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What is behind the recent surge in patenting? [1]

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Abstract

We investigate the cause of an unprecedented surge of US patenting over the past decade. Conventional wisdom points to the establishment of the Court of Appeals of the Federal Circuit by Congress in 1982. We examine whether this institutional change, which has benefited patent holders, explains the burst in US patenting. Using both international and domestic data on patent applications and awards, we conclude that the evidence is not favorable to the conventional view. Instead, it appears that the jump in patenting reflects an increase in US innovation spurred by changes in the management of research.

JEL classification: 030; 032; 034

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1. Introduction

This paper is motivated by the unprecedented recent jump in patenting in the United States. Applications for US patents by US inventors have risen more since 1985 (in either absolute or percentage terms) than in any other decade this century (Fig. 1).[2] From the turn of the century until the mid 1980s, applications fluctuated within a band of between 40,000 and 80,000 per year, but in 1995, US inventors applied for over 120,000 patents on their inventions. The number of patents actually *issued* by the US patent office to US inventors has risen a bit

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[1] The paper is a condensed version of 'Stronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?' Carnegie-Rochester Conference Series on Public Policy, Vol. 48, 1998, 247–304.

[2] The data sources (going from earliest to most recent) are the US Department of Commerce, Bureau of the Census (1976), Federico (1964), WIPO (annual issues), and tabulations of the US Patent and Trademark Office. From 1900–1950, we proxy for US domestic patent applications by multiplying (in each year) total US applications by the fraction of total US grants that were granted to domestic inventors (the fraction of patents granted to domestic inventors varied between about 85 and 90 percent over the years 1900–1950).

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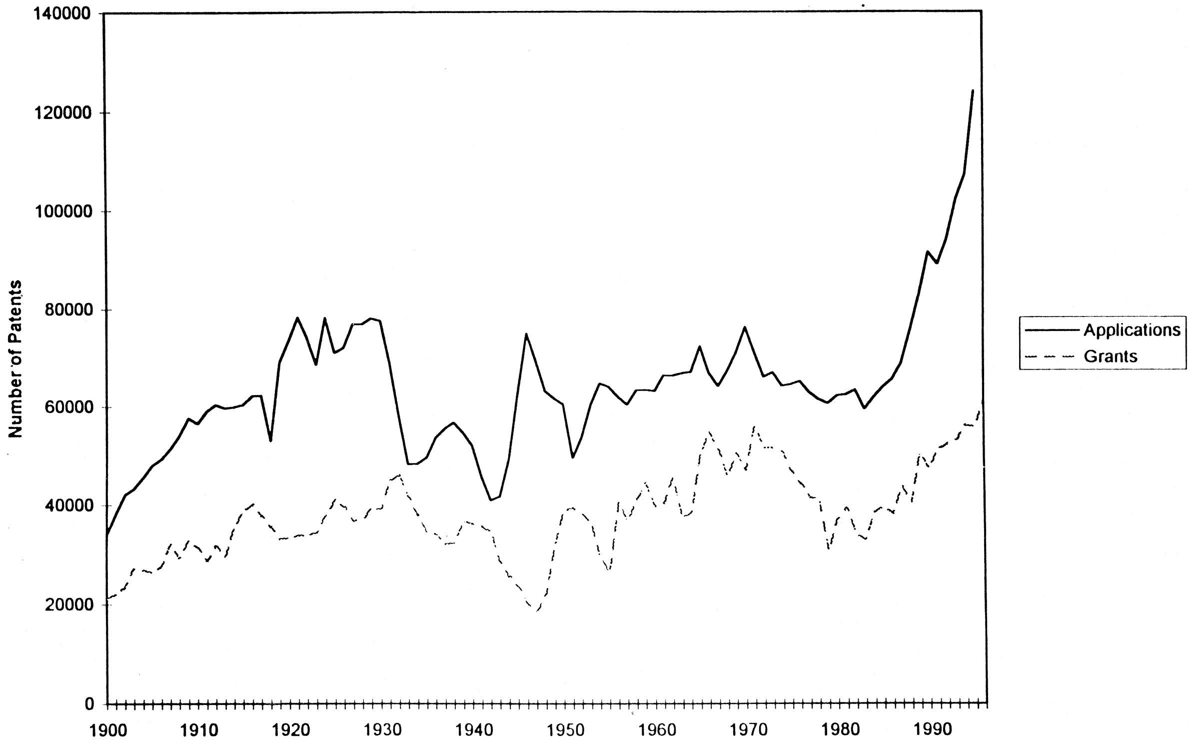

Fig. 1. Patents by US investors.

less dramatically (Fig. 1), but this is to be expected given the time required to examine applications. The patents issued series reached an all-time high in 1996. [3]

The central hypothesis we test is that the jump in patenting reflects an increase in the propensity to patent inventions, driven by changes in the legal environment for patent holders. The upturn in patenting in the United States followed the most dramatic shift in domestic patent policy over the past 150 years. In 1982, a specialized appellate court to hear patent cases, the Court of Appeals of the Federal Circuit, was established by Congress. (Previously, the cases had been heard by quite inconsistent appeals courts in each district.) The new court's decisions have been widely regarded as being 'pro-patent' (Merges, 1992), i.e., they have broadened the rights of patentees. We label this view the *friendly court hypothesis* of why patenting has surged.

We contrast this hypothesis with two alternative explanations. The first of these is that the jump in patenting reflects a widening set of technological opportunities. In particular, the past two decades have seen an explosion of new firm formation and innovation in the high technology sector, particularly in the biotechnology, information technology, and software industries. The specialized financial intermediaries that are critical in funding such firms, venture capital organizations, have grown by more than 10-fold (in inflation-adjusted dollars) during this period. The jump in patenting may indicate a burgeoning technological revolution, as hypothesized by Greenwood and Yorukoglu (1997). Alternatively,

[3] Applications in the United States by US inventors dropped a bit to about 107,000 in 1996, down from the extremely high level of nearly 124,000 in 1995. A change in 1995 of the rules governing the length of the patent term probably led some inventors to rush to apply for patents in 1995 before the change instead of waiting until 1996. Beginning on June 8, 1995, the United States switched exclusively to a new system of a 20-year patent term starting from the date of patent application. Prior to June 8, inventors had the option of choosing between the new system and the old system of a 17-year term from date of grant.

applications of information technology to the discovery process itself may have substantially increased the productivity of R&D (Arora and Gambardella, 1994; Brody, 1995). A third possibility is that changes in the management of R&D facilities in the past decade—in particular, a shift to more applied activities—has raised the yield of patentable discoveries, as articulated by Rosenbloom and Spencer (1996). We lump together this set of ideas as the *fertile technology hypothesis* of why patenting has surged.

A second alternative view is a variant of the friendly court hypothesis. It is suggested by the voluminous political economy literature on interactions between firms and regulators. This body of work documents how entrenched incumbents can use regulatory or administrative changes to enhance their position relative to entrants. In particular, if the shift to stronger patent protection in the United States was not an exogenous event, but a response to the lobbying of a certain set of parties, we would expect these groups to gain more. One implication is that the entities that benefited the most were domestic firms: numerous accounts, such as by Takenaka (1994), suggest that many overseas firms believe the US patent system has become less friendly to foreign patentees. A second implication is that the strengthening of patent protection may have benefited only a *subset* of domestic firms. In particular, the firms most active in pushing for these reforms appear to have been larger firms with established patent departments (Adelman, 1987; Lerner, 1995). Were these firms able to alter the patent system in their favor, they might respond by patenting more aggressively. (Evidence for this hypothesis is presented by Lerner (1995) and Lanjouw and Lerner (1996).) We term this suggestion the *regulatory capture hypothesis*.

