Exploring the Patent Explosion[1]

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ABSTRACT

This paper looks more closely at the sources of patent growth in the United States since 1984. It confirms that the increase is largely due to US patenters, with an earlier surge in Asia, and some increase in Europe. I find that growth has taken place in all technologies, but not in all industries, being concentrated in the electrical technology-based industries (electrical, electronics, computing, and scientific instruments). I then go on to look at the question of whether these patents are valued by the market. We know from survey evidence that patents in these industries are not considered important for appropriability, but are considered necessary to secure financing for entering the industry, so they may yet serve a useful purpose. I argue that one way to test whether patents are successful in lowering financing cost is to compare the market value of patents held by entrant firms in electrical technology-based industries to those held by incumbents (controlling for R&D). Using data on publicly traded firms 1980-1989, I find that the market value of entrants' patents is indeed higher in the electrical and computing industries for entrants in the post-1984 period (after the patenting surge), but not before, when patents were relatively unimportant in these industries.

1 Introduction

The recent rapid growth of patenting worldwide and especially in the United States has renewed economists' interest in evaluating the effectiveness of the patent system in promoting innovative activity among private firms. Although evidence on the effectiveness of patents for securing the returns to innovation is mixed (see the survey evidence reported by Cohen et al 2000 and the summary of empirical work in this area in Hall 2003a), one area where patents are widely viewed as important if not essential is for securing the financing to start a new venture (e.g., see the evidence from semiconductor firms in Hall and Ziedonis 2001). The current paper probes the

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[1] Invited lecture prepared for the ZEW Workshop on Empirical Economics of Innovation and Patenting, Mannheim, Germany, March 14-15, 2003. This is a revision of the preliminary draft. I am very grateful to Josh Lerner for extremely

empirical validity of this assertion by examining the comparative market valuation of patents held by incumbent and entrant firms in the United States during the 1980s, a period in which the use of patents by U.S. firms increased very substantially, partly as a result of changes in the enforceability of patents in the courts.

As several authors have demonstrated, the creation of a centralized court of appeals specializing in patent cases in 1982, together with a few well-publicized infringement cases in the mid-1980s, have led to an increased focus on patenting by firms in industries where patents have not traditionally been important, such as computers and electronics. In the first part of the paper I show that the decomposition of the sources of patent application growth in the United States supports the interpretation that the growth has been driven by increased patenting by U.S. firms in the electric machinery, electronics, and instrument industries, broadly defined. I also show that a time series analysis of patents reveals a very significant structural break between 1983 and 1984, one that was concentrated in the electrical sector.

Using a large sample of publicly traded U. S. manufacturing firms, I then investigate how their patent valuations changed between the early and late 1980s, focusing on the differences between incumbent firms and new entrants to the industry.

2 Changes in the U.S. patent system

A number of changes to the patent system, both legislative and via legal precedent, took place during the 1980s and more recently. These changes are summarized in Table 0. A series of court decisions have expanded legitimate subject matter to include genetically-modified organisms, software, and business methods. Legislative changes have enhanced the ability of patentholders to enforce their patents, both via the creation of a specialized patent court, and via various procedural changes made at the same time.

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helpful comments on the first version of the paper.

Following these legislative changes, the demonstration effect of a series of infringement cases had a powerful effect on the thinking of some firm managers. The Kodak-Polaroid case mentioned in the table cost Kodak a billion dollar judgment and shut down their instant camera business. It also demonstrated that the ability of a patentholder to obtain a preliminary injunction against the use of the supposedly infringing technology before the final decision was reached in a court case was a powerful financial weapon, and one to be avoided even at considerable cost. Fear of this strategy appears to have been a strong motivation for increased defensive patent filings, at least in the semiconductor industry (Hall and Ziedonis 2001).

The result of all these changes was a rapid increase in patent applications. In the next section of the paper I study the timing and composition of this increase in some detail.

