Gavetti 2000, Siggelkow 2001). Our analysis also shows that financial pressures and new leadership explain the eventual adoption of the practices by the laggards such as IBM, thus underscoring the relevance of problemistic
search, rather than profit maximization, as a driver of transformation (in the spirit of Cyert and March 1963, Nelson and Winter 1982, and, more recently, Greve 2008). Hence, not just the shock of environmental change but deteriorating financial health and new leadership play key roles in overturning the forces that resist change in established corporations. Unlike the preponderance of studies that establish incumbent firms’ failure to overturn inertial forces in the face of change (Tripsas and Gavetti 2000 present an excellent survey of such studies), our study demonstrates their successful transformation and provides an account of the circumstances surrounding the transformation. From a methodological perspective, we contribute a careful assessment of the consequences of pro-patent practices to the literature on the management of innovation (Grindley and Teece 1997, Rivette and Kline 2000, Somaya et al. 2007, Di Minin and Bianchi 2011).

A recent line of work on “open-innovation” business models heralds the benefits of pro-patent practices, including licensing, for organizational profitability and the industry-wide diffusion of innovation (Chesbrough 2006). Our findings suggest that firms’ pursuit of profits through aggressive enforcement of their patent rights comes at the cost of foreclosing the diffusion of knowledge across organizational boundaries. To the extent that the adoption of pro-patent practices is associated with superior profits for the adoptees, at least in the short run as suggested by our analysis, we provide a counterpoint to arguments that the shift away from open-science norms decreases firms’ productivity (as argued in Cockburn and Henderson 1998). Although open-science norms may augment firms’ productivity by equipping them to recognize and exploit external knowledge, they may also thwart firms’ attempts to appropriate the returns from their proprietary knowledge.

2. IP Management Practices in the 1980s and 1990s

IP management refers to firm-specific practices that seek to profit from the organization’s intellectual assets (Grindley and Teece 1997). These practices include management’s choice of mechanisms (e.g., patents, copyrights, defensive publications, secrecy) to protect the company’s IP; formal and informal organizational incentives that align employee behavior with the chosen mechanism; and the implementation of specific strategies (e.g., licensing, cross-licensing, litigation) to profit from intellectual property.

2.1. The Post-1983 Patent Explosion

The number of successful patent applications at the U.S. Patent and Trademark Office (USPTO) varied within a narrow range between 61,000 and 66,000 each year for a decade before 1983 but grew to 104,000 in 1992. According to Hall and Ziedonis (2001), this growth in patenting was spurred by a series of legal changes, culminating in the establishment of the CAFC in 1982, which strengthened patent holders’ rights. In the years following the CAFC’s establishment, patent holders started asserting their patents, particularly against product manufacturers in “complex-product” industries—industries such as electronics and semiconductors, in which a single product can embody the IP covered by hundreds of patents (Cohen et al. 2000, Hall 2005). In many cases, individual patent holders succeeded in obtaining not just millions of dollars in royalties and damages from product manufacturers but also injunction orders that prevented the manufacturers from selling their products (e.g., Polaroid’s well-publicized infringement case against Kodak forced the latter to shut down its instant-camera business in 1985 and cost the company upwards of a billion dollars). Thus, stronger patent rights brought about by the CAFC’s establishment in 1982 increased the value of patents both as offensive weapons and as defensive shields in legal battles, and firms, particularly in the electronics and semiconductors industry, responded to the increased value of patents by ramping up their patenting.

2.2. IP Management at IBM

We have defined IP management as firm-specific practices that seek to profit from the firm’s intellectual assets. These practices include a firm’s choice of mechanisms, such as patents, to protect its IP; incentives that align the choice with employee behavior, and strategies to profit from IP. According to Grindley and Teece (1997), large U.S. corporations in the electronics and semiconductor industries started managing their IP in the 1980s to defend themselves against patent litigation and to profit from patent licensing, cross-licensing, and litigation. For example, TI nearly doubled its patent applications from 132 in 1983 to 236 in 1984 and, in 1985, demanded royalties from several Japanese companies for infringing on its “integrated circuit” and “manufacturing methods” patents. When the companies refused, TI litigated them and won $2 billion in damages and royalties between 1986 and 1993. Other U.S. corporations, such as Motorola, HP, AT&T, and IBM, attempted to follow TI’s lead in adopting practices to profit from their IP (Rivette and Kline 2000). Di Minin and Bianchi (2011) document the IP management practices at large telecommunications corporations, arguing that the practices strongly influence the internationalization strategies of the corporations.

We focus on IP management at IBM because R&D managers and patent attorneys at IBM did not file for more patents in response to either the legislative changes in 1981 that made software patentable (IBM was the world’s leading software company at the time) or the CAFC’s formation. IBM’s R&D expenditures doubled from $3 billion in 1981 to $6 billion in 1987 (all monetary figures in this paper are in USD (2000)), but its patent applications dropped from 589 to 541 between the same
years. In 1988, despite being the industry’s leading R&D spender, IBM lagged its foreign rivals, such as Hitachi, Toshiba, Philips, and Siemens, in U.S. patenting. But in 1993, the company emerged as the world’s top patentee, with 1,265 patent applications and 1,085 patent grants.

To gain insight into the management practices that shaped IBM’s remarkable patenting turnaround, we interviewed executives who were in charge of IBM’s research and legal divisions between 1979 and 1998. These executives include Ralph Gomory (director of research, 1970–1986), John Armstrong (director of research, 1986–1989), James McGroddy (director of research, 1989–1996), Marshall Phelps (head of the legal division, 1991–1996), and John Cronin (head of IBM’s “Patent Factory,” 1991–1998). We also perused archival records of IBM’s internal magazine, Think, which communicated key management initiatives and decisions to employees. Thus, by combing the material from interviews, archival records, and scholarly articles, we were able to put together a picture of the major events at IBM that may have affected the company’s patenting between 1979 and 1998.

Table 1 presents a timeline of major events within IBM and its environment that may have affected the company’s patenting propensity. According to our interviews, IBM’s IP management practices changed dramatically with the appointment of James McGroddy to lead the company’s research division in May 1989, and we focus on the effects of these changes. The beginning and end points of our study ensure that we can study the antecedents and consequences of the 1989 changes for roughly 10 years on either side of the changes. Also, IBM (and other firms in its industry) filed a number of patent applications after the CAFC’s 1998 decision to permit patenting of computer implemented business methods; excluding the years after 1998 avoids confounding the influence of this major change on the effects we seek to study.

2.2.1. IP Management at IBM Before 1989. IBM followed a decentralized approach toward managing its IP before 1989, with inventors choosing the mechanism to protect their inventions. IBM inventors submitted their invention disclosures to internal review committees (comprising research managers and attorneys from the company’s legal division). They then elected to either pursue a patent or publish the disclosures in IBM’s Technical Disclosure Bulletin (TDB), which was dedicated to publishing disclosures by the company’s inventors. Inventors received three points for each successful patent application and a point for each TDB publication. An invention could not be both patented and defensively published. The total points that inventors earned each year determined their annual bonuses and other performance-based rewards (publications in scientific journals were