Why do we care why US patenting has jumped? First, if the increase in patenting is due to legal changes, then, it raises important issues for public policy. A long series of economic models (reviewed, for instance, by Tirole, 1989) have argued that the design of patents involves careful trade-offs. Economists have urged policy-makers to balance the ex ante incentives to pursue research that patent protection offers with the monopolies created by patent protection. If patent protection has been substantially broadened—as suggested by the friendly court hypothesis—a careful analysis of the resulting impact on social welfare is in order. Second, patents have long been used as an indicator of innovative activity and technological change in both micro- and macro-economic studies, as reviewed by Griliches (1990). Recently, Kortum (1997) has argued that the relatively constancy of US domestic patenting prior to the late 1980s is consistent with the behavior of other indicators of technological change, in particular, constant productivity growth and rising research effort. From that perspective, a jump in research productivity—as suggested by the fertile technology hypothesis—signals accelerating technological change and a favorable outlook for US productivity growth as more inventions are adopted.

The goal of this paper is to see if the data are more consistent with the friendly court hypothesis or to the two alternative views. We examine evidence from several sources: aggregate statistics on international patent applications, detailed statistics by technology class and assignee of patents granted in the United States, and aggregate measures of research effort. The international patent data allow us to differentiate between the United States as a *destination* for patents and the United States as a *source* of patentable inventions. We can also decompose the rise in patenting by technology and patentee. Is the rise in patenting concentrated in a few dynamic technologies or experienced widely across most technologies? Is the increase confined to the firms which have been most active in patenting in the past, or is it also occurring among less established patentees?

The friendly court hypothesis suggests that the upturn in patenting should be driven by changes in the United States as a destination. Both US and foreign firms should find patenting in the United States increasingly attractive, both absolutely and relative to patenting elsewhere. Furthermore, the increase in patenting by firms should be relatively uniform, both across technologies and patentees.

The alternative views suggest other patterns. The fertile technology hypothesis suggests that the increase in patenting by US inventors is due to a surge in discovery and innovation. In this case, either the United States should increase as a source of patenting (if discoveries are being disproportionately made here) or there should be a general increase in patenting activity worldwide (if the technological revolution is more widespread). If the surge in innovation is driven by breakthroughs in specific technologies, then, we should see an uneven increase in patenting across technologies. If the increase in technological activity is largely due to an improvement in the technology or the management of the discovery process, however, this pattern may not appear. In neither case would the United States appear to be a more popular destination. The regulatory capture view suggests that we should see the changes in US patent law disproportionately taken advantage of by domestic patentees (i.e., we should see a surge in US patents, but only by domestic patentees) and particularly by firms which were already major patentees.

By a process of elimination, we tentatively conclude that the evidence from patent data is most consistent with a variant of the fertile technology view. Contrary to the suggestion of the friendly court hypothesis, the United States has not increased as a destination for patents. Rather, the increase in patent activity here seems to be a consequence of a worldwide increase, along with a recent improvement in the relative performance of US inventors. While this pattern might also be consistent with the regulatory capture view, the pattern of patenting by firm size is not. In particular, the increase in patenting appears to be uniformly distributed, with the relative share of patents by new and small patentees actually increasing more dramatically than in the past. Less consistent with the first variant of the fertile technology hypothesis is the evidence by technology class: we see a more general increase in patenting, rather than a surge in particular activities. Eliminating biotechnology and software patents has little impact on the overall increase in patenting. This suggests that much of the increase may be due to improvements in the management or automation of the innovation process itself.

We subject our tentative conclusion—that a broad increase in research productivity underlies the increase in patenting—to a final test based on the recent behavior of US research effort. Using a model of the determinants of research and patenting, we show that a permanent rise in research productivity should lead to a transitory increase in research intensity (e.g., the fraction of income spent on research). The data are not fully consistent with this prediction, as research intensity has leveled in the 1990s, while patenting has continued to rise. We therefore temper our conclusion by acknowledging that changes in the management of research—involving a reallocation of efforts to more applied activities and a consequent increase in patentable discoveries—may have had costs as well as benefits. The net impact on research productivity was potentially modest.

The plan of the paper is as follows. In Section 2, we review the institutional changes that have taken place in the patent system of the United States. We then analyze in Section 3 the aggregate patterns of international patenting. Section 4 examines differences in patenting across different technologies, while Section 5 presents various supplemental analyses using the patent data and considers the puzzle raised by the recent behavior of research activity. Section 6 draws conclusions.

2. Changes in US patent policy

In recent years, the United States has been among the most aggressive nations in reforming its patent system.[4] This section will review the US changes; the lesser-reaching changes in Europe and Japan are reviewed by Kortum and Lerner (1998).

The dramatic changes in US patent policy, perhaps, should not be surprising, since the United States has had in many respects the most idiosyncratic patent system. Wegner has gone so far as to state that ''there are really but two different systems among the major patent systems of the world, an 'international' system that is found in Europe and Japan, and an 'American' system that until 1989 was found also in Canada but today is uniquely American'' (1993, p. 1). The United States system itself has been characterized by several swings in the effectiveness of patent protection.

The key features of the US system were determined through a series of judicial decisions during the first three decades of the 1800s and the Patent Law of 1836. These include: (i) the awarding of the patent to the first to discover an innovation, rather

[4] This section is based on Adelman (1987), Harmon (1991), Merges (1992), Wegner (1993), Lerner (1995), and Tripp and Stokley (1995).

than the first to file for an invention; (ii) the principle that patent applications would not be published until they were awarded; and (iii) the broad interpretation of patent scope through the doctrine of equivalents. This legal structure underwent few alterations for a century.

In the late 1930s, federal agencies and President Roosevelt's Supreme Court appointees began taking an increasingly hostile view of patents, deeming them as anti-competitive and inconsistent with a free market. The Department of Justice created a special section in the Antitrust Division which was concerned exclusively with anti-patent litigation; the Federal Trade Commission similarly scrutinized transactions involving intellectual property.

A number of calls for reform, such as that of a 1966 presidential commission, went largely unheeded. Meanwhile, the resources going into examining patent applications had been (in inflation-adjusted dollars) steadily reduced. By 1980, the US Patent and Trademark Office (USPTO) was an understaffed, overworked agency in a state of disarray. The USPTO's limited resources prevented it from effectively reviewing more than a small subset of previously-issued patents before judging whether or not a new one should be granted. Consequently, patent awards were often made on the basis of insufficient evidence.

The patent enforcement situation was no better. There was a lengthy backlog of patent cases in many courts. Furthermore, the circuit courts responsible for hearing the cases had geographical rather than subject-matter jurisdiction. This led to 'forum shopping,' defined by the US Commission on Revision of the Federal Court Appellate System (1975) as ''mad and undignified races... between a patentee who wishes to sue for infringement in one circuit believed to be benign toward patents, and a user who wants to obtain a declaration of invalidity or non-infringement in one believed to be hostile to them'' (1975, p. 15). The inconsistencies across regions provided incentives to litigate around patents and circumvent procedures of one region in favor of those of another.

Beginning in 1980, the US Congress, with the encouragement of Presidents Carter and Reagan, sought to address the problems of the patent system. More patent legislation was enacted between 1980 and 1982 than had been passed in the previous two decades. This flurry of legislation included: (i) a measure designed to cut the time and cost involved in patent suits by allowing the PTO to re-examine patents that were challenged, because they were based on findings that had already been patented or published; (ii) a law that extended patent duration on certain types of products (primarily pharmaceuticals and chemicals) by up to seven years, to compensate firms for the loss of marketing time resulting from the complex regulatory clearance process; and (iii) a law designed to enable non-profit research groups to patent and commercialize technologies developed with federal funds (the Bayh-Dole Act).

The fourth measure, and perhaps the most important, was the Federal Court Improvements Act, enacted in March 1982. This act created the Court of Appeals of the Federal Circuit (CAFC). Two existing courts—the appellate division of the Court of Claims and the Court of Customs and Patent Appeals (which heard appeals of cases from these agencies)—were merged into a single twelve-judge court. It was assigned jurisdiction over appeals of patent cases in all the federal circuits.