2.1 The patent explosion

Figure 1 shows grants, applications, and grants by application date for all U.S. utility patents that were granted between January 1965 and December 2002.[2] Because of grant-application lags, the data on grants by application date are only complete through 1997. Figure 2 shows growth rates for the same data, smoothed using a moving average. Both graphs exhibit a substantial break in the mid-1980s: until then, patenting is roughly constant and after that it grows around five per cent per year. Real R&D increased only about 2.4% per year during the late 1980s and patents taken out by U.S. inventors per R&D dollar also increased.[3]

For further investigation, I focus on the patent grants by date of application (which is relevant date for an investigation of firm behavior and abstracts from variations in the application-grant lag). The properties of the patent application series were explored in two ways: first I tested for structural breaks both in the aggregate and by region and main technology class. Then I performed a growth accounting exercise over different 5-year subperiods to identify the sources of the growth displayed in the graphs.

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[2] In the current paper the data are through September 2002, but I have data to update through December 2002.
[3] There is also no evidence of a decline in applications as of December 2001.

2.2 Tests for structural breaks

Table 1 displays the results for the aggregate patent application series. Four different versions of the series were used, two in levels and two in changes, in both cases in levels and logarithms. The presence of a unit root was clearly accepted for the two series in levels, so further analysis was conducted on the differenced series. The next row of the table shows the results of a simple t-test for a change in the mean of the differenced series between 1983 and 1984 (the choice of period was based on inspection of the graph in Figure 1). Either in levels or logs, this test rejects a constant mean resoundingly. The growth rate of patent applications jumps in 1984 from an average of 0.3 per cent per annum to an average of 6.5 per cent per annum. The final rows of the table give Andrews (1993) test for a structural break of unknown date. This too is highly significant, and in the case of the logged series, the break year is identified as 1984. Further analysis in this section is conducted only on the first-differenced log of patent applications.

Tables 2A and 2B show the results of tests for a structural break in patent applications by region of patent application origin, and technology class. The regional breakdown reveals unambiguous evidence of a structural break for U.S. origin patents in 1984. The remaining evidence is more ambiguous: only Asian patents exhibit a structural break according to the Andrews test, and it is in 1981. Although the other regions have no identifiable break, the non-European patents do have significantly different patenting growth rates before and after 1984. The conclusion is that the highly visible increase in growth rates in 1983/1984 is due to inventors resident in the U.S.

In Table 2B, I show similar results for the six broad technology categories developed by Hall, Jaffe, and Trajtenberg 2002. The results are unambiguous: chemicals and pharmaceuticals, the industries that have traditionally identified patents as important for securing returns to innovation, exhibit little evidence of a structural break in 1984. On the contrary, the electrical, computers and communications, mechanical and other technologies all have a significant structural break that occurs either in 1984 or 1985. Beginning in those years, the growth of patent applications increased over 8 per cent per annum in computing and electrical technologies, and over 5 per cent per annum in mechanical and other technologies. The next section of the paper summarizes the contribution of these sectors to the aggregate growth in patenting.

2.3 Accounting for patent growth

In order to carry out a growth accounting exercise on the patent data, I define the following:

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\begin{aligned}
g_t &= \text{growth of patenting from time } t\text{-1 to } t \\
g_{it} &= \text{growth of patenting in class or region } i \text{ from time } t\text{-1 to } t \\
s_{i,t\text{-}1} &= \text{share of patents in class or region } i \text{ at time } t\text{-1}
\end{aligned}
\tag{1.1}
$$

Then the growth in patents at time *t* is given by

$$g_t = \sum_{i=1}^{n} s_{i,t-1} g_{it} \tag{1.2}$$

Table 3 shows the computations for three difference decompositions of the data, by major region of patent origin, by broad technology class, and by broad industry class based on the Compustat firm sample that I use later in the paper. Both of the later breakdowns are for U.S.-origin inventors only, because of the evidence that this is the source of the patent increase (see also Kortum and Lerner 1998 on this point). The plots in Figures 3 to 5 show $s_{it-1}g_{it}$ for the three different decompositions.

