DRUID society

DRUID Working Paper No. 12-08

# Defensive Disclosure under Antitrust Enforcement

By

Ajay Bhaskarabhatla and Enrico Pennings

Danish Research Unit for Industrial Dynamics

www.druid.dk

# Defensive Disclosure under Antitrust Enforcement

**Alay Bhaskarabhatla**
Erasmus School of Economics
E-mail: bhaskarabhatla@ese.eur.nl

**Enrico Pennings**
Erasmus School of Economics
E-mail: pennings@ese.eur.nl

2 July 2012

**Abstract:**
We formulate a simple model of optimal defensive disclosure by a dominant firm facing uncertain antitrust enforcement and test its implications using unique data on defensive disclosures and patents by IBM. Our results indicate that stronger antitrust enforcement leads to more defensive disclosure, that quality inventions are also disclosed defensively, and that defensive disclosure served as an alternative, but less successful, mechanism to patenting at IBM in appropriating returns from R&D. We extend our analysis to two other exceptionally large firms with defensive-disclosure activity, AT&T and Xerox, and show that their patenting propensity declined under increased antitrust enforcement relative to other firms in the industry. Overall, we show how these firms used defensive disclosure as a strategy to balance the benefits of patenting with the costs of uncertain antitrust enforcement.

**Keywords:**

**Jel codes:**

**ISBN 978-87-7873-336-8**

**Acknowledgement**
We thank David Hounshell and participants at the Manheim Conference on Competition and Innovation, the K.U. Leuven Seminar, the Atlanta Competitive Advantage Conference, and the DRUID Conference.

# 1 Introduction

Patent law provides exclusivity in exchange for knowledge disclosure. However, for decades, some large firms have disclosed patentable inventions defensively, sacrificing exclusivity. Extant theories conceive of novel mechanisms through which such disclosure helps firms eventually establish exclusivity on a more valuable invention (e.g., Baker and Mezzetti 2005). Such theories assume that rivals engaged in a patent race know much about each other's progress. Their implications often concern project-level success, are difficult to test, and arguably do not capture the real motive behind programmatic defensive disclosure. That is, what these theories overlook are the institutional reasons for setting up, scaling up, and shutting down defensive-disclosure programs that transcend strategic considerations about project-level outcomes.

We study in rich detail the life cycle of a defensive-disclosure program, albeit at one firm, and uncover a tradeoff between the exclusivity afforded by patent protection and the cost of potential antitrust action. The value of patents is eroded under the threat of antitrust action, which limits a firm's ability to enforce its patents and appropriate returns. Consequently, the threat of antitrust action provides a motive for defensive disclosure of patentable subject matter, which preserves the freedom to use inventions by avoiding holdup due to rivals' patenting, although at the expense of exclusivity.

We study IBM's defensive-disclosure program due to its significant size, scope, and span; the many antitrust cases it faced; the changes to U.S. patent law; the availability of disclosure and patent data; the accessibility of former IBM R&D directors; and the dramatic shifts in IBM's disclosure, patenting, and licensing revenue trends during the period of our study.

We find that IBM embarked on a science-oriented strategy of growth after the first U.S. Department of Justice’s antitrust case in the 1930s. The company began disclosing many inventions defensively in response to the second antitrust action in the mid-1950s and then scaled up the defensive-disclosure program around the time of the third antitrust case (and several private cases) against IBM in 1969. IBM then sustained the program through the European Commission's case that began in 1980.

In the stylized model we develop, a dominant firm's optimal R&D investment is determined by a tradeoff between the expected value of an invention due to patent protection and the expected loss of value from antitrust action. Consequently, inventions are more likely to be disclosed defensively or kept secret under an increased threat of antitrust action. In addition, in our model, the quality of the invention is unrelated to the probability of patenting, which implies that high-quality inventions are just as likely as low-quality inventions to be defensively disclosed or kept secret.

In regression models at the firm level and inventor level, we confirm the theoretical predictions of the model. We show that around the time of the third antitrust action, significantly more inventions were disclosed defensively compared to the earlier period. We extend our analysis to include patenting at Xerox and AT&T and find that, relative to a set of control firms, IBM, Xerox, and AT&T patented less under increased antitrust enforcement.

We examine other empirical findings consistent with our theory. Yale and Carnegie Mellon innovation surveys of high-level R&D executives have found patents to be among the least effective mechanisms for appropriating returns from R&D (Levin et al. 1987; Cohen et al. 2000). We highlight the role that stronger antitrust enforcement played against large R&D-intensive firms in the U.S. in rendering patents ineffective until the early 1980s in a quantitative study (for a descriptive account, see Grindley and Teece 1997). Our study also clarifies why the recent surge in patenting in the U.S. is not accompanied by a commensurate rise in R&D expenditures or innovative activity, as IBM moved away from defensive disclosure toward patenting without raising R&D expenditures (e.g., Jaffe and Lerner 2004; Bessen and Hunt 2007).

The paper is organized as follows. Section 2 presents the related literature. The case of IBM is developed in Section 3. Section 4 presents a theoretical model, and Section 5 tests its implications. Section 6 concludes.

## 2 Literature Review

## 2.1 Defensive Disclosure

Defensive disclosures are patentable inventions that firms disclose without seeking patent rights. Such disclosures are short technical descriptions of inventions and, hence, less expensive to draft than patents. They are typically reported in a technical journal targeted at the U.S. Patent Office; this helps to accurately establish the date of prior art (see, for example, Figure A1). Defensive disclosures often do not contain the firm's and inventor's names.

Prior theoretical literature has proposed several explanations for defensive disclosure by the trailing firm in an innovation race (e.g., Parchomovsky 2000; Lichtman et al. 2000; Baker and Mezzetti 2005; Bar 2006). Since defensive disclosure resets the prior art, it can potentially prolong an innovation race by preventing the leader from reaching the threshold level of patenting. These explanations are not consistent with the fact that defensive disclosure has been a leading-firm phenomenon. Since primarily large R&D-intensive firms have maintained defensive-disclosure programs, theories of why leading firms disclose have also been proposed (Gill 2008). Disclosure by the leader demonstrates commitment to a research program and can discourage rivals' entry. However, firms are increasingly disclosing anonymously, making it difficult to infer commitment. Other theories have incorporated strategic disadvantages of disclosure due to spillovers (Jansen 2006) into such models of commitment through strategic disclosure.

A separate theoretical literature has explored the merits of trade secrecy and patenting, as recent innovation surveys suggest a rise in the importance of secrecy as a preferred mechanism to appropriate R&D returns (e.g., Horstmann et al. 1985; Anton and Yao 2004; Kultti et al. 2007). However, these models do not consider defensive disclosure as an alternative mechanism to patenting and secrecy.

In the empirical literature, Henkel and Pangrel (2008) collate wide-ranging responses of 44 patent professionals at 37 German industrial firms in an exploratory study of defensive disclosure. One response is that low-quality inventions are disclosed defensively following a cost-benefit analysis. Such propositions have not been weighed against the data.

We depart from the above literature in our emphasis on defensive-disclosure programs rather than on optimal invention- or project-level disclosure strategies, as well as in our emphasis on the role of antitrust action in precipitating defensive disclosure. In doing so, we build on a long tradition of research in economics and law examining the tension between patent and antitrust laws. While patent law grants temporary market power to reward innovation, antitrust law limits the market power afforded by patent protection. Prior literature has focused on the implications of this tension for merger policy, as well as for regulating dynamic R&D competition (Carlton and Gertner 2003). Previous studies have also examined the impact of uncertain antitrust enforcement on firm behavior such as collusion and innovation (e.g., Block et al. 1981; Segal and Whinston 2007). However, we are not aware of empirical studies examining the impact of antitrust enforcement on a firm's incentive to patent, disclose, or exercise secrecy.

We begin by exploring the origins of defensive-disclosure programs historically to support our argument that antitrust policy was instrumental in the emergence of corporate research laboratories in the U.S. and the evolution of their patenting and disclosure strategies.

### 2.2 Antitrust and the Origins of Corporate R&D Labs

During the formative period of antitrust policy in the United States, from 1890 to 1930, innovation provided a defense for dominant firms against antitrust action (Hart 2001). Corporate research labs were set up during this period: General Electric set up an R&D lab in 1900; Du Pont in 1902; AT&T during 1910-1912; Eastman Kodak in 1910; and Westinghouse in 1916. However, the ascension of Thurman Arnold to the antitrust division in 1938 heralded a new era of aggressive antitrust policy against large firms with patent portfolios and against patent pools, where cases were settled by consent decrees mandating compulsory patent licensing (Usselman 2009). Patenting by corporate labs was viewed as an abuse of power. Arnold argued that “if patents become an instrument of business policy, things like that [cartelization and monopolization] will happen” (Hounshell and Smith 1988). The number of antitrust cases in the U.S. increased from 57 during 1935-1939 to 223 in the next five years (Posner 1970). Large firms found it difficult to grow through acquisitions in this era and began to expand internal R&D as a strategy for growth, which is reflected in the diversification of Du Pont's R&D program in the late 1940s (Hounshell and Smith 1988).

During the early era, large R&D-intensive firms also began disclosing research results in their own, newly-created technical journals.[1] Such corporate journals fostered an academic environment and helped attract PhDs to join corporate research labs. In response to the changing antitrust climate, by the late 1930s, firms began to search for alternatives to patenting. Discussing the shifting trends in industrial research in the U.S. during 1899-1946, Mowery and Rosenberg (1989:73) note:

> Appropriability concerns, reflected in the drive to strengthen patent positions through internal development or acquisition of innovations, played an important role in the early development of industrial research. With the growth of in-house research, however, patents appear to have declined somewhat in importance within the research strategies of some of the corporate pioneers of industrial research. . . . Both Eastman Kodak and AT&T, for example, which had placed great emphasis on patent strategies in the early years of development of their industrial research strategies, increasingly focused on developing a strong knowledge base through in-house research and gave less weight to patents.

The role of antitrust in the organization of corporate R&D in the U.S. has been investigated (Mowery 2009). We build on this work and argue that firms with leading corporate R&D labs began to disclose defensively due to the increased probability of antitrust enforcement.[2] Next, we develop the case of IBM's disclosure program.

# 3 A Case Study of IBM's Disclosure Program

## 3.1 Antitrust, R&D, and Technical Disclosure Bulletin

---

[1] General Electric published *General Electric Company Review* from 1903 to 1958; AT&T published *Bell Labs Technical Journal* from 1922 to 1983; and Westinghouse published *Electric Journal* from 1904 to 1939 and *Westinghouse Engineer* in later decades. In Europe, Philips opened its central lab in 1914 and published *Philips Technisch Tijdschrift* from 1936 to 1989.

[2] The strengthening of patent protection in the U.S. by the establishment of the patent-friendly Court of Appeals of the Federal Circuit (CAFC) in 1982 and the success firms like Texas Instruments and Polaroid had in asserting their patent rights increased the patent propensity (e.g., Hall and Ziedonis 2001, Hall 2005). Our analysis particularly focuses on the period before the patent reforms of 1982 and emphasizes the role of antitrust enforcement.

Table 1 lists various antitrust cases filed against IBM by the U.S. Department of Justice and private entities. IBM faced its first antitrust case in 1932. Soon after, IBM followed many leading firms at the time by adopting a science-oriented growth strategy, opening a research lab in Endicott, New York and subsequently forming a department of pure science. In 1952, the second antitrust case against IBM began, and in the same year, IBM established its San Jose laboratory to focus on less-directed research. Thomas Watson Jr., the second president of IBM, also initiated an organizational change that led to a *Research* department directed by a physicist, Emanuel Piore (see, for an historical treatment, Usselman 2009).