<table>
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<tr>
<th>Year</th>
<th>Events at IBM</th>
<th>Events in IBM’s environment</th>
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<tr>
<td>1981</td>
<td>U.S. Department of Justice drops last antitrust case against IBM after 13 years of prosecution</td>
<td>U.S. Supreme Court decision on Diamond v. Diehr (450 U.S. 175 (1981)) establishes patentability of software</td>
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<tr>
<td>1982</td>
<td>John Akers replaces John Opel as chief executive officer</td>
<td>Creation of the CAFC with a pro-patent tilt in its opinions and decisions</td>
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<td>1983</td>
<td>John Armstrong replaces Ralph Gomory as director of IBM Research</td>
<td>Polaroid wins infringement battle against Kodak, forcing the latter out of the instant photography business; Texas Instruments starts suing firms for infringing on its integrated circuits and manufacturing methods patents</td>
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<tr>
<td>1986</td>
<td>IBM researchers receive Nobel Prize for their work on scanning tunneling microscopy</td>
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<tr>
<td>1987</td>
<td>IBM researchers receive Nobel Prize for their work on high-temperature superconductivity in a new class of materials</td>
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<tr>
<td>1989</td>
<td>James McGroddy replaces John Armstrong as director of IBM Research and changes inventor points system to require more patenting</td>
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<tr>
<td>1990</td>
<td>McGroddy starts patent academies to educate inventors on patenting best practices</td>
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<tr>
<td>1991</td>
<td>John Cronin leads IBM’s “Patent Factory,” which identifies and converts inventors’ disclosures to patents</td>
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<tr>
<td>1992</td>
<td>IBM reports $5 billion loss, the largest in corporate history; McGroddy starts effort to identify IBM technologies that were not used by the company so they could be licensed out and generate revenues</td>
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<tr>
<td>1993</td>
<td>Louis Gerstner replaces John Akers as IBM Chairman and chief executive officer; Gerstner starts reorganization</td>
<td>CAFC ruling on State Street Bank and Trust Company v. Signature Financial Group, Inc. (149 F.3d 1368 (Fed. Cir. 1998)) and AT&amp;T Corp. v. Excel Communications, Inc. (172 F.3d 1352 (Fed. Cir. 1999)) establishes patentability of business methods</td>
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not rewarded with points but played a significant role in nominations to be appointed an “IBM Fellow,” the highest honor given to four to nine IBM researchers each year).

Unlike successful patent applications, disclosures required little additional work to be published because articles in IBM’s TDB were edited versions of inventors’ project write-ups and typically two to three pages long. Hence, even though a single successful application could garner an inventor three times as many points as a publication, inventors preferred to publish their disclosures as the easiest way to earn points (McGroddy 2011). These incentives that encouraged disclosure via publications rather than patents were consistent with the open-science norms at the company. IBM’s research leadership played no small part in encouraging open-science norms: Ralph Gomory, the director of IBM Research between 1970 and 1986, was an award-winning mathematician; his successor, John Armstrong (director of research between 1986 and 1989), was a noted physicist. According to Gomory, IBM researchers were similar to academic scientists—they rarely worked with the company’s product-development and manufacturing teams and were free from the obligations of contributing to the company’s financial bottom lines (Gomory 1989). Indicative of IBM’s academic orientation and the basic nature of its research, company scientists won the Nobel Prize in Physics in 1986 and 1987.

Scholars have traced IBM’s subdued patenting to the late 1950s, when federal antitrust authorities viewed patenting by large corporations as attempts to strengthen their monopoly and issued “consent decrees” that required the corporations to compulsorily license their patents (Scherer 1987). Although the antitrust authorities dropped their last case against IBM in 1982, the company continued to patent only a small fraction of its inventions each year, primarily to enhance its prestige and recognize its prominent inventors (Bhaskarabhatla and Pennings 2013). Thus, a long history of antitrust stipulations, inventor incentives, and open-science norms at IBM discouraged patenting, and in 1988, IBM inventors patented only 18% of their disclosures, choosing to publish the rest.

2.2.2. \textit{IP Management at IBM, 1989 and After.} James McGroddy started his professional career at IBM in 1965 and was appointed director of research in May 1989 after his predecessor, John Armstrong, was promoted to chief scientific officer. McGroddy had worked on many critical projects at IBM, including the creation of the enormously successful display technology for IBM’s ThinkPad line of laptop computers, and was seen as a natural successor to Armstrong in a company that rewarded a combination of merit and seniority in its promotion decisions (Buderi 2000).

Immediately after his appointment, McGroddy implemented several changes to IBM’s IP management. First, he established patents as the primary mechanism to protect IBM’s inventions. McGroddy started an internal “patent academy” to “educate all technical professionals on writing, evaluating and processing patent disclosures and what makes a good patent” (Boyer 1990, p. 11). Working with the legal division, he directed John Cronin to set up an internal “patent factory.” Cronin traveled to IBM’s various R&D locations with a small team of experienced inventors and attorneys, unearthed hundreds of inventions that were previously neglected, and converted them to patent applications. According to Lynam (2009), the “Patent Factory team expanded its reach throughout IBM’s microelectronics installations and helped the company become the country’s top patentee.”

Second, McGroddy changed inventors’ incentives to align with his chosen mechanism to protect the company’s IP by requiring them to earn more “points,” which determined their annual compensation, from patent applications. According to McGroddy (2011),

Rewards [for IBM inventors] were given to “write and publish” and “write and file for patent.” For instance, some had an arrangement with their patent attorney—to get their inventions rated for “write and publish,” which yielded points quickly. The policy of publishing literature and organizing it for the benefit of everyone did not seem to be a good strategy. After becoming R&D head, [I] unilaterally set standards for the fraction of inventions that had to be “write and file” for rewards. At least [a] quarter or half had to be “write and file” now.

Third, McGroddy started a “business development group,” whose responsibilities included patent licensing. Marshall Phelps, a leading IP attorney, was put in charge of IBM’s out-licensing efforts, and his team was asked to generate enough licensing revenues to fund a significant portion of the company’s R&D expenditures. Inventors were also awarded additional bonuses if their patents received licensing revenues. In McGroddy’s words, “If a patent yielded licensing revenues, inventors of the patent were given $20,000 to $50,000. Even more money if revenues were great” (McGroddy 2011).

Apart from the above changes, IBM also adopted other operational practices to bring down its patenting costs. For example,

IBM has struck this balance between the volume and cost of patenting using an entity it refers to as the virtual law firm. The company recruits its retiring patent attorneys, along with retirement eligible attorneys seeking a stay-at-home work/life balance. It associates these proven performers with one of its outside counsel and guarantees them levels of patent application and prosecution work at fixed fees. This win–win strategy generates a large stable of company-savvy, technologically experienced patent practitioners at rates untouchable in a traditional law firm-corporate relationship.

(Davis and Harrison 2001, p. 33)

In a decade since the adoption of its pro-patent practices, IBM increased its successful patent applications by 492%—from 637 in 1988 to 3,777 in 1998. IBM inventors...
elected to patent nearly 85% of their disclosures in 1998 (compared with 18% in 1988), and the company stopped publishing its TDB in the same year.

2.2.3. Why Did IBM’s IP Management Change in 1989? IBM’s executives and archival records suggest that the company’s pro-patent shift was in response to changes in its IP environment brought about by the CAFC’s establishment in 1982, but it was catalyzed by IBM’s new leadership and financial pressures on IBM Research. Jack Kuehler, president of IBM between 1989 and 1993, communicated the reasons for the company’s pro-patent shift to the company’s employees as follows:

A series of new laws in the [United States]—plus a much-improved court system for handling disputes [the CAFC]—are helping patent holders protect their rights better than before. . . . From a simple means of protecting inventions, patents have evolved into competitive weapons. Recent cases before the courts have resulted in multimillion dollar settlements affecting product line and even corporate profitability in what are now high-stakes battles . . . . Being a world-class manufacturer and marketer is not enough. You need to own the right to compete. That’s why IBM is encouraging more patenting of inventions.

(Boyer 1990, p. 10)

Why did IBM respond to the 1982 changes in its environment only in 1989, several years after other firms in its industry—such as TI, Kodak, HP, and Motorola—started enhancing their patent portfolios? Our discussions with McGroddy, Gomory, and other IBM executives suggests that the following two factors explain the timing of IBM’s response:

- **Leadership change:** IBM was engaged in an antitrust battle with the U.S. Department of Justice (DOJ) between 1956 and 1982. During this time, IBM was restricted from enforcing its patents through a consent decree that required compulsory licensing of its patents. Although the DOJ dropped its last antitrust case against IBM in 1982, incumbent executives were unwilling to change the company’s approach toward patenting. The open-science culture nurtured by IBM’s academically oriented R&D leadership until 1989 contributed to this resistance. The appointment of Gomory as director of IBM Research in 1989 may have made it easier to step away from these open-science norms and adopt pro-patent management practices.