The stated purpose of the CAFC was to consolidate and reconcile patent decisions in an efficient manner. But as Merges points out: ''While the CAFC was ostensibly formed strictly to unify patent doctrine, it was no doubt hoped by some (and expected by others) that the new court would make subtle alterations in the doctrinal fabric, with an eye to enhancing the patent system. To judge by results, that is exactly what happened'' (1992, p. 9). This claim is borne out by the statistical patterns. [5] Circuit courts upheld 62% of district court decisions holding patents to be valid and infringed, while it reversed 12% of the decisions holding patents to be invalid or not infringed between 1953 and 1978 (Koenig, 1980). From 1982 to 1990, the CAFC affirmed 90% of district court decisions holding patents to be valid and infringed, and reversed 28% of the judgments of invalidity and non-infringement (Harmon, 1991).

[5] Such comparisons can be misleading, since the mixture of cases may have been different: firms may have altered their licensing and litigation practices over the four decades. Nonetheless, the magnitude and speed of the shift suggests that it cannot be attributed entirely to the changes in the mix of cases.

This increase in patent protection was accomplished largely through the doctrine of equivalents. The doctrine of equivalents was the idea that inventors should be prevented not only from similar products or processes, but also those outside the literal scope of the claim if they do ''substantially the same thing in substantially the same way to achieve substantially the same result'' [*Machine v. Murphy*, 97 US 120, 125 (1877)]. The CAFC resorted extensively to the doctrine of equivalents, greatly enhancing average patent scope. In addition, analysts have noted that the court displayed a much greater willingness to sustain large damage awards, to grant preliminary injunctive relief to patentees during the resolution of disputes, and to make a variety of other rulings that have been construed as 'pro-patent.'

3. Evidence from patenting across countries

According to the friendly court hypothesis, the changes in US patent policy in the early 1980s should have increased the desirability of patent protection in the United States. This implication can be tested using international patent data. Consider the United States and France, for example. We expect US applications by French inventors and US applications by US inventors to both be stimulated by a strengthening of patent protection in the United States. There is little reason, however, to expect such a strengthening to alter either French applications by French inventors or French applications by US inventors.

The fertile technology hypothesis implies quite a different pattern. A burst of technological opportunities in the United States should lead to a surge in US and French applications by US inventors. If the improvement in technological opportunities is a global phenomenon, then, we also expect an increase in US and French applications by French inventors. We begin our analysis of the international patent data with an informal look at patent applications among the major industrialized countries.

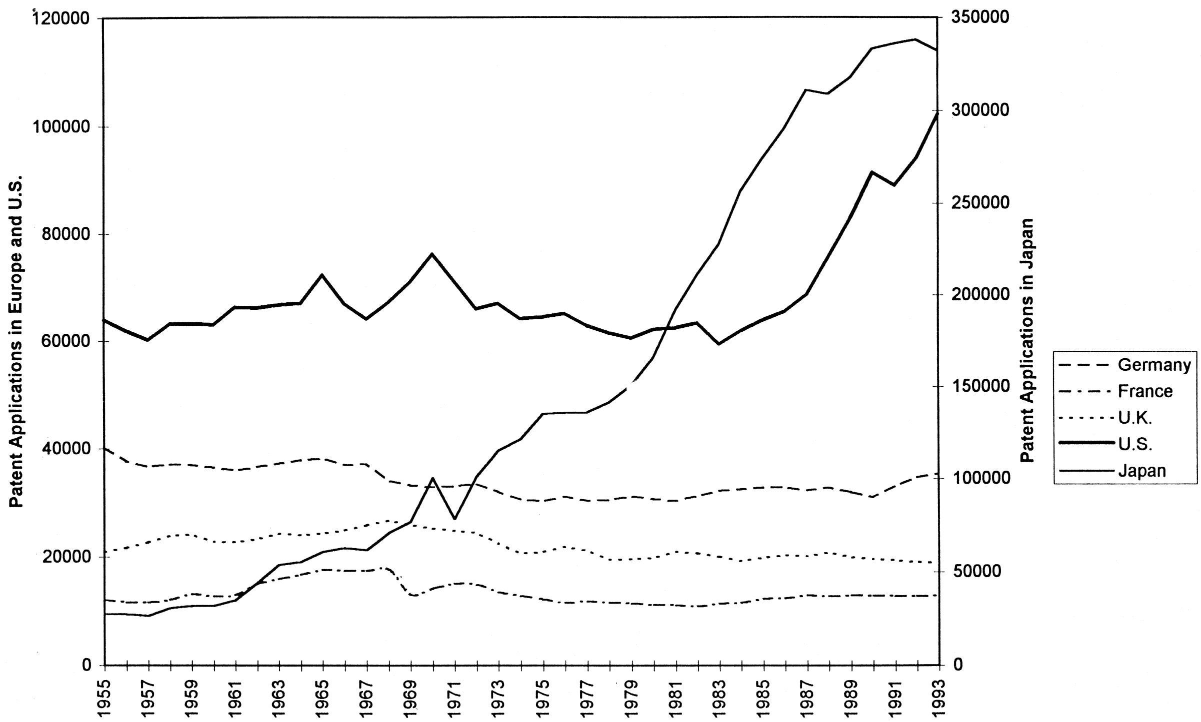

Fig. 2. Domestic patent applications.

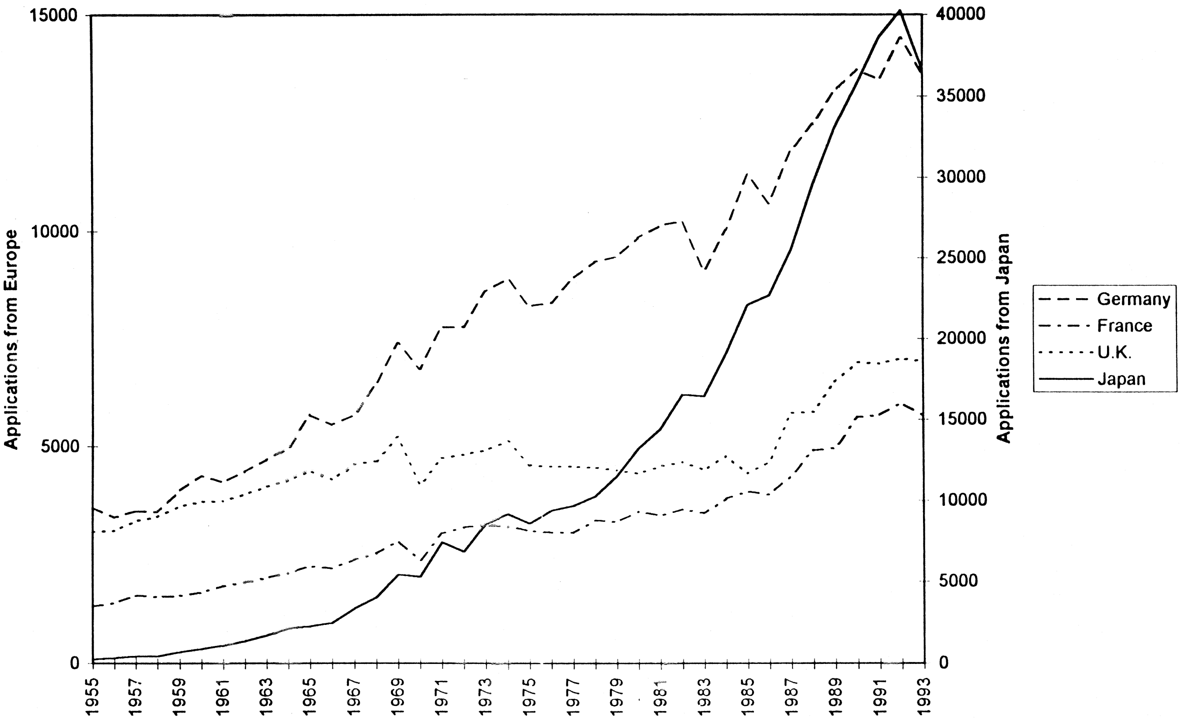

Fig. 3. Foreign patent applications in the United States.

3.1. A glimpse at the data

Fig. 2 compares patent applications by domestic inventors in the United States, Japan, France, Germany, and the United Kingdom. [6] None of the other countries display a pattern like the one in the United States, with its sharp upswing beginning in the mid 1980s. Domestic applications in the three European countries have been essentially flat. By contrast, Japan has witnessed a steep upward trend (reflecting its transition from a technological follower in the 1950s to a technological leader in the 1990s) that is only now beginning to subside. [7] Fig. 2 demonstrates that the recent jump in patenting is something peculiar to the United States.