The second case ended in 1956 with a consent decree, which placed restrictions on IBM's patent portfolio. IBM was ordered to "grant to each person making a written application, an unrestricted, nonexclusive license to use any, some, or all of IBM's existing and future patents without any restrictions." In response, IBM adopted a policy of freedom of action, according to which IBM would continue to increase its investment in R&D and disclose inventions to preserve the freedom to use them by preventing others from patenting them in the future. To do so, IBM increased its R&D investment further, opened a new lab in 1956, and began publishing the *IBM Journal of R&D* in 1957. IBM's R&D expenses doubled from 1952 to 1956 and increased from ten to 50 as a percentage of net income between 1948 and 1960 (Flamm 1988).

Insert Table 1 here

Under the direction of Emanuel Piore, IBM's R&D staff increased from 105 in 1956 to 898 PhDs in 1960 (U.S. National Research Council 1956-1990). The number of physicists alone increased from one in 1946 to 11 in 1956 and to 328 in 1960, the year IBM opened its T.J. Watson Research Center. The number of PhDs at IBM, including some auxiliary staff, increased marginally to 1250 in 1977 and 1600 in 1986, and then dropped to 1000 in 1990. In 1962, IBM also started awarding its most exceptional researchers the title 'IBM Fellow.' These investments in R&D dollars and personnel translated into research output, some of which began to be disclosed defensively, as one distinguished IBM researcher noted about the development of relational databases (McJones 2009): "Since we were in the research division of IBM, our philosophy of research was to publish our results in the open literature. .

. . The project was not a secret and, in fact, we'd been telling everybody about it that would listen."

IBM proactively pursued an open publication policy, as elaborated on by a former executive, Sarasohn (1973):

> Used in a planned and judicious manner, the journal can serve to measure the merit of the work being performed in a laboratory. Its value stems, first of all, from the formulation of a publication strategy as an integral part of each significant technical project. This means that the manager, whether he be a research director, chief engineer, project leader, or department head, must make a conscious and deliberate plan, that takes effect with the start of the work, which implements the expectation of authorship along with other elements that make up the technical undertaking. This strategy should identify the areas of the work for which publication is permissible and expected, and those that must be restricted for valid security, proprietary, or business reasons. Even in the latter case, provision should be made for periodic review to determine when restricted information can be released for publication.

The third government case against IBM was filed during the last days of Lyndon B. Johnson's administration in early 1969. This occurred at around the same time as the sudden deterioration of Watson's health and his early exit from the company (Usselman 2009). Several other private cases had been filed against IBM starting in 1968. Seventeen such cases, listed in Table 1, spanned the 1970s. The accumulation of these cases further strengthened IBM’s disclosure program. Most cases in the U.S. ended by 1982, but the European Commission (E.C.) pursued similar charges formally, starting in 1980 and ending in 1984, and required IBM to disclose information necessary for the interoperability of rival products with IBM's products for the next five years.

### 3.2 IBM Technical Disclosure Bulletin

In 1958, IBM started publishing the *IBM Technical Disclosure Bulletin* (TDB hereafter), dedicated to defensive disclosures targeted at the U.S. Patent Office. The TDB became an increasingly attractive venue for the researchers, as such disclosures received one third of the points awarded for patents, whereas scientific publications earned zero points.[3]

We collected data from the `Table of Contents' section of the monthly IBM TDB for the period 1976-1984 and from IP.com, an online repository of such disclosures, for the remaining period of 1958-1998. In 1985, IBM stopped disclosing researchers' names in the TDB, but, fortunately, IP.com's database, constructed in the late 1990s, contains these names. Our data contain the names of the inventors and the title and date of the invention. We also collected data on IBM patents from the U.S. Patent Office website for all patents issued after 1975. We identified patents issued earlier using announcements of recently issued IBM patents in the monthly issues of IBM's *Journal of R&D*. We used these patent numbers to obtain current patent classification and issue dates from the U.S. Patent Office's website and appended patent filing dates using Google Patent Search. We used contemporary press accounts to measure patent-license revenues.

The time paths of disclosures, patents, and licensing revenues are shown in Figure 1. In 1958, 378 inventions were filed for patenting and 119 inventions were disclosed defensively. The annual number of defensive disclosures rapidly increased more than ten-fold, to 1143, in the next decade, while the number of patents increased by just 16 percent, to 439. The share of reported inventions disclosed defensively increased from 24 percent in 1958 to 72 percent in 1967. Researchers during this period, including those with the most patents, had many disclosures.[4]

Insert Figure 1

The number of disclosures continued to rise even more rapidly in subsequent years. In contrast, the number of patents remained largely constant until 1989, even across top patent classes, as shown in Figure 2. The number of defensive disclosures peaked in 1990 at 4,229 and declined subsequently. At its peak, IBM patented just one in five reported inventions.

---

[3] Researchers at IBM submitted their inventions to decentralized review committees composed of technical and legal members, which decided whether to patent, disclose defensively, or do nothing.

[4] For instance, Clapper, a top IBM inventor during this period specializing in speech and pattern recognition, produced 45 patents and 33 defensive disclosures.

Insert Figure 2

We interviewed the individuals who served as IBM's Directors of R&D from 1970 to 1996, as well as its general counsel during the 1990s. These interviews confirmed the validity of these trends and revealed further insights.[5] IBM did not enforce its patents until the late 1980s, despite known cases of infringement against IBM's intellectual property (e.g., IBM's fundamental patent on DRAM assigned to an IBM Fellow, Robert Dennard, in 1968 was reportedly widely infringed upon). IBM's licensing revenues remained low, at less than $20 million during the 1980s, but began increasing in the 1990s, reflecting the extent of IBM's forgone licensing revenues in the previous decades (see Figure 1). IBM researchers, including the top ones, reached career milestones, known as Plateaus, earning points mostly through defensive disclosures (see Table A1). Our interviews also revealed that researchers themselves appear to have preferred disclosures to patents, as securing the latter involved a much longer process.

Overall, IBM's continued investment in R&D resulted in little licensing revenues, and its research lab became unsustainable, which precipitated significant organizational changes in 1989 (see Bhaskarabhatla and Hegde 2012). IBM's research director and the general counsel at the time confirmed that significant changes were made to incentives for patenting and defensive disclosure. They included: (a) the establishment of a team dedicated to increasing the fraction of patented inventions, known as the Patent Factory; and (b) the institution of *ex post* rewards to inventors whose patents brought in licensing revenues. IBM began to dismantle its defensive disclosure program in 1990. For these reasons, we restrict our attention to the period 1955-1989 and study the impact of antitrust action on IBM's defensive-disclosure program.

We formulate a simple model of defensive disclosure under uncertain antitrust enforcement to explain these patterns of patenting and defensive disclosure.

[5] Those interviewed include R&D Directors Ralph Gomory, John Armstrong, and James McGroddy. We also interviewed Marshall Phelps, the General Counsel at IBM, and John Cronin, a leading inventor at IBM who went on to play a significant role in the rise in patenting since 1989. We also interacted with other high-level former executives and scientists at IBM.

# 4 Model

Consider a dominant firm deciding how much to invest in R&D and, subsequently, what fraction of inventions to patent. Suppose that the dominant firm faces the risk of antitrust enforcement with a given level of uncertainty. The firm's payoffs from decisions to patent, disclose, or exercise secrecy determine its *ex ante* R&D investment.

The timing of decisions is as follows. In the first stage, the firm decides how much to invest in R&D. In the second stage, the firm decides which inventions to patent, disclose defensively, or keep secret. In the third stage, uncertainty about antitrust action is resolved, and the value of an antitrust fine, if there is antitrust action, is realized. Also, payoffs from returns to R&D and patenting are realized. The extent of patenting and disclosure endogenously determine the investment in R&D, the probability of antitrust action, and the expected antitrust fines.

Suppose that the probability of antitrust action is $a(P)$, where $P$ stands for the fraction of discoveries patented. Then, $P = \frac{Patents}{Discoveries}$, where discoveries include patents, secrets, and defensive disclosures.

In the third stage of the game, if the firm discloses an invention, its payoff is $C + R_D$, where $C$ stands for the payoff to the dominant firm from production when the innovation is disclosed in the public domain, and $R_D > 0$ is the additional payoff from disclosure—e.g., through foreclosing a competitor from patenting.

If the firm keeps the innovation secret, its payoff is $M$ under the condition that the trade secret does not leak out. If the trade secret leaks out, the payoff will be $C$. We assume that the probability that a given type of innovation $i$ leaks out is $\theta_i$ (see, also, Kultti et al. 2007). Hence, the expected payoff from keeping innovation $i$ secret equals $\theta_i C + (1 - \theta_i)M$. The optimal fraction of secrecy is denoted by $S$.

Finally, if the firm obtains a patent, its payoff is $M$ with probability $a(P)$ and $C - F$ otherwise, where $F$ is the expected value of the fine from a potential antitrust action. Suppose that the payoff from disclosure is less than the monopoly profit, $C + R_D < M$, and that there is a positive penalty, $F > 0$. The expected payoff from patenting is now $\left(1 - a(P)\right) * M + a(P) * (C - F)$.

In the second stage of the game, the expected payoff for a pool of discoveries, denoted by N, is:

$$E[\pi] = \sum_{i=1}^{N} \{P * \left[\left(1 - a(P)\right)M + a(P)(C - F)\right] + S * [\theta_i C + (1 - \theta_i)M] + D * [C + R_D]\} \quad (1)$$

If a firm chooses not to patent the innovation, it will choose to keep the innovation $i$ secret if $\theta_i C + (1 - \theta_i)M > C + R_D$. Let $\theta_i = \underline{\theta}$ with probability $\phi$ and let $\theta_i = \overline{\theta}$ otherwise, where $\overline{\theta} > \underline{\theta}$ . Furthermore, to ensure the optimality of secrecy when there is a low probability of leakage, we assume that $\underline{\theta}C + \left(1 - \underline{\theta}\right)M > C + R_D$. Similarly, to ensure the optimality of disclosure when there is a high probability of leakage, we assume that $\overline{\theta}C + \left(1 - \overline{\theta}\right)M < C + R_D$. Now we can rewrite equation (1) as

$$E[\pi] = N\{P * \left[\left(1 - a(P)\right)M + a(P)(C - F)\right] + (1 - P) * R\}, \quad (2)$$

where $R = \phi * \left(\underline{\theta}C + \left(1 - \underline{\theta}\right)M\right) + (1 - \phi) * (C + R_D)$ is the expected payoff when the firm decides not to patent.

We assume that $a(P) = zP$ with $0 \leq P \leq 1$ and $z \leq 1$, and maximize the expected payoff with respect to $P$, which leads to the following expression for the optimal fraction of discoveries to be patented:

$$P^* = \frac{M - R}{2z(M - C + F)} \quad (3)$$

The percentage of patents (disclosures or discoveries kept secret) over total discoveries decreases with the penalty if antitrust action is undertaken and decreases with the probability that an antitrust action will be undertaken.

Next, we derive the optimal level of R&D expenditure in the first stage. Substituting the expression for $P^*$ in equation (1),

$$E[\pi] = N\left[\frac{(M-R)^2}{4z(M-C+F)} + C\right] \tag{4}$$

Now, we assume that $N$ is an increasing and concave function of R&D expenditures, denoted by $R$. Then, optimal R&D expenditure, $I^*$, is given by the following equation:

$$N'[I^*] \cdot \left[\frac{(M-R)^2}{4z(M-C+F)} + C\right] = 1 \tag{5}$$

It follows from the above equation that $\frac{\partial I^*}{\partial z} < 0$, or, in other words, that optimal R&D expenditures are negatively related to the probability of antitrust action.