- **Financial troubles:** IBM’s 1989 R&D budget, $7.2 billion, was higher than in any previous year. But the company’s gradual financial decline in the late 1980s increased the pressure on its R&D division to contribute to the company’s revenues (Buderi 2000). IBM’s R&D budget was cut to $5.2 billion in 1992 and to $3.9 billion in 1993, and 25% of IBM’s 3,400-odd research workforce were laid off between 1991 and 1993. IBM’s financial decline and the growing chorus of demands for R&D to contribute to its profitability may have motivated the pro-patent switch, since after the legal changes in 1982, firms were actively deploying patents to either earn licensing revenues or act as “bargaining chips” in negotiations to access to others’ technologies.

3. Did IP Management Changes Affect Patenting?

3.1. The Effect of the 1989 Changes in IBM’s IP Management

Our qualitative research reveals that McGroddy’s appointment triggered IBM’s adoption of pro-patent IP management practices in 1989. Around the same time, however, IBM’s R&D was undergoing a shift toward more applied technologies, and there was an industry-wide increase in patenting propensity. To isolate the effects of IBM-specific pro-patent management on patenting, we employ a differences-in-differences analysis that compares IBM’s patenting propensity to that of a control group of large electronics and semiconductor firms before and after 1989. The analysis controls for several observable company characteristics, including R&D intensity, capital investments in plant and equipment, scale, and other variables that determine patenting. The baseline “patent production function” we estimate can be stated as follows:

\[
\text{PAT}_{it} = \alpha \log \text{RD}_{it} + \beta \log \text{PE}_{it} + \gamma \text{IBM}_{i} + \sum_{t=1979}^{1998} \delta_{t} \text{T}_{i} + \sum_{t=1979}^{1998} \theta_{t}(\text{T}_{i} \times \text{IBM}_{i}) + \sum_{t=1979}^{1998} \eta_{t} \text{I}_{it} + \epsilon_{it},
\]

where \(\text{PAT}_{it}\) denotes the number of successful patent applications by firm \(i\) in year \(t\). The explanatory variables include R&D expenditures, the most important determinant of a firm’s number of patent applications. We follow Hall and Ziedonis (2001) in using investments in plant and equipment as a predictor of the propensity to patent for defensive purposes (since firms’ incentives to protect themselves against patent-infringement suits rise in proportion to their sunk investments in plant and equipment). We use three-year moving averages for R&D and plant and equipment (P&E) expenditures (i.e., the average of expenditures during years \(t\), \(t-1\), and \(t-2\)) to smooth investments and to account for the fact that a firm’s patenting during any year is most likely to be affected by contemporaneous and past-year investments. We normalize R&D and P&E expenditures by corresponding-year sales before calculating the moving averages to avoid confounding their effects with the influence of size and scale. Thus, the variables \(\text{RD} \) and \(\text{PE} \) in the equation denote R&D intensity and capital intensity, respectively. Four control variables comprise \(I\): three-year moving average of revenues (proxy for size/scale); patenting age (proxy for patenting experience); a dummy indicator set to zero if the firm reported R&D expenditures for the years \(t\), \(t-1\), or \(t-2\); and a variable...
that counts the number of years between 1979 and 1998 for which Compustat data were not available for the firm (this variable does not vary with t). Several others before us, including Hall and Ziedonis (2001), Bessen and Hunt (2007), Somaya et al. (2007), and Hegde et al. (2009), have estimated the patent production function with the above set of variables but in different empirical contexts. The 20 dummy variables for each year between 1979 and 1998 in T represent year-specific effects, such as technological and legal changes, that influence the patenting of all firms in the sample, and the interaction terms of the year-specific dummies with the IBM dummy (IBM) identify IBM-specific patenting trends.

The estimation sample consists of 2,009 firm-year observations for the 115 U.S. publicly traded electronics and semiconductor firms, including IBM, between 1979 and 1998. We identified the control-group firms as those that had patented at least once in the same USPTO technology classes as IBM’s patents and whose main line of business was “electronics and semiconductors”, according to Compustat. We do not distinguish between the subindustries within electronics and semiconductors because the large corporations in our sample, including IBM, operated in multiple subindustries within electronics and semiconductors, sometimes changing their Compustat-assigned subindustry category during the period of our study (however, we address the consequences of IBM’s changing technological focus on its patenting below). We retained only firms with at least 15 continuous years of Compustat records during our 20-year study to avoid missing records and to ensure comparability with IBM. We then matched the annual Compustat record of each firm to its total number of successful U.S. patent applications that year.

Between 1979 and 1998, on average, IBM spent $5.1 billion annually on R&D and applied for 1,281 patents, whereas control-group firms spent $2 million annually on R&D and applied for 58.4 patents. Despite these differences in research inputs and outputs, the annual patent/R&D$ ratio for IBM, at 0.1 patents per million R&D$, is similar to that for the average control-group firm. Control-group firms are the 114 Compustat firms described in the Figure 3 notes. The vertical line indicates the introduction of pro-patent management practices at IBM in 1989.

2,009 firm-year observations to (1) are as follows (numbers in brackets represent robust standard errors clustered at the firm level):

\[
PAT_{it} = 7.71 \log RD_{it} + 0.38 \log PE_{it} - 0.12 IBM_t + \sum_{t=1979}^{1998} \hat{\delta}_t T_t + \sum_{t=1979}^{1998} \hat{\theta}_t (T_t \times IBM_t) + \sum \hat{\eta}_i I_i; \]

\[
\log \text{likelihood} = -52,061. \quad (2)
\]

The estimates confirm that R&D intensity is a significant predictor of patenting propensity. The unreported estimated coefficients for sales and the indicator variable denoting firm-years with nonmissing R&D data are positive and significant at p < 0.01; for age and the number of years of missing Compustat data, they are negative but not statistically significant. The estimated coefficient for IBM’s average patent propensity between 1979 and 1998 is not significantly different from that of control-group firms. However, we are interested in the patenting propensity of IBM relative to that of control-group firms before and after the 1989 changes at IBM, which can be gauged from \( \hat{\theta}_t \) for \( t = (1979, 1980, 1981, \ldots, 1998) \). Figure 5 plots these estimates and their 95% confidence intervals after converting them to incident rate ratios (IRRs) for ease of interpretation (1979 is dropped from the full set of estimates).\(^3\)

Figure 5 shows that for given levels of R&D intensity, P&E intensity, revenues, and other variables, IBM’s patent propensity is not significantly different from that...
of control-group firms before 1989, experiences a clear uptick immediately after 1989, and ends up 2.3 times higher than control group firms in 1998 (an IRR estimate of 1 for \( \theta \) indicates that IBM’s patenting rate is similar to that of control-group firms; an estimate greater than 1 indicates IBM’s patenting propensity is higher than control-group firms).

The above estimation restricts the patent/R&D and patent/P&E relationships (\( \alpha \) and \( \beta \), respectively) to be identical for IBM and control-group firms, but the relationships may have changed for IBM in ways that their effects are correlated with that of pro-patent IP management practices. For example, and as discussed before, IBM’s R&D may have yielded more patentable inventions after 1989 because of a shift in the company’s research, thus compromising our interpretation that the post-1989 increase was due to IP management changes. One way to tease out the effects of IBM-specific changes in the relationship between the company’s R&D and patenting is to include “triple-interaction terms” in the regressions—i.e., terms obtained by multiplying the IBM dummy, the R&D intensity variable, and the year dummies. However, such triple-interaction terms are inconsistently estimated in nonlinear models, and we would have to include multiple triple-interaction terms to partial out the effects of the changing relationship between other variables (e.g., P&E intensity) and patenting. Hence, we instead estimate the regressions in four five-year subperiod samples with two-way interaction terms (\( \text{IBM} \times RD \) and \( \text{IBM} \times PE \)) to allow for changes in IBM-specific relationships between the two explanatory variables and patenting across the subperiods. We also include operating income and its interaction with IBM to control for IBM-specific changes in financial performance.

Table 2 shows that the estimated coefficient for the interaction term of IBM and R&D intensity is significantly positive for 1979–1983 and 1984–1988, but it turns negative for the periods 1989–1993 and 1994–1998. This observed inverse relationship between patenting and R&D intensity for the later subperiods reflects the observation that IBM became less research intensive while squeezing more patents out of its R&D dollars in the post-1989 years. Bessen and Hunt (2007) found a similar inverse correlation between software patents and R&D intensity and interpreted this as evidence for the decreased cost of software patenting relative to R&D. The IBM-specific relationship between P&E expenditures and patenting also turns negative for 1994–1998, suggesting that the company was filing for more patents to protect proportionately lower levels of capital investment in the later periods. The IBM-specific relationship between changes in operating income and patenting switches from positive to negative in the last two subperiods, suggesting that increases in patenting followed declining financial performance.