The figures reveal the following interesting fact: although the jump in patent applications within the U.S. occurred in all technology classes, when we look by broad industry class, we find that it occurred *only* in firms that are in the electrical, computing and instruments industries. That is, the increase in chemicals, mechanical and other technologies appears to have been driven by increasing patenting activity by firms that were not traditionally in these industries. This result is consistent with the view that there has been a major strategic shift in patenting in the electrical/computing industries, but not in other industries.

One interpretation of the contrasting findings in Figures 4 and 5 is the following: the first figure suggests an increase in innovation (as measured by patents) from the 1974-84 period to the

1984-94 period that occurred in all technology areas. But the second says that the increase was actually concentrated in firms in one sector, which implies that these firms increased their patenting not only in their own sector but in the other technology sectors as well. This suggests that the increase is due to a strategic shift within the electrical and computing sector, rather than an increase in inventiveness across the board. Further testing of this hypothesis seems warranted, to understand what the patenting behavior of the electrical/computing firms was in the chemicals/ mechanical/ other sector before and after the shift in 1984.

2.4 What changed?

Given these findings with respect to timing of the surge, region of origin, and technology and industry origin, we can identify the following changes in the patent system as having provided an impetus for the increase in growth rate: the 1982 creation of CAFC and the 1985/6 litigation success of Texas Instruments and Polaroid. As a result of the creation of CAFC and as demonstrated by these cases, patents were now more likely to be upheld in litigation, and the consequences were likely to be more negative for alleged infringers, especially in complex product industries like electronic computing and communications.

As Levin et al (1987) and Cohen, Nelson, and Walsh (2000) reported from their survey evidence, patents have not been considered important for appropriating returns to R&D except in some chemicals industries. Nevertheless, Hall and Ziedonis (2001) found that patents are now used for defensive purposes in semiconductors, to defend against suits and for cross licensing. They also found that patents were considered important for securing financing for startups in this industry. The analysis here confirms that the overall surge in patenting is due to an increased use of patents by U.S. firms in industries similar to and including semiconductors. The next section explores the implications of this finding for firm valuation by the market.

3 The market value of patents

3.1 Data sample

The data sample used here is drawn from the sample described in Hall, Jaffe, and Trajtenberg 2002 and Hall et al 1995. It consists of about 1400 U.S. manufacturing firms with at least one patent and at least five years of data between 1980 and 1989. Firms are identified as incumbents (in the sample as of 1979), entrants 1980-84, or entrants 1985-89.

3.2 Model and estimation strategy

The model estimated is a very basic hedonic market value model, similar to that in Griliches 1981 or Hall, Jaffe, and Trajtenberg 2001. The market value of a firm is related to the book value of its assets via the following regression equation:

$$\log Q_{it} = \log\left(\frac{V_{it}}{A_{it}}\right) = \delta_t + \beta_K\left(\frac{K_{it}}{A_{it}}\right) + \beta_P\left(\frac{P_{it}}{K_{it}}\right) + \varepsilon_{it} \qquad (1.3)$$

where

V = market value of firm

A = book value of tangible assets

K = stock of R&D assets

P = stock of patents

The form of the specification is dictated by the fact that patents are roughly proportional to R&D for these firms, so that the separate impact of obtaining a patent successfully can be measured by including a patent productivity variable in the form of patents per R&D in the model. The stocks of both R&D and patents are constructed from the past R&D and patent applications history using a 15 per cent depreciation rate.

The method of estimation is ordinary least squares with robust standard errors reported. In estimation, the slopes and the full set of time dummies δ_t are allowed to vary across the type of firm, whether incumbent or entrant, the time period (1980-84, or 1985-89), and the industry category (in three groups, electrical, chemical, and other).

3.3 Comparing Incumbents and Entrants

The results of these estimations are shown in Tables 4 (for all industries) and 5 (the patent coefficient for the industry and time period breakdown). Several things emerge from these tables: first, except for entrants in the later period, having a higher patent productivity from R&D is not associated with an increase in market value. R&D is highly valued among entrants, and also among established firms in the first period, but patent productivity contributes an insignificant or negative amount to market value.