Fig. 3 plots patent applications in the United States by inventors from different countries. Patenting by foreigners in the United States has been rising, but it is a sustained rise over the entire forty-year period. Overall, the pattern of foreign patenting in the United States shows little similarity to the jump in US domestic applications.

Fig. 4 looks at applications for foreign patent protection by US inventors. Applications in the four

[6] These five countries account for a vast majority of the world's patents. The primary source of data for Figs. 1–4 and the econometric analysis which follows is 'Industrial Property Statistics,' WIPO (annual issues). For patent applications in France, Germany, and the United Kingdom for the years 1978–1993, we use data from OECD (1995). The OECD has eliminated some double counting of patent applications implicit in the WIPO data for European countries. This double counting arose because of the many alternative routes that European patent applications could take following the establishment in 1978 of the European Patent. Prior to 1960, the data are from Federico (1964). Different patent offices report data on the source of patent applications in slightly different ways: (i) the United States reports the residence of the first-named inventor; (ii) France, Germany, and the United Kingdom report the residence of the applicant; and (iii) Japan reports the nationality of the applicant. The US approach (i) captures essentially what we mean when we refer to the source of an invention.

[7] Note the different scale for Japan's domestic applications. Okada (1992) finds that Japanese domestic patents contain only 20% as many claims of invention on average as do foreign patents in Japan.

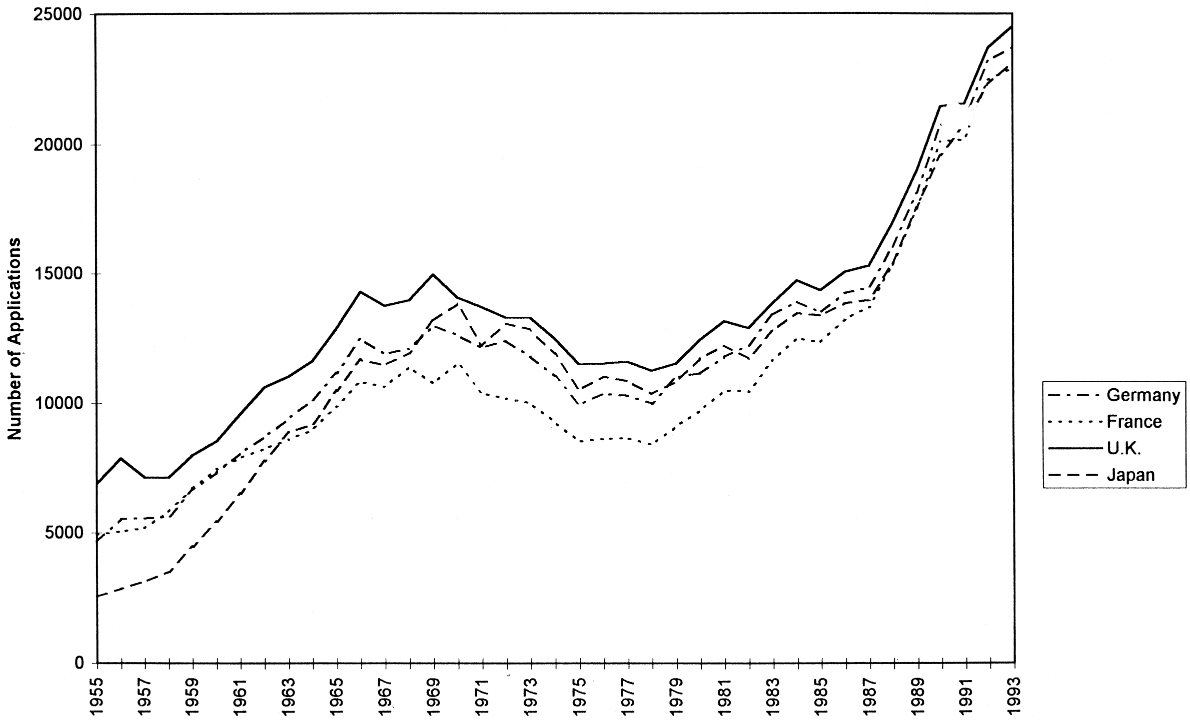

Fig. 4. US patenting abroad.

different foreign countries move together, rising through the 1960s, falling through the 1970s, and rising at increasing rate since then. Although foreign applications represent a fraction—only about 25%—of US domestic applications, they display a similar rapid run-up in the late 1980s and early 1990s. Comparing Figs. 3 and 4, US patenting abroad matches the recent behavior of US domestic applications much more closely than does foreign patenting in the United States.

Our descriptive analysis of the international patent data suggests that the recent jump in patenting is largely a US phenomenon. The analysis points to the United States' increased potency as source of patentable inventions, not its increased desirability as a destination for patents. To investigate further, we apply a more systematic decomposition derived from a simple model of the decision to seek patent protection.

3.2. A statistical decomposition

We decompose the number of applications by inventors from country i (the source country) for patent protection in country n (the destination country) at date t, P_{nit}, into three fundamental factors: (i) *invention*, α_{it}, the rate at which country i generates patentable inventions at date t; (ii) *diffusion*, ϵ_{ni}, the fraction of inventions from country i that find a use in country n; and (iii) the *propensity to patent*, f_{nt}, the fraction of inventions that are worth trying to patent in country n at date t out of those that have a use there. The implied patenting equation is

$$P_{nit} = f_{nt}\epsilon_{ni}\alpha_{it}. \quad (1)$$

Using Eq. (1) does not require taking a stand on the determinants of inventiveness, although presumably, α_{it} depends on resources devoted to research prior to date t in the source country i. A set of factors for each source country and year combination encompasses essentially any model of the invention process. Similarly, the parameters ϵ_{ni} encompass any time-invariant pattern of diffusion among countries. The restriction that the propensity-to-patent terms f_{nt} depend only on the destination country is

Table 1
Model Fit

Set of dummy variables	Number of parameters	Sum of squares
Destination-country	4	16.9
Source-country	5	302.2
Year	38	247.0
Domestic–foreign	1	707.1
Domestic–foreign by destination-country	4	126.1
Source-country by destination-country	15	23.8
Year by destination-country	152	10.9
Year by source-country	190	170.6
Domestic–foreign by year	38	25.5
Total explained		1630.2
Unexplained		15.7

more problematic, but greatly simplifies the analysis. [8]

We estimate a modified version of Eq. (1) to see which set of effects accounts for the big jump in US domestic applications. The friendly court hypothesis predicts that destination-country by year factors (f_{nt}) should account for the increase, while the fertile technology hypothesis predicts it should be the source-country by year factors (α_{it}) that matters (or perhaps simply an overall time factor).

Before proceeding, we extend Eq. (1) to capture the fact that foreign patenting has been rising relative to domestic patenting. For example, note that the number of US applications for French patents was only about 10% as large as the number of US applications for US patents in 1955, but had risen to almost 25% by 1993 (Figs. 2 and 4). There are two potential explanations for this increased globalization of patenting. One is that international technology diffusion has become more important over time. The other is that reforms of the patenting process have made it less costly to obtain patent protection abroad. Without attempting to determine their underlying source, we simply add globalization factors, $g_{h(ni)t}$, to Eq. (1), where $h(ni)$ is a subscript for the home country: it equals 1 if $n = i$ and equals zero otherwise.