The estimated coefficients for the IBM dummies confirm that IBM-specific patent propensity was significantly lower than that of the control-group firms during the subperiods 1979–1983 and 1984–1988 and significantly higher during 1989–1993 and 1994–1998. Hence, IBM-specific factors other than changes in the company’s R&D, P&E, or operating income appear to have played a significant role in increasing its patenting propensity (relative to control group firms) after 1989.

### 3.2. Alternative Explanations

Our differences-in-differences analysis shows that controlling for the observable determinants of patenting, IBM’s patenting rate increased relative to other firms in its industry after 1989. Our qualitative and quantitative research suggests that the adoption of the pro-patent IP management practices at IBM in 1989 explains this jump, but could the increase be due to other influences not adequately controlled for in our regressions? We explore three plausible alternative explanations below.

(i) **Changes in IBM’s technological focus.** Changes in technological focus affect patenting by changing the patent yield of R&D. Hence, allowing for IBM-specific changes in the patent/R&D relationship, as we have done in the regressions, should account for changes in IBM’s R&D focus correlated with changes in patent propensity. Still, one might argue that IBM switched its product portfolio to more patentable technologies in 1989 by making changes not captured by patent/R&D or patent/P&E correlations. We probe this possibility further in Figure 6, by plotting trends in IBM’s patenting in the seven USPTO technology classes that accounted for the lion’s share of its patents (over 70%) in 1979.
Figure 6 reveals the following facts: (i) IBM’s patenting remained relatively flat in all technologies until 1989, declining gradually in some technology classes (e.g., “semiconductor device manufacturing”)—reflecting the company’s shift away from the technologies—while gradually increasing in others (e.g., the database and file management and multicomputer data transfer classes, which are most likely to contain software patents). (ii) IBM’s patenting in all technology classes, even those that were not considered IBM’s focus (e.g., “solid state devices” and “semiconductor device manufacturing”) increased sharply after 1989, suggesting that the increases were not due solely to changes in the company’s focus. Instead, the increases are consistent with IBM’s post-1989 IP management practices to aggressively patent technologies that were not part of its business focus so that they could be deployed to generate licensing revenues (Gomory 1989).

The above analysis does not rule out changes in the nature of R&D within IBM’s patent technology classes. Hence, we explore IBM-specific trends in two patent-level variables—the proportion of backward citations in patents to scientific publications (after excluding citations to IBM’s own TDBs) and the average vintage of citations to prior art in patents—that could reflect changes in the nature of IBM’s R&D (Narin et al. 1997, Sørensen and Stuart 2000). Table 3 confirms that neither the extent to which IBM’s patents cited prior scientific publications nor the average vintage of its backward citations to patents changed sharply in 1989. The table reveals a surprising tendency for IBM’s patents (relative to control group patents) to cite a greater share of scientific publications during later years; IBM’s patents also appear to increasingly build on more recent prior art (relative to control group patents), but neither of these trends, nor the changes in the trends, coincides with the sharp 1989 upturn in patenting. We can thus be confident that sharp changes in the nature of IBM’s R&D and technology did not coincide with its patenting turnaround in 1989.

(ii) Changes in human capital. A second alternative explanation is that, in 1989, IBM started hiring researchers who were better trained to perform patentable research. Figure 7 shows the number of successful patents and
Figure 6: Growth in IBM Patenting by Patent Technology, 1979–1998

Notes: This graph shows the number of successful U.S. patent applications by application year for the seven patent technology classes in which IBM patented most frequently in 1979. The vertical line indicates the introduction of pro-patent management practices at IBM in 1989.

publications assigned to the average inventor in the following three cohorts: inventors with a record of inventions (i.e., patents or publications) at IBM only before 1989; inventors with a record of inventions at IBM only after 1989; and inventors with a record of inventions at IBM both before and after 1989. The last group consists of inventors who received the pro-patent IP management “treatment” in 1989. The figure shows that the number of successful patent applications per year by the average

Table 3: Patent Characteristics for IBM and Control-Group Firms, 1979–1998

<table>
<thead>
<tr>
<th>Patent application year</th>
<th>% share of backward cites to scientific papers</th>
<th>Average vintage of backward cites in years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panel A</td>
<td>Panel B</td>
</tr>
<tr>
<td></td>
<td>IBM</td>
<td>Control firms</td>
</tr>
<tr>
<td>1979</td>
<td>6.0</td>
<td>7.6</td>
</tr>
<tr>
<td>1980</td>
<td>8.8</td>
<td>8.2</td>
</tr>
<tr>
<td>1981</td>
<td>7.9</td>
<td>8.5</td>
</tr>
<tr>
<td>1982</td>
<td>8.7</td>
<td>8.8</td>
</tr>
<tr>
<td>1983</td>
<td>7.6</td>
<td>8.6</td>
</tr>
<tr>
<td>1984</td>
<td>8.1</td>
<td>8.5</td>
</tr>
<tr>
<td>1985</td>
<td>8.8</td>
<td>8.9</td>
</tr>
<tr>
<td>1986</td>
<td>11.0</td>
<td>9.1</td>
</tr>
<tr>
<td>1987</td>
<td>12.0</td>
<td>9.5</td>
</tr>
<tr>
<td>1988</td>
<td>10.3</td>
<td>9.9</td>
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<tr>
<td>1989</td>
<td>11.1</td>
<td>10.3</td>
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<tr>
<td>1990</td>
<td>10.8</td>
<td>10.1</td>
</tr>
<tr>
<td>1991</td>
<td>12.4</td>
<td>10.5</td>
</tr>
<tr>
<td>1992</td>
<td>12.4</td>
<td>11.3</td>
</tr>
<tr>
<td>1993</td>
<td>13.1</td>
<td>11.9</td>
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<tr>
<td>1994</td>
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<td>1995</td>
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<td>10.6</td>
<td>10.5</td>
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<tr>
<td>1997</td>
<td>11.7</td>
<td>10.1</td>
</tr>
<tr>
<td>1998</td>
<td>10.2</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Notes: Panel A shows the percentage of backward citations in IBM and control group patents (by application year) to scientific literature (backward citations can be to either previous patents or scientific papers; we exclude citations from IBM’s patents to disclosures published in its own TDBs), differences in means of IBM and control patents, and p-values obtained from t-tests for the differences. Panel B shows the average age (in years) of citations to previous patents from the focal patent’s application date for IBM and control group patents by application year, differences in means of IBM and control patents, and p-values obtained from t-tests for the differences.

* * p < 0.01; * p < 0.05.
inventor in the last group remained more or less constant at 0.33 patent applications per year from 1979 to 1989 but, after an upturn in 1989, rose to two applications per year in 1998. The figure also shows that the number of publications by the same group of inventors dropped from 2.2 per year in 1979 to 0.8 per year in 1998. Recall that IBM inventors earned their points (tied to their annual compensations) through either TDB publications or patents; in 1989, McGraddy stipulated that inventors earn at least 25%–50% of their points by filing patent applications. This sharp increase in the patenting activity of incumbent inventors at IBM after 1989, along with the accompanying drop in their publications, suggests that the incentive change for existing inventors, not new personnel, was responsible for increased patenting.

4. What Were the Consequences of Pro-Patent IP Management?

4.1. The Private Returns of Patenting

According to IBM executives, the goals of the 1989 changes were to improve profits through licensing revenues and to preserve the company’s “freedom to operate.” This section investigates whether IBM’s delayed adoption of pro-patent practices (relative to other firms in its industry) achieved these goals. IBM’s annual licensing revenues were less than $20 million before 1991, but jumped to $4.1 million in 1992, $345 million in 1993, and $1.1 billion in 1998 (nearly 25% of its R&D budget for that year). Although licensing revenues were welcome, the chief thrust behind IBM’s pro-patent shift was the use of patents as “bargaining chips” in negotiations to gain access to others’ technologies. Kuehler stated the following as the main reason for IBM’s pro-patent shift in 1989:

[T]o shorten our cycles, we need to have access to the inventions of the rest of the world. And this is why IBM’s own patent portfolio is so important. This library of patents gains us access to the inventions of others.