As disclosures can be observed at either the firm level or at the individual-researcher level, the model yields the following related hypotheses:

*Hypothesis 1a. Controlling for other factors, the extent of defensive disclosures by IBM is greater under an increased threat of antitrust sanctions.*

*Hypothesis 1b. Controlling for other factors, the extent of defensive disclosures by researchers at IBM is greater under an increased threat of antitrust sanctions.*

Our model yields other implications concerning optimal secrecy under antitrust enforcement. However, given our limited data, we focus on testing the above two hypotheses.

## 5 Data Analysis

We described the collection of defensive-disclosure and patent data in section 3.2. We merged these patent and disclosure data by matching the names of inventors to a high degree of accuracy (more than 77 percent of the matched names contain two or more initials), which enables us to test the main implication of the model at the inventor level. We also collected IBM's financial data from Compustat for years 1960-1989 and from its annual reports for years 1955-1959. So, our sample period is 1955-1989. However, we restrict our regression analyses to the period 1958-1982—the first year corresponding to the beginning of the defensive-disclosure program at IBM and last year corresponding to the end of the third antitrust case against IBM in the U.S. In addition, we collected antitrust enforcement data in the U.S. In particular, a number of measures, such as the annual number of landmark antitrust cases instituted by the U.S. Department of Justice, are collected from Gallo et al. (2000), which is an extension of data contained in Posner (1970).[6]

## 5.1 Regression Analyses

At the research level, we estimate the following equation:

$$y_{it} = x_{it}^{'}\beta + \alpha_i + u_{it}$$

where $y_{it}$ is the fraction of inventions disclosed defensively, $x_{it}^{'}$ is a vector of covariates, $\alpha_i$ is an inventor-specific time-invariant effect, and $u_{it}$ is the error term. Since the dependent variable ranges between zero and one, we use the conditional maximum likelihood approach to estimate logistic regression with fixed-effects at the inventor level. We also estimate a Tobit regression for IBM (naturally, without the fixed-effects) as our dependent variable is censored.

The key independent variables in these regressions are LANDMARK CASES and IBM CASES. The former measures the exogenous change in the level of antitrust enforcement against exceptionally large firms in the U.S. using four different measures: Sullivan-Hovenkamp (SH); Areeda-Kuplow (AK); Handler et al. (H); and the average (AVG) of these three measures (Gallo et al. 2000). The latter variable—IBM CASES—measures the number of IBM-specific private or federal antitrust cases active in a given year (see Table 1).

[6] An obvious measure of antitrust enforcement is the number of cases opened annually. However, it does not reflect the relative importance among cases. According to Gallo et al. (2000) large firms are more likely to generate important cases, which are most relevant to our study. While alternative approaches exist to identify the count of such important cases, say using news coverage or citations in subsequent legal opinions, we employ the definition developed by Posner of counting cases cited in leading casebooks (1970). The four alternative measures we use are plotted in Figure A2.

The other explanatory variables are R&D Intensity, which is defined as annual R&D expenditures as a percentage of sales, and Capital Intensity, defined as annual capital expenditures as a percentage of sales. R&D and Capital Intensities control for resources for research, more of which lead to more discoveries and potentially more defensive disclosures.

Table 2 shows the coefficient estimates of the regression at the firm level. In specification (1), controlling for other factors, IBM was more likely to disclose inventions defensively with each additional case filed against it, as reflected by the positive and significant coefficient estimate of IBM CASES. Each additional landmark case is also associated with a seven-percentage-point increase in the fraction of inventions defensively disclosed, as reflected by the coefficient estimate of LANDMARK CASES (SH). The control variables R&D Intensity and Capital Intensity have positive coefficient estimates.

Insert Table 2

In specifications (2) to (4), we employ alternative measures of landmark cases and find similar results. The coefficient estimate of LANDMARK CASES (AK) reflects a 22-percentage- point increase in the fraction of defensive disclosure with each additional landmark case. Similarly, LANDMARK (AVG) is associated with an 11-percentage-point increase in the fraction of defensive disclosures. The coefficient estimate of LANDMARK (H) is positive but not statistically significant at the 0.1 level.[7]

Second, we estimate the same specification at the inventor level using conditional maximum likelihood for logistic regression with inventor fixed-effects for the period 1958-1982. In other words, we control for time-invariant factors at the researcher level, such as the field of expertise and ability that explain a researcher's patenting and disclosure preferences. The errors are clustered at the researcher level. The dependent variable is the fraction of reported inventions disclosed defensively in a given year. The independent variables are as described previously.

Insert Table 3

[7] We also experimented with alternative measures of the annual number of antitrust cases reported in Gallo et al. (2000) for all firms and against Fortune 500 firms, but the coefficient estimates were not statistically significant. An ideal measure would be the annual number of cases that mention patent portfolios as an area of concern.

The results are shown in Table 3. The coefficient estimate of IBM CASES is positive and significant in specifications (1) to (8), reflecting that with each additional case active against IBM, it disclosed more inventions defensively, consistent with hypothesis 2. The coefficient estimate in specification (5) reflects an increase of eight percentage points in the fraction of defensive disclosures. The coefficient estimate of `LANDMARK CASES (SH)' is positive and significant at the 0.01 level, reflecting the fact that a stronger antitrust enforcement climate led to a greater fraction of defensive disclosures. The other measures of landmark cases yield similar results.

Our results remain similar when the period of analysis is changed to 1958-1989 instead of 1958-1982, as IBM continued to face the same antitrust case in Europe until the late 1980s. Our results are similar when the sample of inventors is restricted to pre-1969 cohorts with patent or disclosure activity.

### 5.2 Disclosure of Valuable Inventions

In our theoretical model, valuable inventions are just as likely as less valuable inventions to be disclosed defensively, in contrast to theories that predict that only low-value inventions are disclosed defensively. We reason that the economic value of an invention is difficult to determine *ex ante*; it may depend on whether it is patented and what other related inventions are patented. Deciding which inventions are to be patented is further complicated by the threat of antitrust action, under which a firm optimally discloses a large fraction of inventions defensively. The decentralized nature of the decision-making process at IBM adds another layer of complexity. We further provide evidence consistent with our view that high-quality inventions may be defensively disclosed in three parts.

First, IBM Fellows—those who received the highest technical honors at IBM—disclosed more inventions defensively between 1970 and 1989 than previously, as Figure 3 demonstrates. Top researchers at IBM were likely to disclose more during the third antitrust case, as was observed in the overall sample. In addition, from 1958 to 1989, top inventors—as defined by the total number of awarded points—disclosed, on average, 64 percent defensively and earned 40 percent of their points from defensive disclosures (see Table A1 in the Appendix). At the top of the list is J.J. Cuomo, a leading researcher in the area of semiconductor manufacturing, who had 321 points and disclosed 77 percent of all his inventions and earned 53 percent of his points through disclosures.

Insert Figure 3

Second, we grouped inventors with at least one disclosure by the highest number of citations any of their patents received during the period 1963-1999. A small group of 2,420 (9.5 percent) inventors with at least one very-highly-cited patent (in the top decile of cited patents) contributed to 17,895 (21.5 percent) defensive disclosures at an average of 7.4 defensive disclosures per inventor. In contrast, 52.5 percent of inventors with zero patents contributed to 29.5 percent of defensive disclosures at an average of 1.82 disclosures per inventor. These patterns reflect that during the third antitrust case, top inventors contributed disproportionately more to defensive-disclosure activity, which further supports our view.

Third, we collected data on citations to defensive disclosures in aggregate using the USPTO's non-patent literature citations for the period 1975-1989. We found that the aggregate number of citations to the TDB by non-IBM patents steadily increased from 1975 to 1989— from 637 to 2,109—faster than the rate of increase of defensive disclosures during the same period. In addition, citations to the TDB per non-IBM patent increased from 1.25 to 1.41, reflecting the increasing quality of defensive disclosures during this period. The absence of inventor names in TDB citations in the non-patent literature prevents us from investigating, through a citation analysis, whether the quality of disclosures increased at the inventor level.

The concentration of disclosure activity among a few top inventors is consistent with the view that the nearly thousand PhDs that IBM employed systematically defensively disclosed inventions relating to IBM's main research programs. This is borne out by the defensive-disclosure and patenting trends in semiconductor, disk drives, and software domains (see Figures 5 and 6). These trends are not consistent with the view that defensive disclosures are primarily inventions unrelated to and, thus, less valuable to IBM's main research programs and lines of business.

### 5.3 Other, Similar Cases

Xerox: Although we examined only one disclosure program here, our claims apply more broadly. To show this, we elaborate on the case of Xerox's defensive-disclosure program. Xerox, following its merger with Rank-Xerox, faced a Federal Trade Commission (FTC) investigation, which alleged that the patent portfolio of the combined entity created barriers to entry into the plain-paper copier market and that Xerox acted in ways to preserve its monopoly power through patents and marketing practices (see Bresnahan 1985). The case ended in 1975 with a consent decree, which required Xerox to license its patents at low or no royalties to its competitors.

Xerox's management at the time believed that: (a) the weakening of its patent portfolio would not erode its market position given its superior sales force and well-established brand value; (b) refusal to settle the FTC case by agreeing to license its patents would not prevent infringement of its patents, particularly by the Japanese competition; and (c) its suits alleging patent infringement would be answered by antitrust countersuits (Kearns and Nadler 1992:62). Xerox, however, quickly lost its dominant position in the copier market, as rivals entered and benefited from Xerox's patents and disclosures.

In 1976, Xerox began its defensive-disclosure program and disclosed 460 patents and 456 defensive disclosures in that year. Xerox classified its defensive disclosures according to the U.S. patent classification, leaving little doubt as to what it would have done if it had not faced the threat of antitrust action. Rivette and Kline (2000:37,99) note that the consent decree inhibited Xerox from patenting valuable inventions:

> A former Xerox patent attorney says Xerox had even gone so far as to write patent applications for some of its GUI technologies, including everything from pull-down menus to pop-up dialog boxes to scalable windows. But at a critical invention disclosure meeting held at the time, it was decided not to proceed with the filings. Clearly, the 1975 FTC consent decree that forced Xerox to license away its copier patents was still inhibiting the firm's patenting practices. But Xerox also seriously underestimated the GUI's significance.

As shown in Figure 4, the number of patents by filing year declined from 482 in 1975 to 399 in 1976 and 316 in 1977. The number of defensively-disclosed inventions increased from zero in 1975 to 456 in 1976 and declined to 300 in 1977. Xerox's patenting remained relatively low until 1986. A management change at Xerox and the rising cost of patent infringement by Japanese firms led to a turnaround in patenting (for similar developments at other firms, see Hall 2005). The defensive-disclosure program was rapidly scaled down as of the mid-1990s and, by 2000, Xerox had disclosed 21 inventions defensively while it filed for 1,028 patents in the same year.

Insert Figure 4

AT&T's Bell Labs: Another large R&D-intensive U.S. firm that faced antitrust cases concurrently with IBM was AT&T. The first case ended in a consent decree in 1956 inhibiting AT&T's patenting practices. The second case started in 1974 and ended in 1982 with the divestiture of AT&T and the creation of regional telephone companies in 1984. At the start of the first case against AT&T in 1949, its vice president, Keith McHugh, stated AT&T's patent policy in Bell Telephone Magazine: "It is the Bell System's policy to make available upon reasonable terms to all who desire them non-exclusive licenses under its patents for any use."