Including the globalization factors, taking logs, and adding an i.i.d. error u, [9] our patent equation becomes

$$\ln P_{nit} = \ln f_{nt} + \ln \epsilon_{ni} + \ln \alpha_{it} + \ln g_{h(ni)t} + u_{nit}. \quad (2)$$

The dependent variable is the natural log of patent applications, the parameters are the various factors (in logs), and the explanatory variables are various sets of dummy variables: destination-country and year-specific, destination and source-country-specific, source-country and year-specific, and home-country and time-specific (subject to appropriate normalizations). We estimate Eq. (2) using data

[8] The restriction that the value of patent protection does not depend on the source of the invention is a simple working hypothesis. It is in the spirit of the 1880 Paris Convention (which stated that foreign inventors should be treated the same as domestic inventors). There are, however, several arguments for why the restriction will not hold exactly. First, the value of patent protection is likely to be lower in foreign countries either because imitation of non-patented inventions is slower or because courts are biased against foreign patent holders in infringement cases (see Eaton and Kortum, 1996). Second, translation fees and the expense of dealing with patent agents abroad raises the cost of obtaining foreign protection relative to the cost of obtaining patent protection locally. Third, the cost structure and timing for obtaining foreign patent protection is more complicated than what we have modeled. There are some fixed costs of applying for a patent that are unrelated to the number of countries in which protection is sought. Lundberg and Woessner (1993) document these fixed costs, as well as other fees that are paid to extend the option of obtaining foreign protection beyond the usual one-year window. Putnam (1997) develops a dynamic model of the decision to seek foreign patent protection that incorporates these timing considerations.

[9] Eaton et al. (1998) estimate a similar model assuming a Poisson error and where the t subscript ranges over technologies (patent classes) rather than years. Here, because the cell counts are rather large, the Poisson assumption is easily rejected.

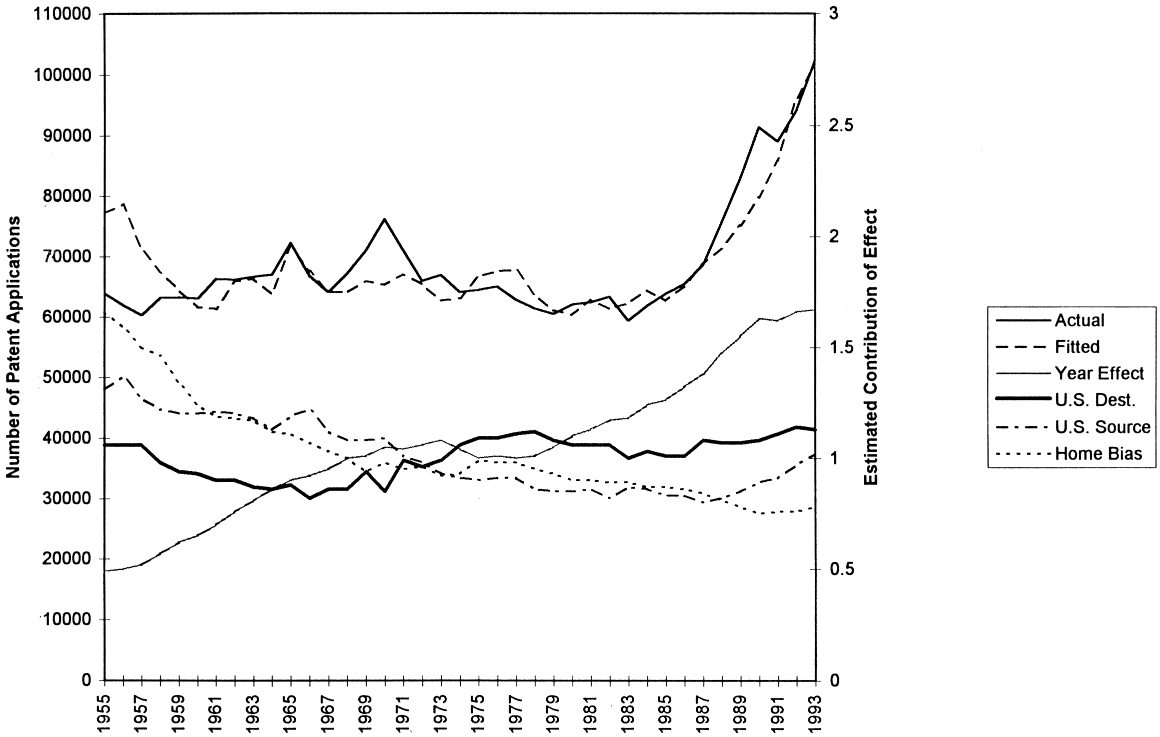

Fig. 5. Decomposition of US domestic patenting.

on patent applications for each year from 1955 to 1993 in Germany, France, the United Kingdom, Japan, and the United States by inventors from each of these five countries or from elsewhere. This gives us 1170 observations (39 years by five destinations by six sources). [10]

The basic fit of Eq. (2) and the explanatory power of each set of dummy variables is presented in Table 1. Notice that one-dimensional factors (e.g., source-country) are entered separately, so that two-dimensional factors (e.g., year by source-country) only capture deviations from the one-dimensional factors. The model picks up almost all of the variation in the dependent variable, ln P_{nit}. It is easy to reject any restriction of the model, corresponding to dropping one of the sets of dummy variables. Nonetheless, it is interesting to identify which sets of factors have substantial explanatory power. Among the two-dimensional sets of dummy variables, the year by source-country dummies account for much of the variation in the data. The year by destination-country dummies do not, i.e., there is little variation over time in the international patent data that is common across inventors (from different countries) seeking patents in a given destination. This finding appears to be evidence against the friendly court hypothesis.

To see clearly the factors underlying the increase in US domestic patent applications, we reparameterize the model along the lines of Eq. (1). [11] We define nine sets of multiplicative effects: (i) destination-country effects D, (ii) source country effects S, (iii) year effects T, (iv) home effects (domestic–foreign) H, (v) destination-country by source-country effects DS, (vi) destination-country by year effects DT, (vii) source-country by year effects ST, (viii) destination-country by domestic-foreign effects DH, and (ix)

[10] The estimation is performed in SAS using PROC GLM.

[11] The parameterization that we choose follows that used in the analysis of categorical data by log–linear models (Bishop et al., 1975; Christensen, 1990).

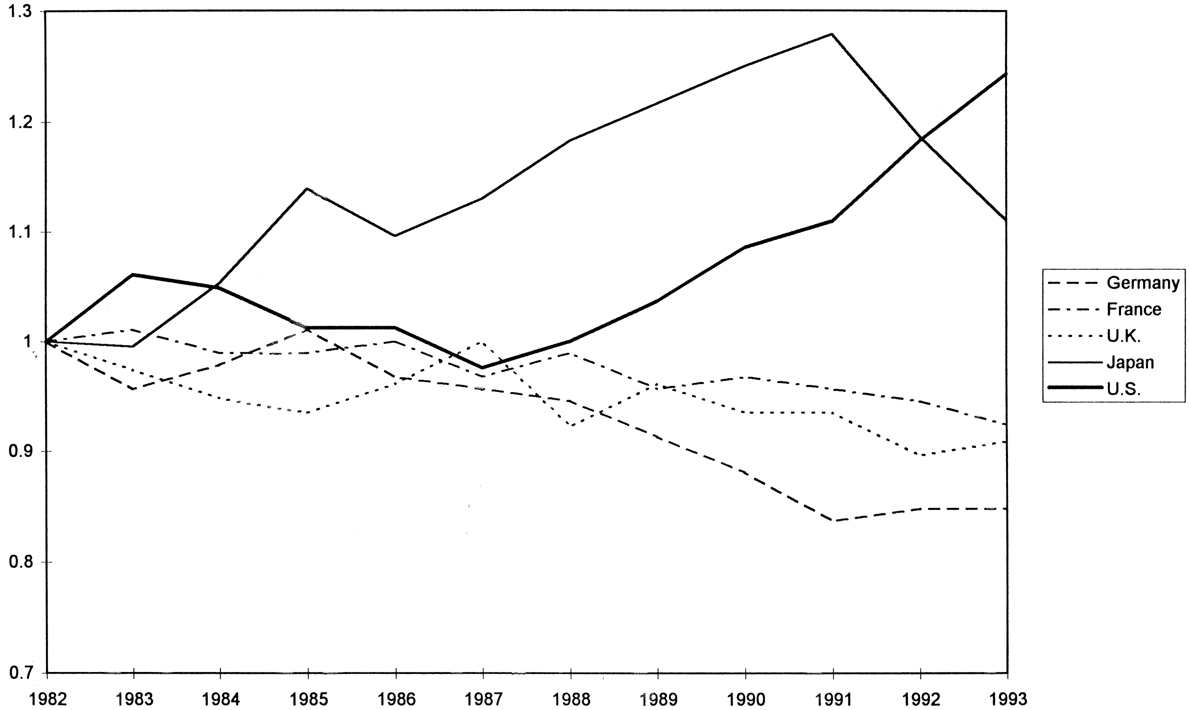

Fig. 6. Estimated source-country effects (normalized to 1982 = 1).