(Boyer 1990, p. 11)

Roger Smith, IBM’s IP counsel, also expressed the access motive for the 1989 changes as follows:

Access is far more valuable to IBM than the fees it receives from its patents. There’s no direct calculation of this value, but it is many times larger than the fee income, perhaps an order of magnitude larger.

(Boyer 1990, p. 10)

As Smith’s quote suggests, the private returns from access to others’ technologies enabled by patents cannot be inferred from conventional profitability metrics. Therefore, we estimate the private returns of IBM’s pro-patent management practices by relating its patent stocks to a measure of the company’s intangible value, its Tobin’s $q$ before and after 1989, relative to a control group. Tobin’s $q$ is the ratio of a firm’s market value to the book value of its tangible assets and is often used as a proxy for the value of firms’ intangible assets (e.g., Hall et al. 2005). We estimate the relationship between IBM’s Tobin’s $q$ and patent stocks in the following differences-in-differences equation:

$$\log Q_{it} = \alpha \log PAT_{it} + \beta IBM_{i} + \delta (\log PAT_{it} \times IBM_{i}) + \sum \theta I_{it} + \epsilon_{it},$$  \hspace{1cm} (3)$$

where $Q$ denotes Tobin’s $q$ of firm $i$ in year $t$. We calculate the numerator in Tobin’s $q$ (market value) as the sum of market value of equity (book value of preferred stock, long-term debt, and current liabilities less current assets) and the denominator (book value of tangible assets) plus the book value of inventory (as in Dowell et al. 2000). $PAT$ denotes three-year aggregate stocks of patent grants to firm $i$ in years $t-1$, $t-2$, and $t-3$; $I$ contains a set of firm-specific variables that control for factors potentially related to both patenting and market value, including R&D intensity ($\text{R&D/revenues}$), capital intensity ($\text{P&E/revenues}$), size/scale ($\text{revenues}$), patent age, and a dummy variable set to zero for firm-years with missing R&D expenditures. We use three-year moving averages for R&D and P&E expenditures, as before, and include for each firm a variable that counts the number of years between 1979 and 1998 for which Compustat data were not available. $T$ is a vector of year-specific controls for changes in firms’ technological and legal environments that influence patenting. The IBM dummy ($IBM$), set to 1 for IBM observations and 0 for the control-group firms, controls for IBM-specific determinants of market value, and the interaction of the IBM dummy with the patent stock variable captures the IBM-specific relationship between patent stocks and market value.


Table 4 shows that the three-year patent stock variable is not positively related to Tobin’s $q$ in any subperiod for the control-group firms. In contrast, the relationship between patent stock and market value varies significantly across the four subperiods for IBM: between 1979 and 1983, when IBM’s patent intensity was higher than that of the average control-group firm, a 1% increase in its patent stock is associated with a 2.6% increase in its Tobin’s $q$ ($p < 0.01$); between 1984 and 1988, when IBM fell behind its rivals in patenting, the relationship between its patent
stocks and market value is negative ($\hat{\beta} = 2.97; p < 0.01$); between 1989 and 1993, when IBM’s patenting caught up to its rivals’, the relationship between its patent stocks and Tobin’s $q$ is not statistically different than that of the average control-group firm ($\hat{\beta} = 0$); and in the 1994–1998 subperiod, when IBM was the world’s largest patentee, a 1% increase in its patent stocks is associated with a 2% increase in Tobin’s $q$ ($p < 0.01$).

We acknowledge that the relationship between patenting and private value is complex and shaped by several factors not considered by our analysis, such as industry structure and competitors’ patenting strategies. Executives also make decisions about the optimum level of patenting after considering their benefits. Thus, the above conditional correlations are not causal estimates but provide suggestive evidence for the success of IBM’s pro-patent management practices in enhancing the intangible returns to the company from its patents.

### 4.2. Patenting and Knowledge Spillovers

In theory, patents enhance the private returns of knowledge investments by increasing competitors’ cost of using proprietary knowledge. This tension between private appropriability and public diffusion associated with patents has been empirically studied in the context of increased patenting by U.S. universities after the Bayh–Dole Act of 1980 (e.g., Argyres and Liebeskind 1998, Heller and Eisenberg 1998, Henderson et al. 1998, Mowery et al. 2001, Murray and Stern 2006). However, few studies have investigated the effects of corporate patenting on knowledge spillovers. A stream of research closely related to our work investigates the benefits to corporations of engaging in open-science norms, including investments in basic research, collaborations with academic scientists, and corporate incentives to publish (Cohen and Levinthal 1990, Cockburn and Henderson 1998). This research suggests that the adoption of open-science norms by firms increases the productivity of their R&D by equipping the firms to effectively identify and utilize external knowledge. However, this work has stopped short of examining the industry-wide consequences of firms’ adoption of open-science norms.

We investigate the consequences of pro-patent practices, which represent a move away from open-science norms for knowledge diffusion in the context of corporate patentees, particularly IBM. One indicator of the importance of IBM’s research is that the company accounted for nearly 4%, whereas U.S. universities accounted for less than 1% of all patents in electronics and semiconductor technologies between 1979 and 1998. During the
same period, the average IBM patent received 14 citations, whereas the average university patent received 12.5 citations (in comparable five-year citation windows and technology classes) indicative of both the high quality and spillovers associated with IBM’s inventions. According to Gomory (1989), the company’s competitors benefited tremendously from the knowledge spillovers made possible through a combination of IBM’s publications and limited patenting before 1989.

Did the 1989 pro-patent shift at IBM reduce its knowledge spillovers? Figure 8 shows that IBM’s published disclosures, in its TDBs, dropped after 1984 and, after reaching a high of 4,229 articles in 1990, declined by 18% to 3,459 articles in 1991 and by 82% to 759 articles in 1998 (publications by IBM inventors in other scientific journals also decreased, but only after 1992). The number of IBM publications appears to have declined one to two years after the 1989 changes (and the increase in patenting) because the years reflect their publication dates, and the numbers for patents reflect their application dates. These aggregate patterns are consistent with those in Figure 7, which shows that the post-1989 drop in the number of publications per inventor was accompanied by a sharp increase in patenting. Therefore, IBM’s 1989 pro-patent policies appear to have curtailed the dissemination of its knowledge through publications.10

We further probe the implications of IBM’s pro-patent shift for knowledge spillovers by comparing citations to IBM’s patents with citations to control group patents before and after 1989. Citations are noisy measures of knowledge spillovers, but we use them because of their ready availability for each invention (patent) in our study, their use by several scholars before us to measure spillovers (since the pioneering work of Jaffe et al. 1993), and the absence of a compelling argument suggesting that the noise is correlated with the errors in our regression.11

We estimate

\[
CITES_{it} = \alpha + \beta SCITES_{it} + \delta (SCITES_{it} \times IBM) + \sum_{t=1979}^{1998} \rho_t T_t + \sum_{t=1979}^{1998} \theta_t (T_t \times IBM) + \sum_{c} \eta_c \text{CLASS}_c + \sum_{g=1979}^{1998} \gamma_g \text{GYEAR}_g + \epsilon, \tag{4}
\]

where the dependent variable, \(CITES\), is the annual number of citations to each patent \(i\) from inventors other than the patent owner in year \(t\); \(T_t\) is a dummy variable that indicates the citation year \(t\); \(IBM\) is a dummy variable set to 1 for IBM patents and 0 for control-group patents; \(CLASS\) is a vector of 258 dummy variables that represent the USPTO technology class of the patent; and \(GYEAR\) is a dummy variable that indicates the patent grant year \(g\). Other inventors’ citations to a patent depend on the underlying invention’s quality as well as the extent to which its owner enforces the patent. We include \(SCITES\), the number of self-citations to the patent (i.e., the number of citations to the patent from the company’s own patents) each year, to control for the invention’s quality and isolate the effect of appropriability on spillovers. \(CLASS\) and \(GYEAR\) control for patent technology class- and patent grant year-specific features that influence citations, respectively.