Ralph Bown, vice president in charge of research and patents at Bell Labs in 1954, who had overseen the successful patenting and publication strategy following the invention of the transistor in 1948, reiterated AT&T's patent policy (Bown 1954):

> Although our patent system may make it possible for a successful industrial research laboratory to follow a publication policy nearly as free as that of an individual worker in pure science, it is not the only thing necessary. The patent system is available to all, but not all companies permit easy publication. There is always a temptation to hold a new invention back until a pattern of related ideas and alternative inventions can be embroidered about it and all the easy smart alternatives it suggests are covered. Also the advantage of hitting the market with a new product fully developed and ready to deliver in advance of any competition is a powerful motive. A publication policy is a judicious mixture of these influences together with the desire for the reputation which flows from scientific leadership, and with a realization that submission of new ideas to other minds will result in faster over-all progress. The fact that the

> Bell System wants only freedom to use the best ideas man can produce, and is willing to buy or trade for these when necessary, is a powerful factor in our publication-policy thinking.

In addition, Bell Labs facilitated the diffusion of its newly accumulated semiconductor technology by holding symposia for several U.S. and foreign firms and began licensing its patents at a zero rate following the 1956 antitrust settlement (Scherer 1996). We found that firms like AT&T and IBM used the patent system to preserve freedom of action rather than to exclude others from using their inventions.[8]

### 5.4 Extending Regression Analysis

Next, we extended the regression analyses to IBM, AT&T and Xerox. They form three of the seven most important antitrust cases in the U.S. identified by Scherer (2008). We estimated the patenting propensity for these three firms and 152 control firms chosen from COMPUSTAT that have patents in the electronics and semiconductor industries, as defined by four-digit SIC codes (see, for a similar estimation strategy, Hall and Ziedonis 2001; Bhaskarabhatla and Hegde 2012). As a robustness check, we used patent classification to define the group of control firms, which did not change our results. We used three-year moving averages for R&D and Capital 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 likely to be affected by contemporaneous and past-year investments. Consequently, our sample period extends from 1971 (two years after the NBER Patent dataset begins) and extends until 1982, when federal antitrust cases against the three firms ended. We also controlled for employment, firm age, whether or not the firm has R&D activity, and dummies for AT&T, Xerox, and IBM. The firm dummies control for the time-invariant part of any factor that determines firm-specific patenting (and disclosure) propensities not already controlled for by measures of R&D and firm size—such as a firm's ability to secure returns from complementary assets without patenting extensively. The key

[8] There is further evidence to suggest that in building up its research in the late 1950s, IBM learned from similar firms such as Westinghouse and AT&T, both of which had maintained technical journals (see Hounshell 1996). For instance, Mervin Kelly, a retired chairman of Bell Telephone Laboratories, served as a consultant to Emanuel Piore, the director of IBM R&D from 1956 to 1960, at the request of Tom Watson (Pugh 1995). These similarities among large firms in the organization and management of R&D labs suggest that the lessons we learned from the case of IBM apply more generally to other, similar firms during this period.

explanatory variables are various measures of landmark cases and their interactions with dummies for AT&T, Xerox, and IBM.

Insert Table 4

The descriptive statistics are shown in Table A3, and regression results are shown in Table 4. The coefficient estimates of R&D Intensity and Capital Intensity are not statistically significant. Similarly, the coefficient estimate of 'R&D not zero' is positive but not significant. The coefficient estimates of log (Employment) and log (Age) are positive, reflecting that larger firms have a higher propensity to patent. The coefficient estimate of AT&T is not statistically significant, showing that AT&T did not differ from an average firm in the sample in terms of its propensity to patent during this period. IBM and Xerox, however, have large, positive and significant coefficient estimates, reflecting a relatively higher patent propensity.

We turn next to the coefficient estimates of landmark cases variables. The coefficient estimate of LANDMARK CASES (SH) is negative and significant, reflecting that under increased antitrust enforcement, all firms in the industry patent less. The coefficient estimates of interaction terms of ATT, Xerox, and IBM firm dummies with LANDMARK CASES (SH) are negative and significant, reflecting a lower propensity to patent for these three firms relative to other firms in the industry. We find similar results with other measures of landmark cases in specifications (2), (3), and (4). These results imply that exceptionally large firms under an increased threat of antitrust enforcement used defensive-disclosure strategies, as we showed earlier, and reduced their patenting activity.

### 5.6 Limitations

A number of limitations persist with our study. One set of limitations derives from our research design determined by data availability. Ideally, we would use a 'differences-in-differences' approach to test whether the fraction of inventions defensively disclosed by firms increased after an increase in the threat of antitrust enforcement—relative to before and relative to a set of similar control firms that maintained defensive-disclosure programs, but did not experience an increased threat of antitrust enforcement. However, data on defensive disclosures are prohibitively expensive to collect for other firms, particularly for firms that did not face antitrust enforcement. In addition, patent and scientific publication datasets have very limited coverage for years prior to 1969. For instance, NBER patent data do not identify assignee names for patents issued prior to January 1969, limiting our ability to build a control group for years prior to 1969 in our industry-level analyses presented in the previous section. Similarly, Web of Science's coverage of scientific journals is very limited for years prior to 1973, which prevents us from controlling for publication propensity over time for firms in the U.S., particularly before 1969. The lack of citation data disaggregated at the defensive-disclosure level precludes analyses of the quality of individual disclosures, although we showed that, in aggregate, the IBM disclosure bulletin received more citations over time, adjusting for its expansion.

One alternative would be to treat IBM technology sectors were not subject to the antitrust suit as a control group to assess the differential impact of the suit on technology sectors that were subject to increased antitrust enforcement. However, the IBM antitrust suit was comprehensive and covered five submarkets—tape drives, disk drives, memories, printers, and communications controllers—leaving no workable control group. We can show that the disclosure activity, however, increased across all the top patent classes as antitrust suits against IBM accumulated. We separately plot disclosures in hardware- and software-related classes in Figures 5 and 6, as software-related inventions began to become patentable in 1982.[9]

Insert Figures 5 and 6

Solidstate- and semiconductor-device-related disclosures spiked in 1970. The number of disclosures in class 438 related to semiconductor manufacturing rose from 54 in 1969 to 201 in 1970 and peaked at 247 in 1989. In addition, most of the entry in the hard-disk-drive industry occurred between 1977 and 1984, when IBM disclosed at a high level, contrary to some theories that predict the entry-deterrence effect of disclosures. Disclosure activity increased in software-related classes after 1969 but experienced a more significant increase

[9] Since IBM disclosures, unlike Xerox disclosures, are not assigned a patent class, we assign a class based on the patent classes in which authors of these disclosures received patents. For instance, we identify all inventors of disk-drive patents in 360 patent classes and subsequently identify all their disclosures and classify them as disk-drive related disclosures. We underestimate the actual disclosure activity in each technology area, as disclosures by researchers who have never patented are not counted. However, we do not expect disclosures by such researchers to change significantly and in the opposite direction after 1969 to confound our results.

after 1982, when software inventions became patentable, increasing the threat of holdup for IBM from others' patenting.

A second set of limitations derives from other contemporaneous events at IBM around 1969 that can plausibly explain the rise in defensive-disclosure activity. We argued earlier that defensive-disclosure activity was not limited to a few but spread across several technology classes in which IBM played a dominant role. However, it may be argued that IBM's decision to unbundle software and hardware or IBM's adoption of open architecture explains our results. These changes themselves were triggered by the 1969 antitrust case, and they still do not explain the origin of defensive-disclosure programs at IBM in 1958 and at Xerox in 1976 (Usselman 2009). We can, however, exclude the explanation that new product launches in non-patentable areas around 1969 drove disclosure activity, as IBM's most successful product, System 360, was launched in 1964, and the rise in disclosure activity after 1969 included patentable and nonpatentable areas such as hardware and software. In addition, IBM's collaborative activity with universities was emphasized only in the early 1980s and does not explain IBM's substantial disclosure activity earlier (Branscomb 1986). Finally, collaborative research among firms by participation in research consortia also increased during the 1980s and does not explain the earlier disclosure activity (Grindley et al. 1994).

## 6 Discussion

We investigated IBM's defensive-disclosure program in rich detail and found several insights. IBM's defensive disclosures were intended neither to slow a leader nor to scare a follower in an innovation race. We argued that IBM started and rapidly expanded its defensive-disclosure activity as a coping mechanism in response to the antitrust action taken by the U.S. Department of Justice, starting in the 1950s.

Soon after the second antitrust case against IBM ended in a consent decree, IBM adopted a science-oriented business strategy accompanied by a policy of `freedom of action,' which involved large investments in corporate research and open disclosure of scientific results and technical inventions. IBM hoped to preserve the freedom to use its inventions without applying for costly patents, given its limited ability to enforce patents and extract licensing revenues. Consistent with this policy, IBM began defensively disclosing inventions after the consent decree in 1956 and scaled up the disclosure program in 1969, when it faced the imminent threat of antitrust action.

We found evidence that researchers at IBM patented an increasingly smaller fraction of their inventions as of 1958, when the TDB began. During the third antitrust case, IBM continued to patent a smaller fraction of its inventions. A small group of top IBM researchers and Fellows contributed disproportionately more defensive disclosures compared to other IBM employees, which reflects the fact that the defensive disclosures were not necessarily low-value inventions unrelated to IBM's main lines of business. IBM reached a crisis in the late 1980s, as its investment in research failed to translate into competitive advantage. IBM finally downshifted its defensive-disclosure program and began patenting aggressively. The case of the Xerox disclosure program, which resembles IBM's program in several aspects, further supports our view.

The nature and extent of IBM's defensive-disclosure program have not been previously characterized. As a result, the business history of IBM, the evolution of industries in which it participated, and the lessons from its turnaround should be revisited (e.g., Lerner 1997). IBM's generous disclosure and limited patenting, we argue, created room for several firms in component markets to enter, grow, and eventually compete with IBM in the manufacture of software, storage, and semiconductors (see also, Grindley and Teece 1997).

Our characterization of IBM's disclosure program sheds new light on the variation in the effectiveness of patents across industries—as innovation surveys show—by highlighting the role of antitrust enforcement against dominant firms in some industries (Levin et al. 1987). In addition, our results provide a better context for the `patent paradox' observed in innovation surveys, where firms, since the mid-1980s, report deriving a modest return from patents but patenting on a large scale nonetheless (Cohen et al. 2000). There are several explanations for the patent paradox in the literature (e.g., Hall and Ziedonis 2001; Arora and Gambardella 1994; Rosenbloom and Spencer 1996; Kortum and Lerner 1998).

In a study of the semiconductor industry, Hall and Ziedonis (2001) suggest that the surge in patenting in the U.S. following the establishment of the Court of Appeals of the Federal Circuit (CAFC) in 1982 was driven by aggressive patenting by capital-intensive firms as a defensive mechanism against the problem of hold-up caused by small rival firms' patenting.