year by domestic–foreign effects TH. In terms of these effects, the exponentiated value of the fitted values $\hat{P}$ from estimating Eq. (2) exactly satisfy

$$\hat{P}_{nit} = AD_n S_i T_t H_{h(ni)} (\mathrm{DS})_{ni} (\mathrm{DT})_{nt} (\mathrm{ST})_{it} (\mathrm{DH})_{nh(ni)} \times (\mathrm{TH})_{th(ni)}, \qquad (3)$$

for $n = 1,\dots,5$; $i = 1,\dots,6$; $t = 1,\dots,39$; $h(ni) = 1$ if $n = i$ ($h = 2$, otherwise); and where A is an overall constant term. The parameters are now multiplicative effects and should be interpreted relative to a standard of 1. [12] To get the parameters in Eq. (3), we apply an iterative proportional fitting algorithm (Bishop et al., 1975) to the exponentiated fitted values, $\hat{P}$, obtained by estimating Eq. (2).

The fit of the model and the estimated effects describing the behavior of US domestic patent applications are illustrated in Fig. 5. The top two lines of Fig. 5 show that the model explains the basic contour of US domestic patent applications and, particularly, the upturn after 1985. The estimated parameters provide a simple interpretation of what happened. In the early years, the aggregate time effects gave an upward tilt to patenting, but were offset by a decline in the bias toward patenting domestically and a smaller decline in the relative importance of the United States as a source of innovations. On net, US domestic applications were roughly constant. Beginning in the late 1970s, the aggregate time effect began to rise more steeply and the bias toward patenting domestically flattened. Furthermore, the United States' relative position as a source stabilized in the 1980s. Together, these trends led to a rise in US domestic applications in the mid-1980s. By the

[12] To achieve identification, the parameters are subject to numerous restrictions. For example:

$$\sum_{n=1}^{5} \ln D_n = 0,$$

$$\sum_{n=1}^{5} \ln(\mathrm{DS})_{ni} = 0 \quad i = 1,\dots,6, \quad \sum_{i=1}^{6} \ln(\mathrm{DS})_{ni} = 0 \quad n = 1,\dots 5, \qquad (4)$$

and

$\ln(\mathrm{DS})_{nn} = 0 \quad n = 1,\dots,5.$

end of the 1980s, the US relative position as a source began to move up, leading to a more rapid increase in US domestic applications. The US position as a destination for patenting displays little variation over time.

Since our focus is on the rapid upturn in US patenting over the past decade, we enlarge that part of the picture. Fig. 6 illustrates the patterns of source-country effects over the past 12 years (each country's source effect is scaled to unity in 1982). Over the past five years, the United States has become a more potent source of patentable inventions. The increase is large, about 25% relative to the average and about 40% relative to Germany. During the 1980s (and in the previous years not shown), the rise in Japan was more dramatic, but recently, Japan has slipped. The three European countries, particularly Germany, decline throughout.

Fig. 7 takes a closer look at the destination-country effects. To facilitate comparison with Fig. 6, the vertical scale is the same. The most striking feature of Fig. 7 is the lack of variation in the destination-country effects relative to the source-country effects in Fig. 6.

If our model is correct, then, the empirical analysis suggests that the friendly court hypothesis is not the explanation for the rise in US patenting. This finding, although surprising, is corroborated by survey evidence that the importance of patents has not increased relative to other means of appropriating the returns to invention (Cohen et al. (1997)). In light of this evidence, a more plausible explanation for the rise in patenting is that either technological opportunities or the process of doing research has improved, particularly in the United States as of late. To distinguish between these two variants of the fertile technology hypothesis, we turn to an analysis of patenting across different technology classes.

4. Evidence from patenting across technologies

By their very nature, opportunities arise in specific areas of technology. If the arrival of new tech-

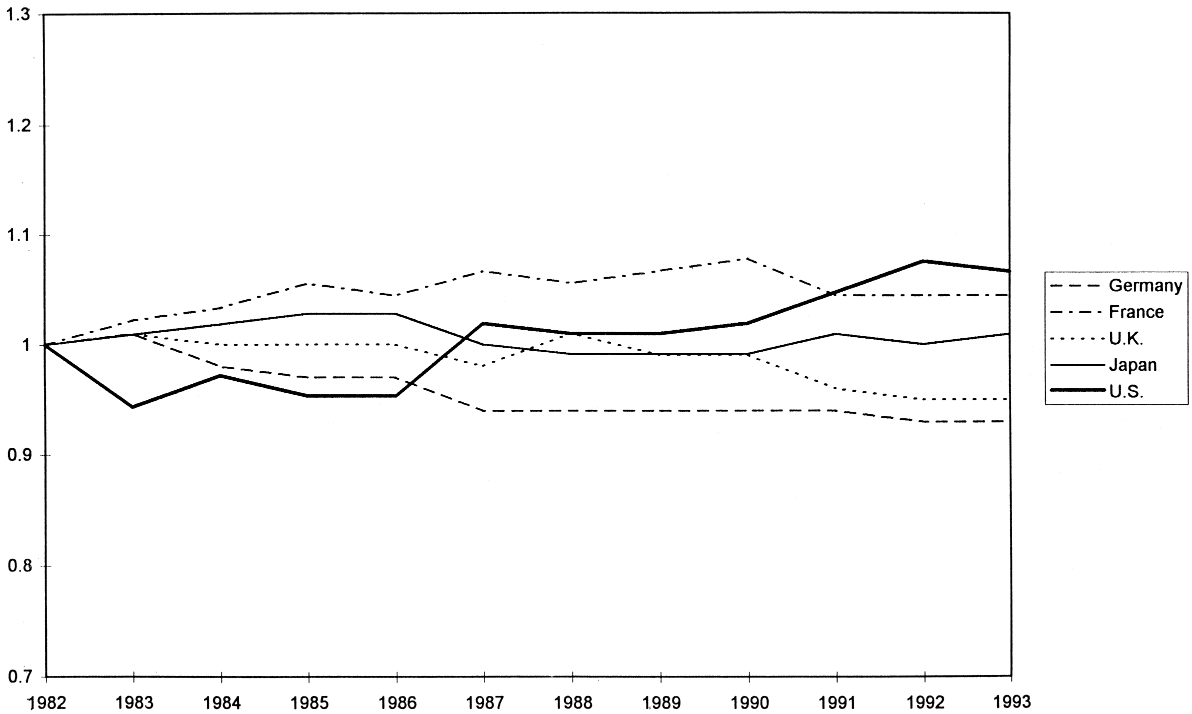

Fig. 7. Estimated destination-country effects (normalized to 1982 = 1).

nological opportunities is driving the surge in US patenting, then, we expect the increase in patenting to be highly concentrated in technology space. The majority of technologies should experience little increase in patenting, while a few experience a dramatic rise. Other explanations of the increase in patenting do not predict that it should be technologically concentrated. The friendly court hypothesis suggests that the propensity to patent should be as sensitive to institutional changes in the US patent system in one technology as in any other. Alternative variants of the fertile technology hypothesis—such as an improvement in the management of research or the technology of doing research—also predict an impact on patenting across a wide spectrum of technologies.

To check the prediction of a variant of the fertile technology hypothesis – a technologically concentrated increase in patenting – we exploit the technological dimension of the data generated by patent classes. During the patent examination process, patents are assigned to detailed technologies as defined by patent classes. These assignments are performed with care to facilitate future searches of the prior art in a specific area of technology.