Second, entrants are valued at a substantial premium over incumbent firms, controlling for their tangible and intangible knowledge assets (almost twice as much in the first period and 30 per cent more in the second). This is what we would expect, since these entrants are a selected group, those who have succeeded in doing an IPO and being listed on NASDAQ or the New York Stock Exchange.

Third, looking at Table 5, which focuses on the value of patent productivity across industry grouping, we see a significant difference between the two periods. In the first, patent productivity is valued negatively or not at all by the market, whether the firm is an incumbent or an entrant. In the second period, after the changes in the patent environment have taken place, patent productivity remains negative or insignificant for the value of the incumbent firms, whereas it is now significant and positive for firms in the electrical and other industries. In all three industries, the coefficient is significantly larger for entrants than for incumbents.

4 Conclusions

A preliminary interpretation of these results is the following: in established firms, accumulating patents for defensive reasons has little impact on market value because the past history of R&D spending is already a good indicator of the firm's technology position. On the other hand, above average accumulation could be slightly negative for value if it indicates the present of threatened suits for infringement.

On the other hand, for new entrants, especially in industries like electronics where patents were previously unimportant, ownership of patents may have become an important signal of viability, especially because these firms have a median intangible to tangible asset ratio of above one half. That is, as the venture capitalists argue when considering funding these firms earlier in the life cycle process, patents are essential to provide a claim on the most important asset of the firm, its knowledge capital. In the market value equation, this translates into a premium for high patent productivity, especially post-1984.

Figure 1
USPTO Utility Patents 1965-2002

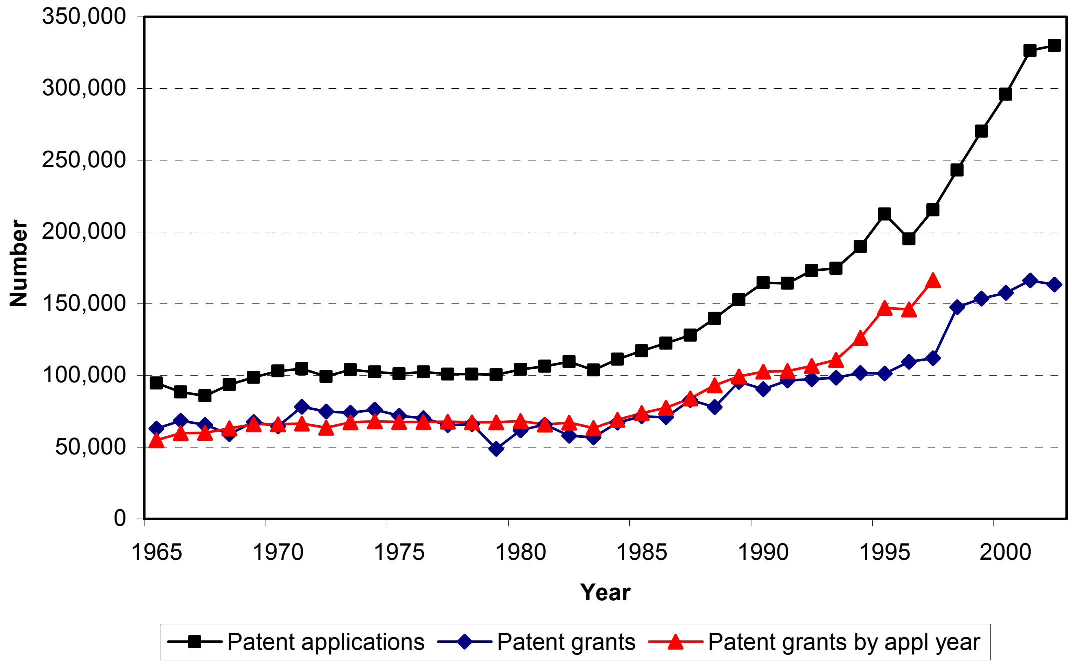

Figure 2
Growth of Aggregate US Patent Grants And Applications
1966-1998 (5-year moving average)