While they attribute the shift in `defensive' patenting to the strengthening of patent rights since the 1980s, we offer an explanation rooted in the history of antitrust action in the U.S. Patent reforms under the threat of antitrust action against large firms will cause, in relative terms, more defensive disclosure than patenting as observed in the case of the software sector at IBM after 1982 (see Figure 4). The subsequent increase in patenting by large firms, led by IBM, suggests a fundamental change in the way the U.S. Department of Justice dealt with the patent portfolios of some large firms and a shift in the political economy of antitrust enforcement in the U.S. in the 1980s (Ghosal forthcoming). The case of IBM's disclosure program also clarifies how patenting surged despite reductions in R&D, as IBM substituted away from defensive disclosures to patents in the 1990s.

Since the rise of industrial research in the early 20th century, large R&D-intensive firms have driven technological and economic progress, and IBM's role has been well-recognized (Reich 1985; Mowery and Rosenberg 1989; Bresnahan and Malerba 1997). Empirical studies have shown a positive relationship between firm size and process R&D (Cohen and Klepper 1996a, 1996b). More recently, however, the usefulness and sustainability of centralized corporate research labs have been questioned, as pioneering R&D firms have significantly shrunk their R&D investments (Rosenbloom and Spencer 1996). We argue that such firms had to balance a science-oriented strategy of growth with concerns of appropriability and punitive antitrust action. This tension between intellectual-property laws and antitrust laws is well-noted (Carlton and Gertner 2003). The case of IBM has provided an unusual opportunity to study the impact of this tension on an innovative, dominant firm's ability to stay competitive in the dynamic markets that it first pioneered, raising questions about the efficacy of antitrust laws to regulate dynamic R&D competition with the hope of promoting incentives for innovation.

## References


Anton, James, and Dennis Yao. 2004. ``Little Patents and Big Secrets: Managing Intellectual Property," RAND Journal of Economics 35:1-22.

Arora, Ashish, and Alfonso Gambardella. 1994. ``The changing technology of technological change: general and abstract knowledge and the division of innovative labour," Research Policy 23:523-32.

Baker, Scott, and Claudio Mezzetti. 2005. ``Disclosure and Investment Strategies in the Patent Race," Journal of Law and Economics 48:173-94.

Bar, Talia. 2006. ``Defensive Publications in an R&D Race," Journal of Economics and Management Strategy 15:229-54.

Bessen, James, and Robert Hunt. 2007. ``An empirical look at software patents," Journal of Economics and Management Strategy 16:157-89.

Bhaskarabhatla, Ajay, and Deepak Hegde. 2012. ``Does Management of Intellectual Property Matter?," Working paper.

Block, Michael, Frederick Nold, and J. Gregory Sidak. 1981. ``The Deterrent Effect of Antitrust Enforcement," Journal of Political Economy 89:429-45

Bown, Ralph. 1954. ``Inventing and Patenting at Bell Laboratories," Bell Laboratories Record 32:5-10.

Branscomb, Lewis. 1986. ``IBM and U.S. Universities—An Evolving Partnership," IEEE Transactions on Education 29:69-77.

Bresnahan, Timothy. 1985. ``Post-Entry Competition in the Plain Paper Copier Market," American Economic Review 75:15-19

Bresnahan, Timothy, and Franco Malerba. 1997. ``Industrial dynamics and the evolution of firms' and nations' competitive capabilities in the world computer industry," Working paper. Stanford University.

Carlton, Dennis, and Robert Gertner. 2003. ``Intellectual Property, Antitrust and Strategic Behavior," in Adam Jaffee and Joshua Lerner, ed., 3 Innovation Policy and the Economy, MIT Press.

Cohen, Wesley, Richard Nelson, and John Walsh. 2000. ``Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)," NBER Working Paper No. 7552.

Cohen, Wesley, and Steven Klepper. 1996a. ``A Reprise of Firm Size and R&D," Economic Journal 106:925-51.

Cohen, Wesley, and Steven Klepper. 1996b. ``Firm Size and the Nature of Innovation Within Industries: The Case of Process and Product R&D," Review of Economics and Statistics 78:232-43.

Fisher, Franklin, James McKie, and Richard Mancke. 1983. IBM and the US Data Processing Industry: An Economic History. New York, NY: Praeger Publishers.

Flamm, Kenneth. 1988. Creating the Computer. Washington, D.C.: Brookings Institution Press.

Gallo, Joseph, Kenneth Dau-Schmidt, Joseph Craycraft, and Charles Parker. 2000. ``Department of Justice Antitrust Enforcement, 1955-1997: An Empirical Study," Review of Industrial Organization 17:75-133.

Ghosal, Vivek. Forthcoming. ``Regime Shift in Antitrust Laws, Economics and Enforcement," Journal of Competition Law and Economics.

Gill, David. 2008. ``Strategic Disclosure of Intermediate Research Results," Journal of Economics & Management Strategy 17:733-58.

Grindley, Peter, and David Teece. 1997. ``Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics," California Management Review 39:8-41.

Grindley, Peter, David Mowery, and Brian Silverman. 1994. ``SEMATECH and collaborative research: Lessons in the design of high-technology consortia," Journal of Policy Analysis and Management 13:723-758.

Hall, Bronwyn, and Rosemarie Ziedonis. 2001. ``The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995," RAND Journal of Economics 32:101-28.

Hall, Bronwyn. 2005. ``Exploring the Patent Explosion," Journal of Technology Transfer 30:35-48.

Hart, David. 2001. ``Antitrust and Technological Innovation in the U.S.: Ideas, Institutions, Decisions, and Outcomes, 1890-2000," Research Policy 30:923-36.

Henkel, Joachim, and Stefanie Pangerl. 2008. ``Defensive publishing: An empirical study," DRUID Working Paper.

Horstmann, Ignatius, Glenn MacDonald, and Al Slivinski. 1985. ``Patents as Information Transfer Mechanisms: To Patent or (Maybe) Not to Patent," Journal of Political Economy 93:837-58.

Hounshell, David, and John Smith Jr. 1988. Science and Corporate Strategy: DuPont R&D, 1902-1980. Cambridge, UK: Cambridge University Press.

Hounshell, David. 1996. ``The evolution of industrial research," in Richard Rosenbloom and William Spencer, ed., Engines of innovation: U.S. industrial research at the end of an era. Boston, MA: Harvard Business School Press.

Jaffe, Adam, and Joshua Lerner. 2004. Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It. Princeton University Press.

Jansen, Jan. 2006. ``The Effects of Disclosure Regulation on an Innovative Firm," in Jay Pil Choi, ed., Recent Developments in Antitrust: Theory and Evidence, Boston, MA: MIT Press.

Kearns, David, and David Nadler. 1992. Prophets in the Dark: How Xerox Reinvented Itself and Beat Back the Japanese. New York, NY: HarperCollins.

Kortum, Samuel, and Joshua Lerner. 1998. ``Stronger Protection or Technological Revolution: What Is Behind the Recent Surge in Patenting?" Carnegie-Rochester Conference Series on Public Policy 49:247-304.

Kultti, Klaus, Tuomas Takalo, and Juuso Toikka. 2007. ``Secrecy versus patenting," Rand Journal of Economics 38:22-42.

Lerner, Joshua. 1997. ``An Empirical Exploration of Technology Race," Rand Journal of Economics, 28:228-47.

Levin, Richard, Alvin Klevorick, Richard Nelson, Sidney Winter. 1987. ``Appropriating the Returns from Industrial Research and Development," Brookings Papers on Economic Activity 18:783-831.

Lichtman, Douglas, Scott Baker, and Kate Kraus. 2000. ``Strategic disclosure in the patent system," Vanderbilt Law Review 53:2175-224.

McJones, Paul. 2009. Oral History of Donald Chamberlin. Computing History Museum.

Mowery, David, and Nathan Rosenberg. 1989. Technology and the Pursuit of Economic Growth. Cambridge, UK: Cambridge University Press.

Mowery, David. 2009. ``Plus ca change: Industrial R&D in the “third industrial revolution”," Industrial and Corporate Change 18:1-50.

Parchomovsky, Gideon. 2000. ``Publish or perish," Michigan Law Review 18:926-52.

Posner, Richard. 1970. ``A Statistical Study of Antitrust Enforcement," Journal of Law and Economics 13:365-419.

Pugh, Emerson. 1995. Building IBM: Shaping an Industry and its Technology. Boston, MA: MIT Press.

Reich, Leonard. 1985. The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926. Cambridge, UK: Cambridge University Press.

Rivette, Kevin, and David Kline. 2000. Rembrandts in the Attic - Unlocking the Hidden Value of Patents. Boston, MA: Harvard Business School Press.

Rosenbloom, Richard, and William Spencer. 1996. Engines of Innovation: U.S. Industrial Research at the End of an Era. Boston, MA: Harvard Business School Press.

Sarasohn, Homer. 1973. ``The Technical Journal - Who needs it?" IEEE Transactions on Professional Communication 16:129-80.

Scherer, Frederick. 1996. Industry Structure, Strategy, and Public Policy. New York, NY: HarperCollins College Publisher.

Scherer, Frederick. 2008. Technological Innovation and Monopolization. In Issues in Competition Law and Policy: Volume II. American Bar Association. W. D. Collins, ed., 1033.

Segal, Ilya, and Michael Whinston. 2007. "Antitrust in Innovative Industries." American Economic Review, 97: 1703–1730.

Usselman, Steven. 2009. ``Unbundling IBM: Antitrust and the Incentives to Innovation in American Computing," Sally Clark, Naomi Lamoreaux, and Steven Usselman, ed., The Challenge of Remaining Innovative. Stanford, CA: Stanford University Press.

U.S. National Research Council, 1956-1990. Industrial Research Laboratories in the United States. Washington, D.C.: National Academy of Sciences.

## Figures and Tables

Figure 1: IBM R&D Expenditures, Disclosures, Patents, and Licensing Revenues

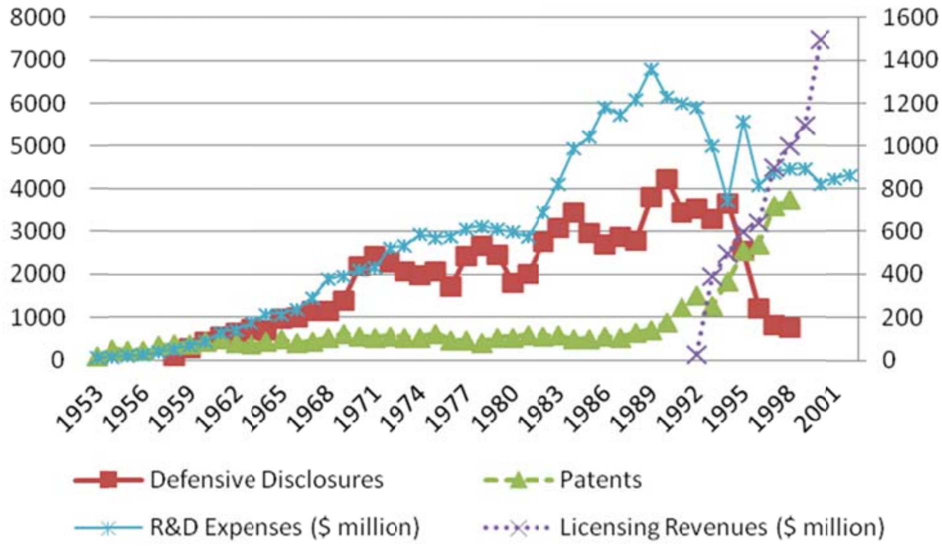


FIGURE 1 NOTES: The figure shows the time path of IBM's R&D Expenditures, Defensive Disclosures, Successful U.S. Patent Applications, and Licensing Revenues. Licensing revenues, in $ million, are shown on the secondary Y-axis.