We seek to identify the distinct effects of pro-patent management practices on IBM’s industry-wide knowledge spillovers; this requires controlling for changes in the nature and quality of IBM’s research that may have coincided with the adoption of pro-patent practices. Section 3.2 produced evidence from the vintage of IBM patents’ backward citations and references to scientific papers to rule out the possibility that IBM’s shift toward increased patenting in 1989 coincided with a switch to more applied research. Still, one might argue that any post-1989 decrease in others’ citations to IBM patents may stem from the declining quality of IBM patents (since IBM started filing more patents) not adequately controlled for by our self-citations measure of quality. Hence, we remove IBM’s post-1989 patents from our analysis and analyze whether other inventors’ citations to IBM’s pre-1989 patents decreased, relative to control group patents, after 1989. If others’ citations to IBM’s pre-1989 patents decrease relative to the citations received by control patents after 1989, then we can be confident that the drop reflects decreased spillovers of IBM’s knowledge, not changes in the quality of IBM’s patents.

Our estimation sample retains only the 5,665 IBM patents granted between 1979 and 1989, which correspond to 41,366 citation-year observations for IBM and 440,478...
citation-year observations for 114 control-group firms. We employ PPML regressions to estimate Equation (4) and do not report the full set of estimates here for brevity’s sake. We find that, on average, IBM’s patents receive more citations each year from other inventors (1.79) than control-group patents do (1.66) for patents granted between 1979 and 1989. Since we are interested in the differences in citation trends for IBM and control-group patents (estimated by \( \theta \), for years \( t = 1979, \ldots, 1998 \)), we plot the corresponding estimates in Figure 9 (the last two columns of Table A4 in the supplementary appendix reports the full set of estimates). The figure shows that the annual number of other inventors’ citations to IBM patents (relative to control patents) increases until 1989 and decreases during 1990–1998. Since we control for self-citations, technology field, and grant year-specific effects, the estimates imply that an “average” IBM patent received 17% \( \exp(0.16) - 1 \) more citations than an identical control group patent in 1989, but 14% fewer citations than an identical control group patent in 1998 (the decline is statistically significant at \( p < 0.05 \)). It is also noteworthy that others’ citations to IBM patents do not recover in the later years of our study, even after IBM recovers profitability, suggesting that the drop is likely due to decreased spillovers rather than a “declining firm” effect. The observed drop in others’ citations to IBM patents after 1989 is also robust to alternative constructions of the estimation sample such as inclusion of post-1989 IBM patents and their citations and exclusion of post-1989 control group patents and their citations.

Next, we investigate trends in the propensity of non-IBM inventors to cite IBM’s publications.12 We collect data on the number of times IBM publications are cited by IBM patents and non-IBM patents by patent-application year. Figure 10 shows that non-IBM patents accounted for 85% of the citations to IBM’s publications between 1979 and 1989 but for only 74% of the citations to IBM’s publications between 1990 and 1998, with a pronounced drop in 1990.

We conclude that the decrease in others citations to IBM’s patents and publications after 1989 indicates reduced spillovers. What might be the mechanisms through which pro-patent management practices reduce spillovers? As suggested above, we argue that the cost of using IBM’s knowledge was relatively low to other inventors before 1989, either because IBM did not patent all its inventions or because it did not enforce its patents through licensing deals. However, IBM’s aggressive patenting and patent licensing practices increased the costs of using IBM’s knowledge to other inventors after 1989, potentially deterring some inventors from building on IBM’s patented knowledge and thus reducing industry-wide spillovers. Of course, each of our above measures of knowledge spillovers—the post-1989 decrease in the number of IBM publications, the drop in others’ citations to IBM’s pre-1989 patents, and the drop in others’ citations to IBM’s TDB publications relative to its own citations—has its limitations, but all consistently suggest that pro-patent management practices effectively curtailed IBM’s knowledge spillovers.

5. IP Management at Other Firms

We have shown that IBM’s patenting surged after the adoption of pro-patent practices in 1989. In the years following adoption, IBM’s patent stocks are related to higher private returns and lower knowledge spillovers. Can we conclude from IBM’s case that pro-patent practices affected patenting propensity, private returns, and knowledge spillovers of other corporate patentees? We next
specifically test whether the adoption of pro-patent practices explains these outcomes for large U.S. corporate patentees other than IBM.

Extending our qualitative research on IP management practices to a larger sample requires information on firm-specific causes and correlates of the practices, which is not easily available. Hence, we selected the top 20 patentees in 1998 from our control group and searched media reports, popular books on IP, annual company reports, and scholarly articles for descriptions of changes in their IP management. We were able to find information on significant pro-patent IP management changes in eight firms other than IBM between 1979 and 1998. (Exhibit 1 briefly describes these changes and their timing for each of the eight corporations.) These eight firms (Advanced Micro Devices (AMD), Eastman Kodak, Hewlett-Packard, Intel, Micron Technologies, Motorola, Texas Instruments, and Xerox) owned 47% of the non-IBM patents between 1979 and 1998 in our sample, and we check whether the adoption of pro-patent management practices in these eight firms are related to changes in their patenting propensity, market value, and industry-wide knowledge spillovers. To avoid influencing the analysis with IBM-specific effects, we omit IBM observations from the following analysis.

First, we consider the eight firms for which we have information on their IP management practices as the treatment group and the remaining 106 firms as part of the control group. Since each of the eight treatment group firms received the “treatment” (that is, sharp and well-publicized pro-patent IP management changes) in different years, we capture the average treatment effect by including a dummy variable that indicates the years after the treated firms received the treatment. We then estimate our differences-in-differences equation, comparable to the one in Equation (1), with the number of successful patents (PAT) of firms each year as the dependent variable. Our estimation sample consists of 1,874 observations, and we obtain the following PPML estimates for firm-year patenting propensity:

\[
\hat{PAT}_{it} = 4.56 \log RD_{it} - 0.14 \log PE_{it} - 0.46 \text{TREATED}_{it} + 0.80 \text{TREATED\_AFTER}_{it} - 0.00 \text{OIC}_{it} + \sum_{t=1979}^{1998} \delta_t + \sum_{i} \eta_i; \\
\text{log likelihood} = -35,149. \quad (5)
\]

Converting the estimated coefficient of the treatment effect (TREATED\_AFTER: 0.80, \( p < 0.01 \)) to its IRR implies that the treated firms’ patenting increased by 122% in the years following their adoption of pro-patent management practices, holding other factors that influence patenting constant (control variables are as described in §3.1 and employed in Table 2). The estimated coefficient of operating income change (OIC) is negative, reflecting an increase in patent propensity with declining financial performance but the effect is not statistically significant.

One might argue that our analysis, since it considers firms that received treatment from among the top patentees in 1998, suffers from biases associated with sampling on successful outcomes. The advantage of the differences-in-differences estimator is that it estimates the effects of the treatment after controlling for the fact that the treated firms are different from the control group firms. Still, in a robustness check, we limited the “treated firms” to only those firms that were among the top 20 patentees in the first five years of our study (Kodak, Xerox, Motorola, TI, HP, and Intel) and adopted pro-patent changes. We then limited the estimation sample to the top 20 patentees during 1979–1983 and reestimated our patent-propensity regressions. This specification limits the estimation sample to firms with the highest patent propensity during 1979–1983 (rather than in 1998, thus avoiding sampling on outcomes) and checks whether the patenting propensity of these firms is explained by their pro-patent management practices. Two of the eight treated firms (AMD and Micron) are not part of the top 20 patentees during 1979–1983 and are excluded from the analysis. The estimated PPML coefficient on TREATED\_AFTER obtained from this regression is 0.97 (\( p < 0.01 \)). It is statistically comparable to the treatment effect (0.80, \( p < 0.01 \)) estimated in the sample with 114 firms. The estimates reported in (5) are also qualitatively similar to the ones obtained through firm random-effects and fixed-effects estimations.\(^{13}\)

Next, we estimate the market-value regression, specified in Equation (3), with the eight firms that underwent pro-patent IP management changes as part of our original treatment group. The estimation sample consists of 1,989 firm-year observations, and we obtain the following OLS estimates for Tobin’s \( q \):

\[
\log Q_{it} = -0.003 \log PAT_{it} + 0.83 \text{TREATED}_{it} - 0.17(\log PAT_{it} \times \text{TREATED}_{it}) + 0.115(\log PAT_{it} \times \text{TREATED\_AFTER}_{it}) + \sum \hat{\theta}_i; \quad \text{adjusted } R^2 = 0.45. \quad (6)
\]
The statistically significant positive effect of the interaction term of patent stocks and post-IP management years on Tobin’s $q$, observed in the case of IBM, extends to other large patentees. The estimates share another aspect in common with the estimates for IBM’s Tobin’s $q$: the significant negative relationship between patent stocks and Tobin’s $q$ before the adoption of pro-patent IP management practices. The estimates appear robust in models specified with firm-fixed effects and random effects (see columns (3) and (4) of Table A5).