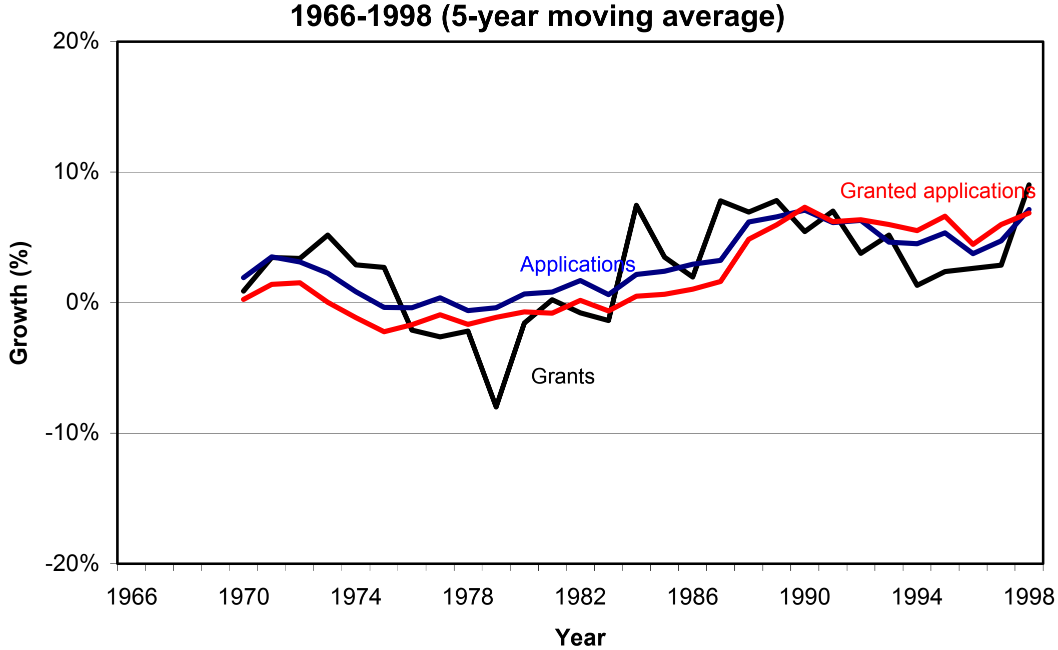

Figure 3
Accounting for U.S. Patent Application Growth by Region of Inventor

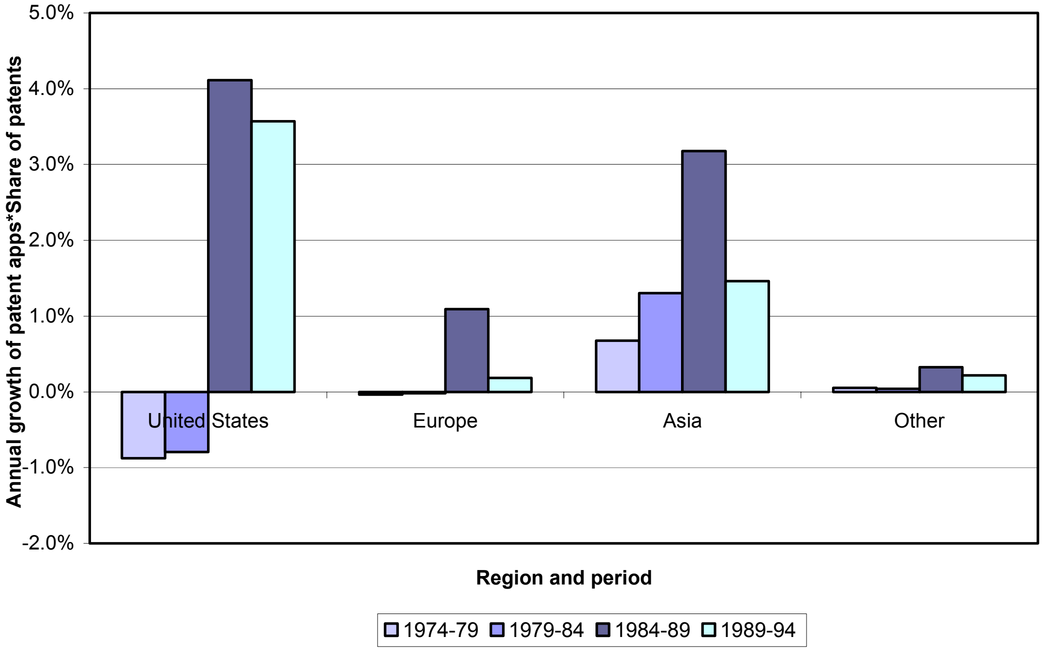

Figure 4