Figure 2: IBM patents in top IBM three-digit patent classes

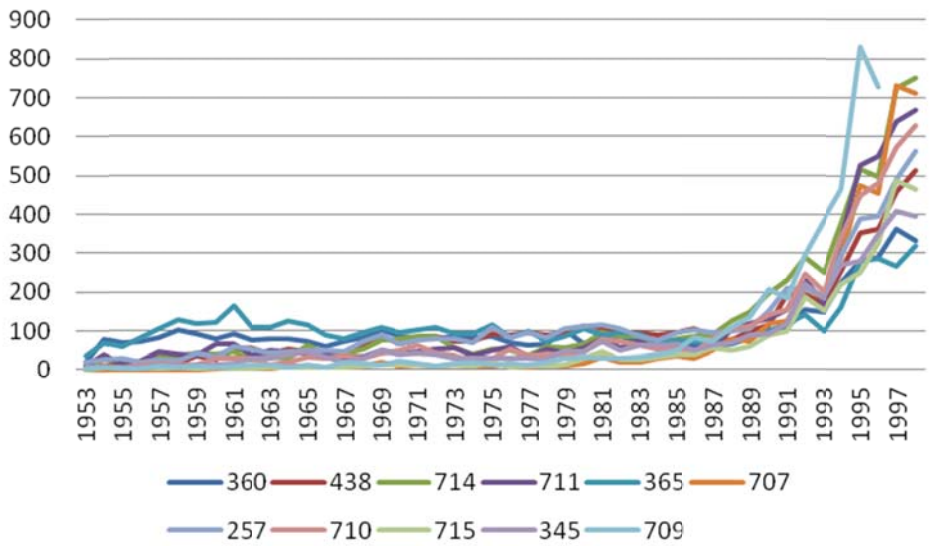


FIGURE 2 NOTES: U.S. patent class 360 refers to dynamic information storage and retrieval, 438 semiconductor manufacturing, 365 static information storage and retrieval, 257 active solid state devices, 714 error detection/correction & fault detection/recovery, 711 electrical computers & digital processing systems: memory, 707 data processing: database & file management or data structures, 710 electrical computers & digital processing systems: input output, 715 data processing: presentation processing of document, operator interface processing, and screen saver display processing, 709 multicomputer data transferring, 345 computer graphics processing and selective visual display systems.

Figure 3: Disclosure and Patenting by IBM Fellows

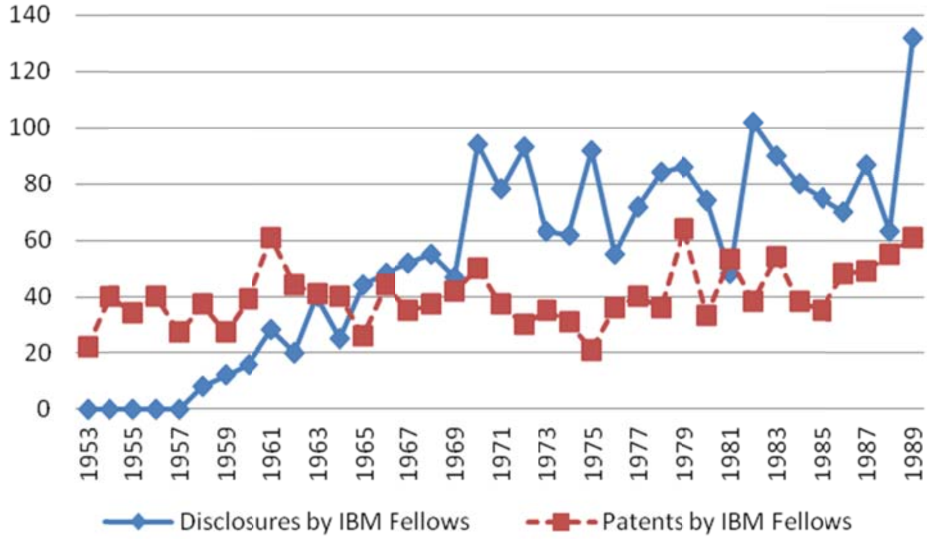


FIGURE 3 NOTES: The figure plots aggregate disclosure and patenting activity by a group of researchers that receive IBM Fellow title during their career at IBM.

Figure 4: Disclosure and Patenting by Xerox

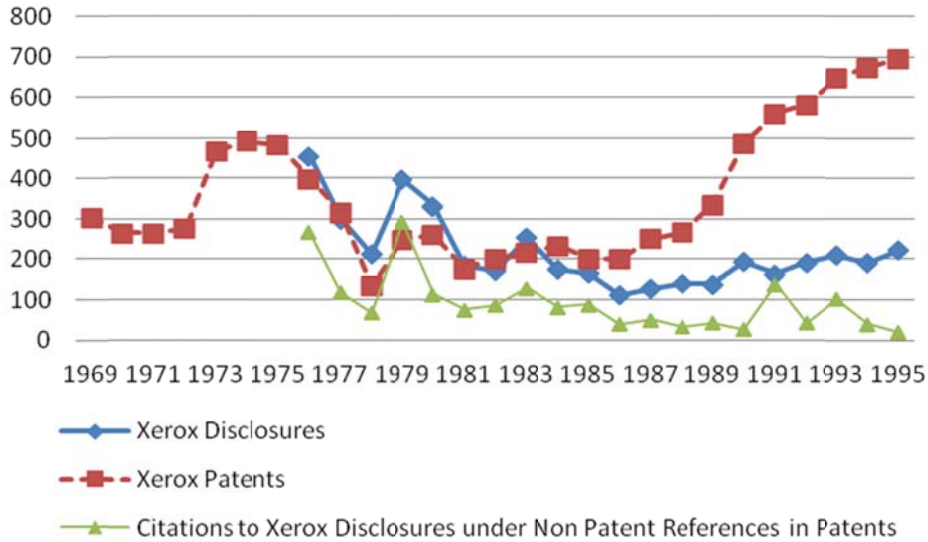


FIGURE 4 NOTES: The figure plots the number of patents by application year and the number of Xerox disclosure articles by publication year.

Figure 5: Disclosures by IBM inventors with patents in top hardware-related IBM patent classes

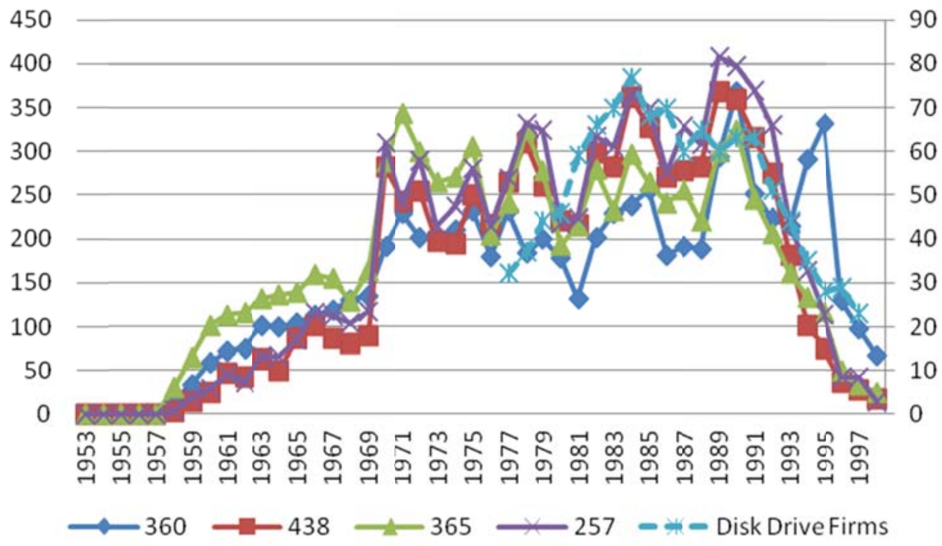


FIGURE 5 NOTES: U.S. patent class 360 refers to dynamic information storage and retrieval, 438 semiconductor manufacturing, 365 static information storage and retrieval, and 257 active solid state devices. The number of active disk-drive firms is shown on the secondary Y-axis.

Figure 6: Disclosures by IBM inventors with patents in top software-related IBM patent classes

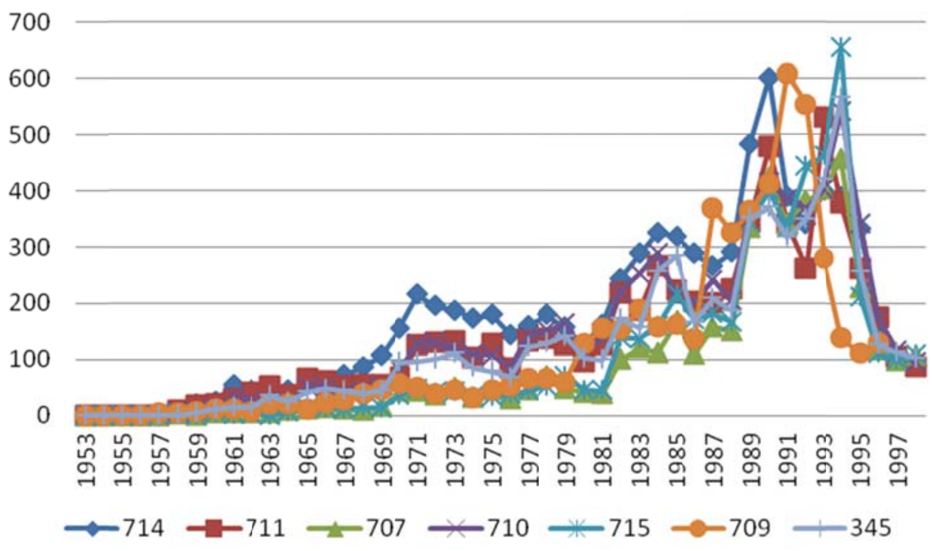


FIGURE 6 NOTES: US patent class 714 refers to error detection/correction and fault detection/recovery, 711 electrical computers and digital processing systems: memory, 707 data processing: database and file management or data structures, 710 electrical computers and digital processing systems: input output, 715 data processing: presentation processing of document, operator interface processing, and screen saver display processing, 709 electrical computers and digital processing systems: multicomputer data transferring, 345 computer graphics processing and selective visual display systems.

Table 1. Antitrust Cases against IBM

| N | Case | Start Date | End Date |
|---|---|---|---|
| 1 | First US Department of Justice Case | 1932 | 1936 |
| 2 | Second US Department of Justice Case | 1952 | 1956 |
| 3 | Control Data Corp | December 11 1968 | January 12 1973 |
| 4 | Third US Department of Justice Case | January 17 1969 | January 1 1982 |
| 5 | Greyhound | October 28 1969 | January 26 1981 |
| 6 | Telex | January 21 1972 | October 3 1975 |
| 7 | California Computer Products | October 3 1973 | February 15 1977 |
| 8 | Hudson General Corporation | November 30 1973 | 1979 |
| 9 | Marshall Industries | December 26 1973 | October 2 1975 |
| 10 | Memorex Corp | December 14 1973 | 1980 |
| 11 | Transamerica Corp | October 15 1973 | 1982 |
| 12 | Forro Precision Inc | August 6 1974 | 1982 |
| 13 | Memory Technology Inc | November 4 1974 | March 17 1976 |
| 14 | Sanders Associates Inc | January 7 1975 | January 27 1977 |
| 15 | Itel | 1972 | 1977 |
| 16 | Potter Instruments | 1972 | October 15 1973 |
| 17 | Data Processing Financial and General | September 17 1974 | 1979 |
| 18 | Eaton Allen | October 14 1974 | April 28 1975 |
| 19 | Advanced Memory Systems Inc | 1972 | 1972 |
| 20 | Applied Data Research | April 1969 | 1970 |
| 21 | European Commission Case | 1980 | July 1984 |

TABLE 1 NOTES: Private and U.S. Department of Justice antitrust cases against IBM, particularly during the 1970s, are listed here (Fisher et al. 1983). The E.C. case that began in 1980 ended in an ‘undertaking,’ which was to remain in force until January 1990. It finally was discontinued in 1994. Similarly, a number of private suits were decided at several intermediate courts before cases finally came to rest. The private suits and the government suit inspired a few additional suits, but ours is a comprehensive list of all major cases.