We begin by examining how patenting has grown in different patent classes. This allows us to determine whether the increase in patenting is broadly distributed across technologies or confined to a only a few. Next, we examine two particular technologies. Biotechnology and software have been areas with extensive new firm formation, rapid technological change, and extensive use of patent protection. We attempt to single out technology classes in these areas to see if they are major contributors to the overall rise in patenting.

Since patents are assigned to technologies during the examination process, we must use patents actually issued (rather than patent applications) for this analysis. To make the data more comparable to the applications data, and to avoid anomalies in the mean lag between application and grant, we continue

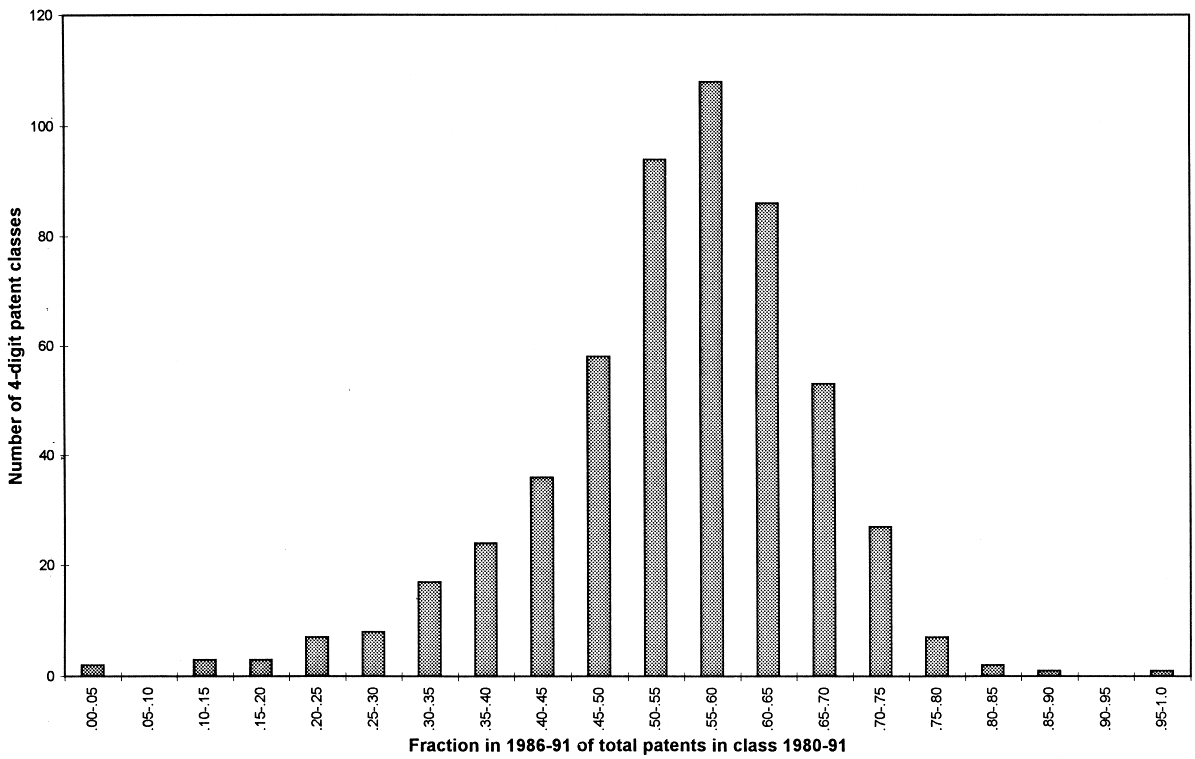

Fig. 8. The distribution of patenting growth across technologies.

to date the patents according to the application year. Since our goal is to understand the rise in US patenting by US inventors, we limit the analysis to that subset of the data.[13] The classes of technology are defined by the International Patent Classification System (WIPO, 1984). We use the 'four-digit' level of the IPC System, containing on the order of a thousand classes.[14]

4.1. All technologies

We examine the (application) years 1980–1991 and divide that twelve-year period into two six-year periods: 1980–1985 and 1986–1991. During the first six years, patenting was slowly declining, while over the second six years, patenting began to increase rapidly. To get at what was happening within technology classes, we calculate for each one, the fraction of its patents that came in the second six-year period. We then plot the distribution of this ratio.

There are two reasons for this fraction to vary by technology class: the first is underlying structural differences and the second is randomness in outcomes. The structural factors are that different technology classes may have experienced different increases in technological opportunities. The technologies that experienced a relative improvement in opportunities should, in general, have large fractions of patents appearing in the second period. But, even if there are no structural differences across the technology classes, randomness in the inventive process will generate variation across technology classes in the fraction of patents appearing in the second period. If there are structural differences, randomness will add to the underlying structural variation. In order to highlight the structural variation, we select only the 537 technology classes with at least 50 patents over the entire twelve-year period. Over 99% of patents are assigned to these larger patent classes.

In Fig. 8, we plot the density of the fraction of patents in the second period across all technology classes with over 50 patents (the unweighted mean of this distribution is 0.54). The striking feature of Fig. 8 is that there are few technology classes in the upper tail. In particular, there are only 11 technology classes in which over 75% of the patents came in the second period. The left tail of the distribution is somewhat fatter. In particular, 158 patent classes experienced a decline in patenting. But, the basic pattern is of a widespread increase in patenting (experienced by over 70% of the technology classes).

There are not very many technology classes that appear to be rapidly improving areas for discovery. We display in Table 2 the five classes containing over 300 patents in which over 75% of the patents appear in the second period.

The fastest growing technologies are generally related to biotechnology and software: B05D shows up in the patenting of both biotech and software firms, B32B shows up in the patenting of biotech firms, and both H04J and H04K show up in the patenting of software firms. Nonetheless, these technologies alone do not explain much of the increase in patenting over the period. We now turn to a more systematic attempt to identify technology classes associated with biotech and software.

4.2. Biotechnology and software

Since we believe that biotech and software are the most technologically dynamic fields over this period, we perform an analysis focusing on their impact. In particular, we look at patent classes in which software and biotech firms do most of their patenting. Our procedure for generating time series of patents for software and for biotech is described by Kortum and Lerner (1998). While we do not seek to ascertain all the classes in which these firms patent, we do

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[13] In the patent data with technology assignments, we do not actually know the residence of the first-named inventor (as we did for patent applications in the United States). We do know the country in which patent protection was first sought, i.e., the 'priority' country. We limit the sample to US priority patents in order to focus primarily on patenting by US inventors. Inventors from the United States generally patent first in the United States, hence, their patents will have US priority. Some inventors from other countries may also seek US priority, since the United States is a big market in which patent protection is particularly desirable. Based on a crude calculation from figures in WIPO (1996), about 10% of the patents in our sample are likely to be from non-US inventors. There is no reason to believe that the inclusion of these foreign patents will bias our conclusions.

[14] The technology assignments are available at an even more detailed level. For this analysis, we decided that the more detailed classifications would generate problems due to changes in their definitions over time.

Table 2
Fast-growing patent classes

IPC	Definition	Patents (2nd period) (1986–1991)	Patents (both periods) (1980–1991)	Fraction in 2nd period
B05D	Processes for applying liquids to surfaces	2042	2541	0.80
B21F	Working or processing of wire	256	341	0.75
B32B	Layered products	5029	6071	0.83
H04J	Multiplex communication	997	1296	0.77
H04K	Secret communication	250	315	0.79

identify the key patent classes in which either biotech or software firms play a major role.

Fig. 9 shows that patenting in both biotech and software has risen considerably since the late 1970s, both absolutely and as a share of the total patenting in the United States. But, it also makes clear that the overall increase in US patenting is not simply a biotech- and software-driven phenomenon. Total patenting rose by almost 70% from 1983 to 1991 (based on the data of patents granted by year of application). With biotech and software patents excluded, the increase in overall patenting is reduced by only five percentage points.