Accounting for U.S. Inventor Patent Application Growth
Broad Technology Class

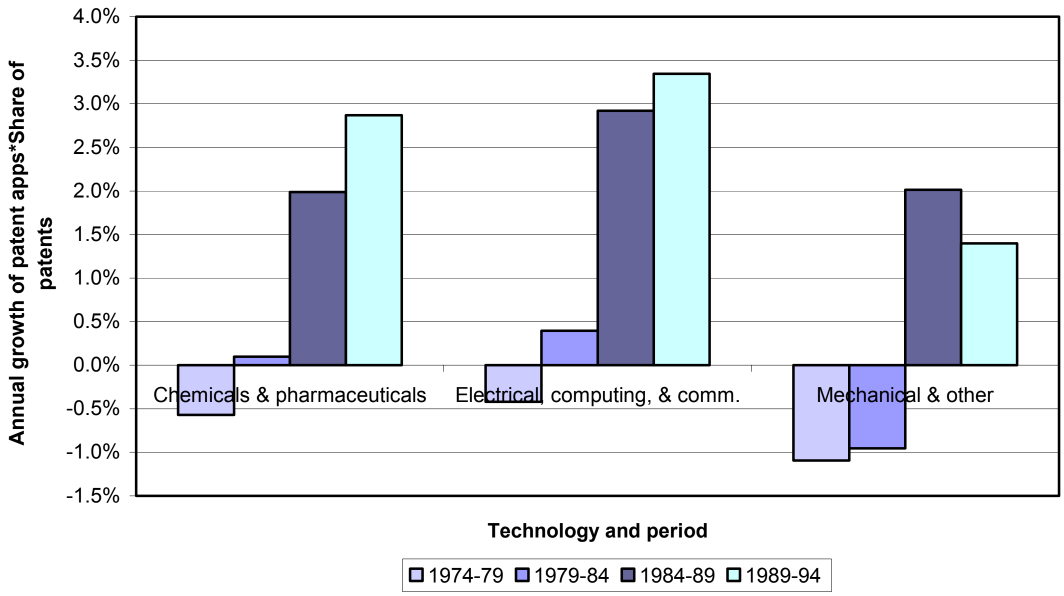

Figure 5
Accounting for U.S. Inventor Patent Application Growth
Compustat Firms - Broad Industry Class