Table 2: Impact of Antitrust Case on Disclosures at the Firm Level

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| D.V.= | Fraction of Inventions Disclosed | | | |
| IBM CASES | 0.03** | 0.03** | 0.03** | 0.03** |
| | [0.01] | [0.01] | [0.01] | [0.01] |
| R&D Intensity | 0.07+ | 0.05 | 0.05 | 0.06 |
| | [0.04] | [0.03] | [0.04] | [0.04] |
| Capital Intensity | 0.01* | 0.01* | 0 | 0.01* |
| | [0.00] | [0.00] | [0.00] | [0.00] |
| LANDMARK CASES (SH) | 0.07** | | | |
| | [0.02] | | | |
| LANDMARK CASES (AK) | | 0.22** | | |
| | | [0.04] | | |
| LANDMARK CASES (H) | | | 0.05 | |
| | | | [0.04] | |
| LANDMARK CASES (AVG) | | | | 0.11** |
| | | | | [0.03] |
| Constant | -0.4 | -0.31 | -0.04 | -0.3 |
| | [0.39] | [0.36] | [0.41] | [0.39] |
| Observations | 25 | 25 | 25 | 25 |
| Log-Likelihood | 25 | 26.15 | 21.09 | 23.92 |

S.E. in brackets; ** p<0.01, * p<0.05, + p<0.1

TABLE 2 NOTES: Method of estimation is maximum likelihood for censored Tobit. The dependent variable is the fraction of inventions defensively disclosed. The key independent variables are IBM CASES and various alternative measures of LANDMARK CASES. The sample extends from 1958 to 1982.

Table 3: Impact of Antitrust Case on Disclosures at the Inventor Level

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | XTREG | | | | XTLOGIT | | | |
| D.V.= | Fraction of Inventions Defensively Disclosed | | | | | | | |
| IBM CASES | 0.01** | 0.02** | 0.01** | 0.02** | 0.08** | 0.09** | 0.07** | 0.09** |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.01] | [0.01] | [0.01] | [0.01] |
| R&D Intensity | 0.06** | 0.05** | 0.05** | 0.05** | 0.34** | 0.27** | 0.27** | 0.29** |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.03] | [0.03] | [0.03] | [0.03] |
| Capital Intensity | 0.00** | 0.00** | 0.00** | 0.00** | 0.02** | 0.02** | 0.02** | 0.02** |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| LANDMARK CASES (SH) | 0.03** | | | | 0.16** | | | |
| | [0.00] | | | | [0.02] | | | |
| LANDMARK CASES (AK) | | 0.10** | | | | 0.48** | | |
| | | [0.01] | | | | [0.05] | | |
| LANDMARK CASES (H) | | | 0.02** | | | | 0.12** | |
| | | | [0.01] | | | | [0.04] | |
| LANDMARK CASES (AVG) | | | | 0.05** | | | | 0.24** |
| | | | | [0.01] | | | | [0.03] |
| Constant | -0.03 | -0.01 | 0.18** | 0.02 | | | | |
| | [0.05] | [0.05] | [0.04] | [0.05] | | | | |
| Observations | 37,894 | 37,894 | 37,894 | 37,894 | 27,072 | 27,072 | 27,072 | 27,072 |
| Inventor FE | YES | YES | YES | YES | YES | YES | YES | YES |
| R-squared | 0.015 | 0.016 | 0.012 | 0.014 | | | | |
| N of Clusters | 8,760 | 8,760 | 8,760 | 8,760 | 4,960 | 4,960 | 4,960 | 4,960 |
| Log-likelihood | | | | | -9954 | -9949 | -9984 | -9962 |

Inventor-Clustered S.E. in brackets; ** p<0.01, * p<0.05, + p<0.1

TABLE 3 NOTES: Method of estimation is maximum likelihood for linear regression with fixed-effects (XTREG) for (1) to (4) and conditional maximum likelihood for fixed-effects logistic regression (XTLOGIT) for (5) to (8). Specifications (5) through (8) exclude inventors who did not file for a patent (or a disclosure) during 1958-1982. The dependent variable is the fraction of inventions defensively disclosed at the individual-inventor level. The key independent variables are IBM CASES and various alternative measures of LANDMARK CASES.

Table 4: Impact of Antitrust Cases on Patent Propensity

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| D.V.=Patent Count | NBREG | | | |
| log (R&D/Sales) | 0.01 | -0.02 | -0.02 | 0 |
| | [0.12] | [0.12] | [0.12] | [0.12] |
| log (Capital Expenditure/Sales) | -0.03 | -0.02 | -0.03 | -0.03 |
| | [0.24] | [0.25] | [0.25] | [0.25] |
| R&D not zero | 0.21 | 0.33 | 0.32 | 0.27 |
| | [0.34] | [0.32] | [0.32] | [0.33] |
| log (Employees) | 0.76** | 0.76** | 0.76** | 0.76** |
| | [0.09] | [0.09] | [0.09] | [0.09] |
| log (Age) | 0.83** | 0.72** | 0.74** | 0.79** |
| | [0.21] | [0.20] | [0.20] | [0.20] |
| AT&T | 0.01 | -0.02 | -0.01 | 0.01 |
| | [0.57] | [0.58] | [0.58] | [0.57] |
| XEROX | 1.51** | 1.93** | 1.78** | 1.67** |
| | [0.24] | [0.25] | [0.24] | [0.24] |
| IBM | 0.76** | 0.88** | 0.85** | 0.82** |
| | [0.29] | [0.29] | [0.29] | [0.29] |
| LANDMARK CASES (SH) | -0.15* | | | |
| | [0.07] | | | |
| ATT x LANDMARK CASES (SH) | -0.13* | | | |
| | [0.06] | | | |
| XEROX x LANDMARK CASES (SH) | -0.38** | | | |
| | [0.05] | | | |
| IBM x LANDMARK CASES (SH) | -0.13* | | | |
| | [0.05] | | | |
| LANDMARK CASES (AK) | | -0.17 | | |
| | | [0.16] | | |
| ATT x LANDMARK CASES (AK) | | -0.28+ | | |
| | | [0.16] | | |
| XEROX x LANDMARK CASES (AK) | | -1.20** | | |
| | | [0.15] | | |
| IBM x LANDMARK CASES (AK) | | -0.37** | | |
| | | [0.14] | | |
| LANDMARK CASES (H) | | | -0.18 | |
| | | | [0.13] | |
| ATT x LANDMARK CASES (H) | | | -0.26* | |
| | | | [0.13] | |
| XEROX x LANDMARK CASES (H) | | | -0.93** | |
| | | | [0.12] | |
| IBM x LANDMARK CASES (H) | | | -0.31** | |
| | | | [0.12] | |
| LANDMARK CASES (AVG) | | | | -0.20+ |

| | | | | |
|---|---|---|---|---|
| | | | | [0.11] |
| ATT x LANDMARK CASES (AVG) | | | | -0.21* |
| | | | | [0.10] |
| XEROX x LANDMARK CASES (AVG) | | | | -0.67** |
| | | | | [0.09] |
| IBM x LANDMARK CASES (AVG) | | | | -0.23** |
| | | | | [0.09] |
| Constant | 0.26* | 0.27* | 0.27* | 0.27* |
| | [0.12] | [0.12] | [0.12] | [0.12] |
| Observations | 800 | 800 | 800 | 800 |
| N of Clusters | 155 | 155 | 155 | 155 |
| Log-likelihood | -3353 | -3359 | -3358 | -3356 |

Firm-Clustered S.E. in brackets; ** p<0.01, * p<0.05, + p<0.1

TABLE 4 NOTES: Method of estimation is Maximum Likelihood for Negative Binomial (NBREG), and estimates represent Incidence Rate Ratios. The dependent variable is the number of successful patent applications for each firm-year. Time-period of analysis is 1971-1982 containing 155 firms, each with annual Compustat records and at least one successful patent application in IBM's industry (electronics and semiconductors) defined based on four-digit SIC codes. The results are robust to alternative definitions of the industry based on patent classes. 3-year moving averages (for years t, t-1 and t-2) are used for R&D/Sales and Capital Expenditure/Sales. Employees are in the thousands.

# Appendix

Figure A1. Sample Defensive Disclosure

## XEROX DISCLOSURE JOURNAL

**NEXT GENERATION PAPER FEEDER**
Denis J. Stemmle

Proposed Classification
U. S. Cl. 399/383
Int. Cl. G03g 15/00

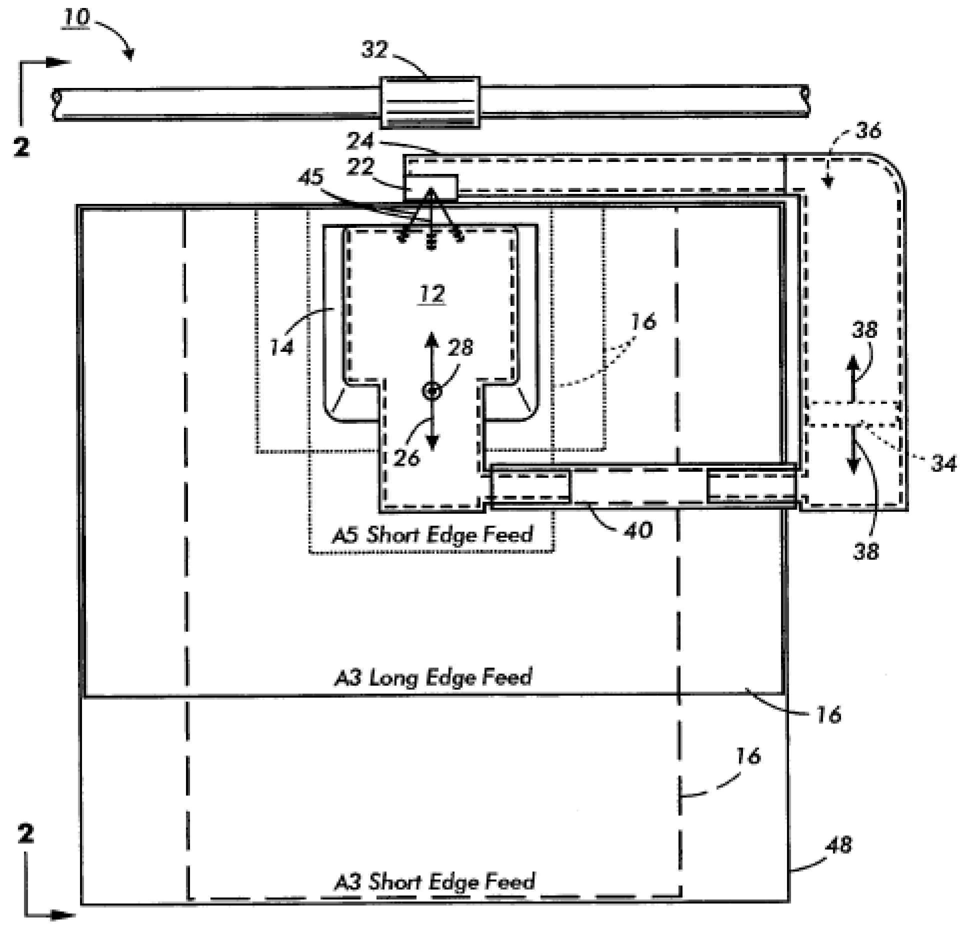


*FIG. 1*

FIGURE A1 NOTES: The figure shows a page from a sample defensive disclosure from *Xerox Disclosure Journal*. The page contains the title of the invention, the name of the inventor, proposed U.S. and International Patent Classifications, and a rendering of the invention-specific apparatus.