Although we do not investigate in detail the reasons behind the uptake of IP management practices, this finding suggests that, like IBM, the treatment group firms adopted new practices when their returns from patenting were either declining or below average, perhaps because organizational changes are easier to justify and implement during “bad times.” Our qualitative research confirms that at least four of the treatment group firms adopted pro-patent practices under the shadow of negative events: Xerox ramped up its patenting in 1984 after failing to patent and exploit its groundbreaking inventions such as the personal computer and the graphical user interface underlying the Windows and Macintosh operating systems (Rivette and Kline 2000); Kodak, in 1986, after it was found guilty of infringing on Polaroid’s instant-photography patents and was sued for $1 billion to Polaroid in damages (Chesbrough 2006); AMD, in 1995, in the midst of its losing IP battle with Intel (Miele 2001); and Motorola, in 1987, after competition from Japanese rivals threatened the profitability of its cellular business (Sosnin 2000). The descriptions of IP management changes at four of the treated firms (AMD, HP, Motorola, and Xerox) mentioned changes in their IP leadership. These findings echo the ones from IBM’s case and suggested that established organizations did not all embrace greater patenting in response to the legal changes that increased the value of patents. Instead, declining profits and changes in leadership played an important role in hastening the adoption of pro-patent practices among firms that did not immediately respond to the legal changes.

Finally, as with IBM, we check whether citations from others to the patents of treated firms changed after the firms adopted pro-patent management practices by estimating an equation identical to the one specified in (4) after excluding IBM patents. As before, we purge the sample of patents belonging to the treatment firms after they adopted pro-patent management practices to ensure that any drop in the post-treatment quality of patents is not due to the lower quality of the patents. The estimates obtained from a sample of 306,317 citation-year observations are as follows:

$$
\text{CITES} = -0.03 \text{SCITES} + 0.01(\text{SCITES} \times \text{TREATED}) \frac{0.010}{0.020}
+ 0.07 \text{TREATED} - 0.08 \text{TREATED}\text{AFTER} \frac{0.016}{0.017}
$$

The treatment group patents, on average, receive significantly more citations compared with control-group patents before treatment. As in the case of IBM, firms that implemented pro-patent IP management experience a decline (of 7.7%, significant at $p < 0.01$) in citations to their patents.

We conclude from the above analysis that our findings from IBM’s case about the effects of pro-patent IP management practices apply to a larger sample of U.S. electronics and semiconductors corporations. Still, this analysis suffers from important limitations. First, because of the difficulty associated with tracking firm-level adoption of management practices, we selectively identified corporations with sharp and well-publicized changes in their IP management strategy as part of the treatment group. It is possible that to the extent that these are also the firms for which the changes worked as intended (in increasing patenting and private returns), we have overestimated the effects of pro-patent IP management practices. Relatedly, just because we were unable to find information on the IP management practices of control group firms does not mean that they did not adopt pro-patent practices. Our differences-in-differences estimation accounts for this purposive (and potentially erroneous) assignment of firms into the treatment and control groups, but perhaps not perfectly. Second, we have identified the effect of IP management practices through the timing of their adoption. Although we have controlled for the influences of first-order variables (such as R&D and firm size) that affect patent propensity, our analysis does not rule out the effect of other practices that may have been implemented with changes in IP management and increased the patenting output of firms. We have carefully examined and ruled out the possibility of these alternative influences in IBM’s case, but replicating this exercise for a larger sample is difficult. Third, our measures of private returns and knowledge spillovers are imperfect and may have induced unknown biases in our estimations.

6. Conclusion
Our research was motivated by the heterogeneity in firms’ responses to an important change in their legal institution that increased the value of patents. We focused on the case of IBM, which lagged its competitors in responding to the increased value of patents but emerged...
as the world’s largest patentee in 1993. After ruling out several alternative influences—including changes in IBM’s R&D intensity, defensive patenting, hiring practices, and technological focus—we show that the adoption of pro-patent IP management practices brought about IBM’s patenting turnaround.

We find an immediate, striking, and persistent consequence of IBM’s pro-patent practices: in the decade following their adoption, IBM inventors increased their patent applications by three times and decreased their publications by the same number. IBM’s knowledge spillovers, as evidenced by citations of other inventors to IBM’s patents and publications, were substantially reduced after the adoption of pro-patent practices. We obtain similar results for a sample of top U.S. corporations that adopted pro-patent practices. Hence, pro-patent IP management appears to augment private returns by restricting knowledge spillovers. Although we have not provided a full welfare analysis that measures the gains from licensing made possible through increased patenting, our results provide a cautionary note that pro-patent policies associated with open-innovation practices might foreclose the free diffusion of knowledge (Chesbrough 2006).

According to Cockburn and Henderson (1998), firms in the biomedical sector encourage open-science practices such as publications, in-house conduct of basic research, and collaborations with academic scientists to develop the “absorptive capacity” required to exploit, and profit from, external knowledge (Cohen and Levinthal 1990). Although we have not fully investigated the effects of a shift away from other open-science practices, we find that firms were able to augment their private returns by making it costly for others to use their knowledge through stronger patent enforcement. Our findings, taken together with the prevailing wisdom on the benefits to corporations of pursuing open-science practices, suggest that organizations face a trade-off: practices to plug leakages of proprietary knowledge may make it hard to identify and exploit external knowledge. A careful analysis of the long-term consequences of aggressive patenting, which is outside the scope of our present analysis, is necessary to establish the outcome of this trade-off.

More broadly, our findings raise the natural question: If certain practices (in our context, pro-patent management) augment profitability, then why do firms delay their adoption? Recent economic theories explain delayed adoption by suggesting the presence of informational constraints in markets such that “laggards” are not aware of the benefits and costs of new practices (see Bloom et al. 2013). Yet, in our context, the legal change to U.S. patent laws were well known in the industry, after a series of high-profile patent infringement cases following the CAFC’s establishment in 1982 (Hall 2005). Hence, it is not probable that firms, particularly large corporations with access to expert legal counsel, were unaware of the benefits of strengthening their patent portfolios. Our qualitative research on IBM suggests that rather than informational constraints, inertia may have played a role in resisting a switch to increased patenting.

How did IBM and other laggards come to adapt to changes in their environment? Our quantitative analysis reveals that adaptation was systematically related to flailing financial health, and, in a significant number of cases, adaptation was initiated by new leadership. Hence, our findings suggest a general process of organizational response to environmental changes. Firms are motivated by profits, but rather than seamlessly embracing new practices associated with superior profits, established firms are more likely to act when they face threats to their survival. To an extent, new leadership may better perceive the severity of threats and thus play an important role in shaping organizational response to the threats. 

Some established firms that adopt the new practices are able to emerge as successful. Our study’s contribution thus lies in articulating an instance in which established firms successfully overcame inertial resistance to a literature that largely focuses on incumbents’ failures (Cooper and Schendel 1976, Hannan and Freeman 1977, Majumdar 1982, Tushman and Anderson 1986, Henderson and Clark 1990, Amburgey et al. 1993, Tushman and O’Reilly 1996, Christensen 1997, Tripsas and Gavetti 2000). By demonstrating the role of financial pressures and new leadership in facilitating transformation, we contribute to a deeper understanding of the processes that shape organizational adaptation to their environment (in the spirit of Cyert and March 1963, Nelson and Winter 1982, Levinthal 1997, and, more recently, Greve 2008). Our study suggests that realistic theories of organizations should incorporate the interactions between environmental change and intraorganizational processes to understand the sources and consequences of organizational change.