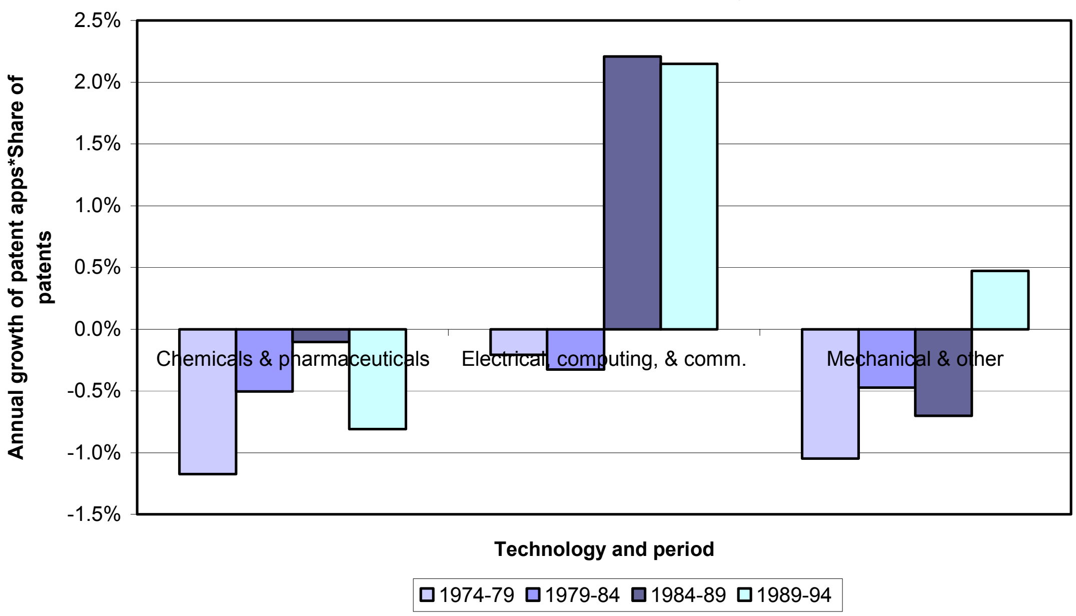

Table 0
Major Changes to the U.S. Patent System

Year	Event or case	Result
1980	Diamond v Chakrabarty	patentability of artificially engineered genetic organisms
1980	Bayh-Dole legislation	increase in university patenting
1981	Diamond v Diehr	patentability of software
1982	legislation	Creation of CAFC; patent validity more likely to be upheld
1985/6	TI sues Japanese semiconductor firms	
1986	Kodak-Polaroid	Decision on instant camera patent; $1B judgment; preliminary injunction
1994	TRIPS agreement	harmonization drive begins
1998	State Street and ATT vs. Excel	patentability of business methods

Table 1

Tests for Unit Roots and Structural Breaks in Patent Application Series

Total Patent Applications 1966-1997 (granted by Sept. 2002)

	Series			
Statistic	**Patent applications**	**Log of patent applications**	**Change in patent applications**	**Change in logs of pat applications**
Weighted symmetric unit root test	0.50	-0.16	-5.37	-5.30
p-value	*1.0000*	*0.9980*	*0.0000*	*0.0000*
T-test on break between 1983 and 1984			7146 (1734)	.065 (.014)
p-value			*0.0000*	*0.0000*
Andrews (1993) test for unknown structural break (T=32)	95.9	137.0	20.0	21.4
p-value	*0.0001*	*0.0001*	*0.0004*	*0.0002*
Break year chosen by Andrews test	1989	1988	1993	1984

Table 2A
Tests for Structural Breaks by Region

Statistic	USA	Europe	Asia & Japan	Other Developed	Other
Total patents	1,564,292	555,808	486,523	74,974	6,701
T-test on break between 1983 and 1984	.081 (.016)	.032 (.019)	-.018 (.031)	.055 (.022)	.085 (.038)
p-value	*0.000*	*0.108*	*0.573*	*0.019*	*0.033*
Andrews (1993) test for structural break at unknown point (T=31)	26.49	4.01	17.61	6.13	5.93
p-value	*0.0001*	*>.10*	*0.0010*	*>.10*	*>.10*
Year test is at max	1984	1993	1981	1984	1990

Table 2B
Tests for Structural Breaks by Technology Class

Statistic	Chemical	Drugs & medicine	Computers & comm.	Electrical	Mechanical	Other
Total patents						
T-test on break between 1983 and 1984	.041 (.021)	.031 (.040)	.087 (.023)	.080 (.017)	.056 (.013)	.055 (.012)
p-value	*0.063*	*0.441*	*0.001*	*0.000*	*0.000*	*0.000*
Andrews (1993) test for structural break at unknown point (T=31)	3.74	1.06	16.9	22.4	17.81	23.45
p-value	*>.10*	*>.10*	*0.0020*	*0.0001*	*0.0010*	*0.0001*
Year test is at max	1984	1976	1985	1984	1984	1984

Table 3
Accounting for the Growth of U.S. Patent Applications
By Region of Inventor