Figure A2: Landmark Cases during 1958-1982

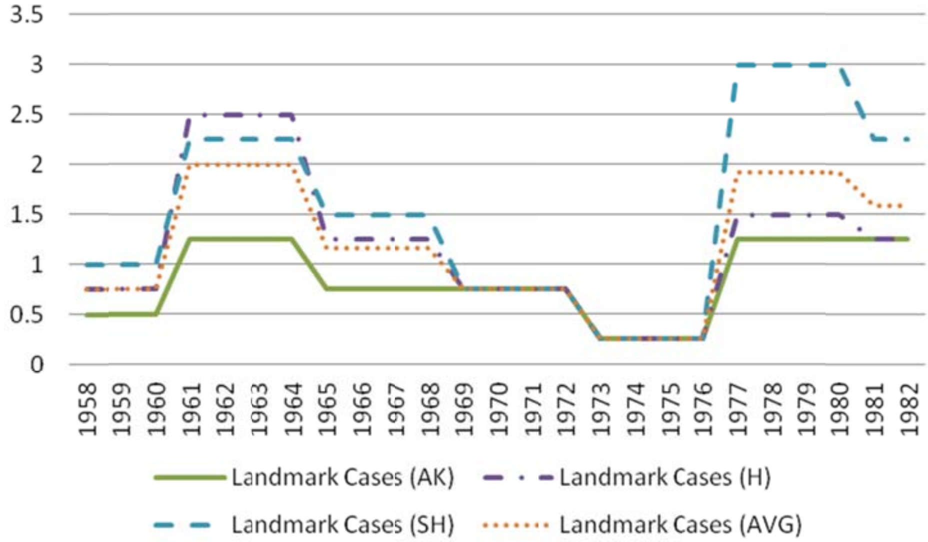


FIGURE A2 NOTES: The figure plots the number of landmark cases during 1958-1982. Source: Gallo et al. (2000).

Table A1. IBM Inventors with more than 100 points obtained through patents and disclosures

| Name | Pats | Discs | % | P* | Name | Pats | Discs | % | P* |
|---|---|---|---|---|---|---|---|---|---|
| Cuomo JJ | 50 | 171 | 77 | 321 | Dorler JA | 18 | 71 | 80 | 125 |
| Woodall JM | 60 | 106 | 64 | 286 | Gambino RJ | 18 | 71 | 80 | 125 |
| Wiedmann SK | 51 | 88 | 63 | 241 | Harris TJ | 34 | 23 | 40 | 125 |
| Romankiw LT | 39 | 101 | 72 | 218 | Grebe KR | 25 | 49 | 66 | 124 |
| Riseman J | 55 | 51 | 48 | 216 | Hinkel H | 15 | 79 | 84 | 124 |
| Clapper GL | 53 | 55 | 51 | 214 | Irwin JW | 24 | 52 | 68 | 124 |
| Marinace JC | 43 | 61 | 59 | 190 | Thompson DA | 25 | 47 | 65 | 122 |
| Vinal AW | 57 | 19 | 25 | 190 | Hernandez IH | 15 | 76 | 84 | 121 |
| Pricer WD | 44 | 46 | 51 | 178 | Poponiak MR | 19 | 63 | 77 | 120 |
| Barker BA | 23 | 107 | 82 | 176 | Stuckert PE | 29 | 32 | 52 | 119 |
| Ahn KY | 22 | 104 | 83 | 170 | Garwin RL | 30 | 27 | 47 | 117 |
| Reisman A | 42 | 42 | 50 | 168 | Greschner J | 26 | 39 | 60 | 117 |
| Pennington K | 31 | 73 | 70 | 166 | Nassimbene EG | 18 | 63 | 78 | 117 |
| Pomerene JH | 20 | 103 | 84 | 163 | Schmeckenbecher AF | 20 | 56 | 74 | 116 |
| Malaviya SD | 32 | 58 | 64 | 154 | Lin Y | 16 | 67 | 81 | 115 |
| Patel AM | 38 | 40 | 51 | 154 | Roth JP | 7 | 94 | 93 | 115 |
| Briska M | 26 | 73 | 74 | 151 | Rutz RF | 30 | 23 | 43 | 113 |
| Sincerbox GT | 31 | 55 | 64 | 148 | Fleisher H | 31 | 19 | 38 | 112 |
| Hunt RE | 30 | 57 | 66 | 147 | Pawletko JP | 22 | 46 | 68 | 112 |
| Pennebaker WB | 39 | 28 | 42 | 145 | Galand CR | 24 | 39 | 62 | 111 |
| Weinberger A | 23 | 74 | 76 | 143 | Helinski EF | 15 | 65 | 81 | 110 |
| Chu RC | 19 | 85 | 82 | 142 | Magdo S | 28 | 25 | 47 | 109 |
| Beausoleil WF | 34 | 39 | 53 | 141 | Queener CA | 27 | 27 | 50 | 108 |
| Howard JK | 35 | 36 | 51 | 141 | Criscimagna TN | 21 | 44 | 68 | 107 |
| Anantha NG | 26 | 62 | 70 | 140 | Esaki L | 23 | 38 | 62 | 107 |
| Bhatia H | 23 | 71 | 76 | 140 | Torres RJ | 6 | 89 | 94 | 107 |
| Rechtschaffen RN | 14 | 98 | 88 | 140 | Brownlow JM | 24 | 34 | 59 | 106 |
| Magdo IE | 42 | 13 | 24 | 139 | Tummala RR | 24 | 33 | 58 | 105 |
| Sparacio FJ | 19 | 82 | 81 | 139 | Bohg A | 17 | 53 | 76 | 104 |
| Uberbacher EC | 22 | 73 | 77 | 139 | Gersbach JE | 14 | 62 | 82 | 104 |
| Jambotkar CG | 21 | 73 | 78 | 136 | Najmann K | 12 | 68 | 85 | 104 |
| Sambucetti CJ | 20 | 76 | 79 | 136 | Schettler H | 14 | 62 | 82 | 104 |
| Chang H | 26 | 57 | 69 | 135 | Terman LM | 19 | 47 | 71 | 104 |
| Maley GA | 32 | 38 | 54 | 134 | Cronin JE | 8 | 79 | 91 | 103 |
| Walsh JL | 34 | 32 | 48 | 134 | Edel TR | 10 | 73 | 88 | 103 |
| Keefe GE | 28 | 49 | 64 | 133 | Hoffman H | 20 | 43 | 68 | 103 |
| Lean EGH | 23 | 62 | 73 | 131 | Max E | 27 | 22 | 45 | 103 |
| Schaefer JO | 33 | 32 | 49 | 131 | Aviram A | 19 | 45 | 70 | 102 |
| Fang FF | 25 | 54 | 68 | 129 | Hodgson RT | 13 | 62 | 83 | 101 |
| Matyas SM | 25 | 54 | 68 | 129 | Hovel HJ | 19 | 44 | 70 | 101 |
| Voegeli O | 36 | 20 | 36 | 128 | Kollar EP | 24 | 29 | 55 | 101 |
| Ho IT | 31 | 34 | 52 | 127 | Meyer CH | 18 | 47 | 72 | 101 |

Notes: * P≡Points=3xPatents+Disclosures

% denotes fraction of inventions disclosed defensively

Table A2. Descriptive Statistics

| Variable | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Fraction of Disclosures | 37894 | 0.69 | 0.42 | 0 | 1 |
| IBM CASES | 37894 | 4.70 | 3.80 | 0 | 13 |
| R&D Intensity | 37894 | 6.24 | 0.59 | 4.12 | 7.96 |
| Capital Intensity | 37894 | 54.23 | 6.98 | 43.51 | 72.95 |
| LANDMARK CASES (AK) | 37894 | 0.86 | 0.39 | 0.25 | 1.25 |
| LANDMARK CASES (H) | 37894 | 1.09 | 0.62 | 0.25 | 2.5 |
| LANDMARK CASES (SH) | 37894 | 1.58 | 1.03 | 0.25 | 3 |
| LANDMARK CASES (AVG) | 37894 | 1.17 | 0.65 | 0.25 | 2 |

Table A3. Descriptive Statistics (Continued)

| Variable | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Patent Count | 800 | 67.59 | 145.53 | 1 | 891 |
| log (R&D/Sales) | 800 | -3.22 | 0.88 | -6.36 | 1.48 |
| log (Capital Expenditure/Sales) | 800 | -0.77 | 0.65 | -3.04 | 1.46 |
| log (Employment) | 800 | 2.18 | 2.02 | -3.61 | 6.74 |
| log (Age) | 800 | 1.96 | 0.46 | 1.10 | 2.64 |
| R&D not zero | 800 | 0.01 | 0.07 | 0 | 1 |
| AT&T | 800 | 0.02 | 0.12 | 0 | 1 |
| XEROX | 800 | 0.02 | 0.12 | 0 | 1 |
| IBM | 800 | 0.02 | 0.12 | 0 | 1 |
| LANDMARK CASES (SH) | 800 | 1.62 | 1.24 | 0.25 | 3 |
| ATT x LANDMARK CASES (SH) | 800 | 0.02 | 0.24 | 0 | 3 |
| XEROX x LANDMARK CASES (SH) | 800 | 0.02 | 0.24 | 0 | 3 |
| IBM x LANDMARK CASES (SH) | 800 | 0.02 | 0.24 | 0 | 3 |
| LANDMARK CASES (AK) | 800 | 0.83 | 0.47 | 0.25 | 1.25 |
| ATT x LANDMARK CASES (AK) | 800 | 0.01 | 0.12 | 0 | 1.25 |
| XEROX x LANDMARK CASES (AK) | 800 | 0.01 | 0.12 | 0 | 1.25 |
| IBM x LANDMARK CASES (AK) | 800 | 0.01 | 0.12 | 0 | 1.25 |
| LANDMARK CASES (H) | 800 | 0.91 | 0.56 | 0.25 | 1.5 |
| ATT x LANDMARK CASES (H) | 800 | 0.01 | 0.13 | 0 | 1.5 |
| XEROX x LANDMARK CASES (H) | 800 | 0.01 | 0.13 | 0 | 1.5 |
| IBM x LANDMARK CASES (H) | 800 | 0.01 | 0.13 | 0 | 1.5 |
| LANDMARK CASES (AVG) | 800 | 1.12 | 0.75 | 0.25 | 1.92 |
| ATT x LANDMARK CASES (AVG) | 800 | 0.02 | 0.16 | 0 | 1.92 |
| XEROX x LANDMARK CASES (AVG) | 800 | 0.02 | 0.16 | 0 | 1.92 |
| IBM x LANDMARK CASES (AVG) | 800 | 0.02 | 0.16 | 0 | 1.92 |