Acknowledgments
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Supplemental Material
Supplemental material to this paper is available at http://dx.doi.org/10.1287/orsc.2014.0911.
1. **Hewlett-Packard Company:** In 1984, Hewlett-Packard hired John Anthens, a former patent attorney, as vice president of product development. HP needed cross-licensing agreements to maintain its freedom to innovate, which, in turn, required a large patent portfolio. Anthens developed a formal IP strategy at HP, which included the following elements: “1. Getting information from innovators through the use of incentives. 2. Building the patent portfolio through the patent coordination process, strategic patenting initiatives, and patent portfolio management. 3. Extracting value from the patent portfolio through assessment of business purposes and the offensive use of patents.”

2. **Xerox:** Rafik Loutfy and Joe Daniele claim to have established a corporate Intellectual Capital Business Unit (ICBU) and the Corporate Office for Management of Intellectual Property (COMIP) to leverage Xerox’s intellectual assets in 1984. Jan Jaferian, vice president of intellectual property at Xerox, also notes that there has been a proactive effort to generate revenue from patents at Xerox since 1984 (cited in Rivette and Kline 2000).

3. **Texas Instruments Inc.:** TI changed its IP management strategy in 1985 when it embarked on a strategy of deriving licensing revenues from its patents. TI had acquired some fundamental patents on manufacturing DRAMs, known as the “Kilby patents,” and demanded licensing fees from nine Japanese manufacturers for infringing on its patents. When the manufacturers refused, TI successfully litigated them. As a consequence, TI’s licensing revenues increased from $30 million in 1986 to $200 million in 1987.

4. **Eastman Kodak Co.:** Kodak changed its IP management in 1986, the year after it was found guilty of infringing on Polaroid’s instant-photography patents (Polaroid filed the infringement case against Kodak in 1976) and was ordered to pay approximately $909 million to Polaroid in damages and to shutter its instant-photography business. Kodak realized the importance of a strong patent portfolio and undertook to grow its patenting and licensing in the following years.

5. **Intel Corporation:** Intel appears to have started aggressively enforcing its patents in 1985. Intel had a number of licensing agreements with its partners, such as AMD, that called licensees to provide intellectual property of equal value to Intel. Yet, in 1985, Intel management concluded that it was “giving away” its technology to other companies, most notably AMD, and not getting fair value in return. In 1985, after four years and approximately $200 million in developing the 80386 (the first 32-bit processor), Intel made the decision to enforce its IP and be the sole-source manufacturer for the first time.

6. **Advanced Micro Devices:** AMD adopted several pro-patent management practices after promoting Richard Roddy to be chief patent & trademark counsel in 1995. AMD also hired Paul Drake from IBM to be global IP portfolio counsel. Under Richard Roddy’s leadership, AMD’s patenting increased 10-fold in five years. According to Miele (2001, p. 21), AMD’s pro-patent switch was closely related to its ongoing IP battles with Intel: “[E]arly in 1994, apparently in response to threats of litigation, AMD planned further litigation with Intel, with Cyrix possibly joining in. Apparently, AMD intended on challenging Intel’s Crawford microprocessor patent.”

7. **Micron Technology Inc.:** In its 1990 annual report, Micron mentions for the first time the need to build a patent portfolio. “To be a leader in our industry requires early introduction of new generation products, development of proprietary products, and a strong patent portfolio. Our team’s efforts are focused on all these objectives.” Micron also began to enter into cross-licensing agreements, three in 1990. The company’s annual report mentions steps to set aside money to pay for possible patent infringement claims in 1990.

8. **Motorola Inc.:** Motorola changed its IP management strategy in 1987. Vincent Rauner, senior vice president for patents, trademarks, and licensing at Motorola, realized the value of patents after the firm’s cellular business was threatened by Japanese manufacturers with similar products in the mid-1980s. Motorola subsequently started a patenting and licensing program in 1987. Rauner explained the success of this program, citing the increased licensing revenues from Motorola’s patents in 1991. According to Sosnin (2000), “Motorola’s program gives a cash bonus to inventors when the application for a patent is filed and another bonus when a patent is issued . . . The company also presents engineers with a sizeable check when they receive their 10th patent. If a patent generates revenue for the company, Motorola may give the inventor a lump sum ranging from $10,000 to $40,000, depending on the estimated commercial value of the patent.”

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### Exhibit 1

**IP Management Changes at U.S. Corporations, 1979–1998**

1. **Hewlett-Packard Company:** In 1984, Hewlett-Packard hired John Anthens, a former patent attorney, as vice president of product development. HP needed cross-licensing agreements to maintain its freedom to innovate, which, in turn, required a large patent portfolio. Anthens developed a formal IP strategy at HP, which included the following elements: “1. Getting information from innovators through the use of incentives. 2. Building the patent portfolio through the patent coordination process, strategic patenting initiatives, and patent portfolio management. 3. Extracting value from the patent portfolio through assessment of business purposes and the offensive use of patents.”

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### Endnotes


We used three-year moving averages to smooth out fluctuations in R&D and P&E expenditures and also because typical project cycles in semiconductors and electronics yield patents after two–three years of R&D investments (see the discussion in Hall et al. 1986). Experimenting with different lag structures yielded results qualitatively similar to the ones obtained by using the three-year moving averages.

Table A1 of the supplementary appendix compares IBM and the average control-group firm along several key variables (patents, R&D, P&E expenditures, and sales) for each year between 1979 and 1998. Table A2 of the supplementary appendix reports correlations among the variables in our sample.

In our case, PPML regressions yield coefficient estimates identical to those of the simple Poisson regressions.

The standard deviation of the number of patents for each firm-year, 226, is significantly greater than the mean, 68.5, thus providing evidence of overdispersion.

The IRR is obtained by calculating \((e^{\hat{b}_i} - 1) \times 100\%\), where \(b_i\) is the corresponding PPML coefficient.

The magnitudes of some the four IBM-specific coefficients are quite large because they are estimated using within-IBM variation across just five years (and thus five observations) in each subsample. For example, the estimated magnitude of the \(IBM \times RD\) coefficient drops substantially if we leave out one of the IBM-specific interaction coefficients—say, \(IBM \times Operating\ income\ change\) from the regressions (see Table A3 of the supplementary appendix for the corresponding estimates).

Hall (2005) estimates changing trends in the market value of patent stocks and reports that the coefficients on patent stocks (in an equation that predicts Tobin’s \(q\)) turns from negative and significant in the pre-1984 years to insignificant in the post-1984 years for firms in the electrical and electronics industry; this finding is broadly consistent with our estimated coefficients for the control group firms.

Of course, technical knowledge may also be disseminated after the publication of patents, but, unlike publications, a patent confers the inventor the legal rights to exclude others from using the patented invention during its term.

Alcacer and Gittelman (2006) and Lampe (2012) thoughtfully discuss examiner citations and strategic applicant citations as potential sources of noise in patent citations. These sources of noise are unlikely to be systematically different for IBM and control-group patents assigned to other large corporations and thus bias our estimates. However, one might argue that patentees strategically withhold citing the “prior art” of entities more likely to enforce their patents. To the extent that IBM was more likely to enforce its patents after 1989, a decline in its post-1989 citations may reflect strategic (non)citation, and not reduced spillovers, although the USPTO’s “duty of candor” requirement, and examiners’ search for prior art impose a check on such strategic (non)citations.

We are unable to perform this analysis in a formal differences-in-differences setup because most control group firms do not publish in their own publication outlets. For this reason, it is also difficult to identify citations by patents to the publications of control group firms.

The first two columns of Table A5 of the supplementary appendix report the corresponding Poisson estimates. The fixed-effects specifications drop TREATED from the estimations since the variable’s value does not change within firms and is perfectly collinear with firm-fixed effects.

Incidently, Lim (2010) suggests that IBM researchers continued to publish their R&D results in some areas while at the same time keeping valuable, process-specific inventions proprietary.

Eggers and Kaplan (2009) provide evidence that variation in managers’ ability to recognize the technical changes affecting their industry explains the variation in the timing of firms’ entry into new markets.

References


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