	1974-79				1979-84				1984-1989			
Region	Pat apps beg period	Growth	Share	Growth *share	Pat apps beg period	Growth	Share	Growth *share	Pat apps beg period	Growth	Share	Growth *share
United States	42701	-1.4%	62.8%	-0.9%	39723	-1.3%	58.9%	-0.8%	37055	7.7%	53.6%	4.1%
Europe	16677	-0.2%	24.5%	0.0%	16550	-0.1%	24.6%	0.0%	16483	4.6%	23.8%	1.1%
Asia	6761	6.8%	9.9%	0.7%	9065	9.7%	13.4%	1.3%	13458	16.3%	19.5%	3.2%
Other	1890	1.8%	2.8%	0.1%	2063	1.3%	3.1%	0.0%	2192	10.2%	3.2%	0.3%
Total	68029	-0.2%	100.0%	-0.2%	67401	0.5%	100.0%	0.5%	69188	8.7%	100.0%	8.7%
By Broad Technology Category (US Inventors Only)												
Chemicals & pharmaceuticals	11,163	-1.8%	31.7%	-0.6%	10158	0.3%	32.2%	0.1%	10312	5.9%	33.5%	2.0%
Electrical, computing, & comm.	9,175	-1.6%	26.1%	-0.4%	8437	1.5%	26.8%	0.4%	9062	9.9%	29.4%	2.9%
Mechanical & other	14,867	-2.6%	42.2%	-1.1%	12943	-2.3%	41.0%	-1.0%	11437	5.4%	37.1%	2.0%
Total	35205	-2.1%	100.0%	-2.1%	31538	-0.5%	100.0%	-0.5%	30811	6.9%	100.0%	6.9%
By Broad Industry Category (US Compustat Firms)												
Chemicals & pharmaceuticals	6,401	-3.1%	38.4%	-1.2%	5424	-1.4%	37.1%	-0.5%	5054	-0.3%	37.0%	-0.1%
Electrical, computing, & comm.	5,907	-0.6%	35.5%	-0.2%	5734	-0.8%	39.2%	-0.3%	5495	5.5%	40.2%	2.2%
Mechanical & other	4,346	-4.0%	26.1%	-1.0%	3473	-2.0%	23.7%	-0.5%	3127	-3.1%	22.9%	-0.7%
Total	16654	-2.4%	100.0%	-2.4%	14631	-1.3%	100.0%	-1.3%	13676	1.4%	100.0%	1.4%

Table 4
Comparing Incumbents with Entrants
All Industries

	1980-1984				1985-1989			
	Incumbents 1979		Entrants 1980-84		Incumbents 1984		Entrants 1985-89	
Variable	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
R&D Stock/ Assets	0.8818	0.0629	0.5940	0.0814	0.0268	0.0350	0.4660	0.0407
Patent Stock/ R&D Stock	-0.0264	0.0094	-0.0230	0.0296	-0.1207	0.0147	0.0578	0.0527
D(no R&D)	-0.0777	0.0263	-0.4105	0.0915	-0.2572	0.0279	-0.2064	0.0795
Entrant dummy in first year			0.9447	0.1529			0.3055	0.1172
Firms	1001		218		1011		195	
Observations	4385		653		4139		540	

All equations include a full set of time dummies for each group.
Standard error estimates are robust to heteroskedasticity.

Table 5
Coefficient of Patent stock/R&D stock

Industry	All	Electrical	Chemical	Other
1980-84				
Incumbents	-.026 (.009)**	-.062 (.020)**	-.040 (.014)**	.005 (.012)
Entrants	-.023 (.030)	-.002 (.055)	-.261 (.063)**	.021 (.035)
Difference	.003 (.027)	.060 (.058)	-.221 (.064)**	.016 (.037)
1985-89				
Incumbents	-.121 (.015)**	-.146 (.029)**	-.186 (.054)**	-.050 (.018)**
Entrants	.058(.053)	.192 (.051)**	.011 (.014)	.276 (.101)**
Difference	.179 (.055)**	.338 (.059)**	.197 (.055)**	.326 (.102)**

**Significant at the 5% level

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