5. Other evidence from patent statistics

5.1. Patenting by experienced and inexperienced patentees

The next analysis that we undertake is to examine the shift in patenting by the type of firm. The 'regulatory capture' hypothesis suggests that the in-

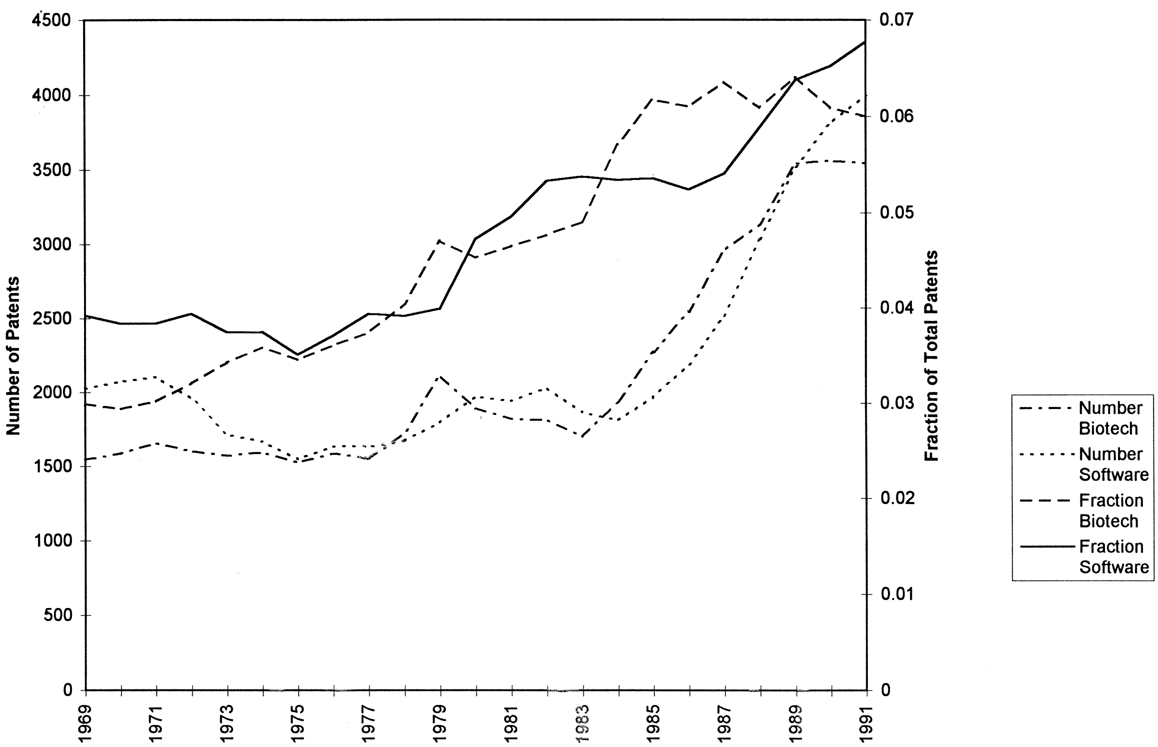

Fig. 9. Patenting in biotech and software.

crease in patenting activity, far from being an exogenous event, may have been the product of lobbying by the firms who thought that it would make their strategic position better. Consistent with other studies (Bartel and Thomas, 1987; Thomas, 1990), established US firms—with substantial patent practices and well-organized lobbying efforts—may have pushed for these changes to strengthen their competitive position viz-a-viz smaller firms.

In this case, the increase in patenting activity may be concentrated in these firms, as they sought to exploit the advantages that strong patent position gave them. Particularly striking, practitioner accounts suggest, has been the growth of litigation and threats of litigation between large and small firms. Examples may include the dispute between Cetus and New England Biolabs regarding taq DNA polymerase and that between Texas Instruments and LSI Logic regarding semiconductor technology (these and other examples are discussed by Chu, 1992 and Rutter, 1993). Several observers argue that the proliferation of such threats may be leading to transfers of financial resources from some of the youngest and most innovative firms to more established, better capitalized concerns. Even if the target firm feels that it does not infringe, it may choose to settle rather than fight. It either may be unable to raise the capital to finance a protracted court battle, or else may believe that the publicity associated with the litigation will depress the valuation of its equity.

This hypothesis suggests that the greatest growth in patenting will occur in established firms who are already active in patenting. To examine this implication of the regulatory capture hypothesis, we examine the composition of patentees in recent years. In particular, we rank the firms into five cohorts on the basis of their patenting activity between 1979 and 1984. We then examine how many patents have been awarded to firms in the various cohorts in subsequent years. We compare these patterns to those of earlier years, using patents awarded between 1969 and 1974. The results suggest that, contrary to the regulatory capture hypothesis, the role of newer and less frequent patentees has actually increased.

To undertake this analysis, we use a data-set compiled by researchers at Case-Western University

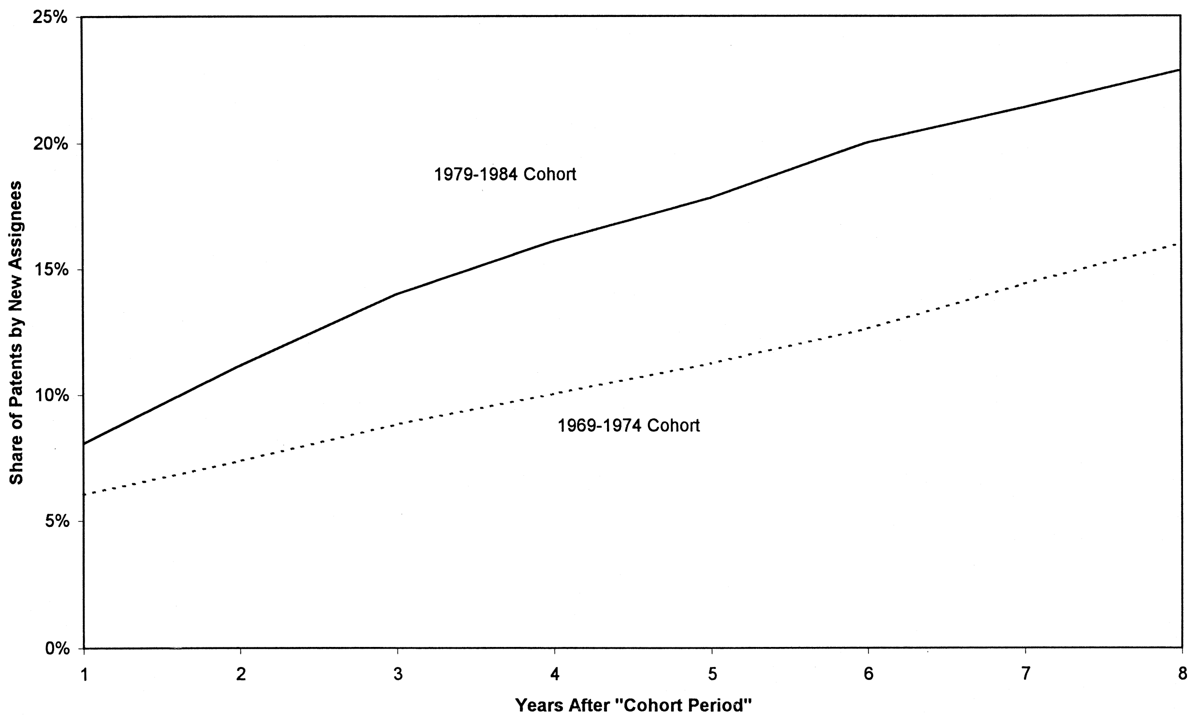

Fig. 10. Patenting by inexperienced patentees.

and the National Bureau of Economic Research. This database links the first assignee of each US patent award through 1993 to a CUSIP or other identifier. Assignees that are subsidiaries or joint ventures are linked up to their parent firms.

We first examine the extent to which new firms that have not patented during the previous six-year period (1969 through 1974 and 1979 through 1984) are active patentees. For each subsequent year, we calculate the ratio of the number of patents awarded to entities (i.e., not including awards to individuals) that had not previously patented to the total number of patent awards in that year. In Fig. 10, we arrange the observations by year after these six-year periods (which we dub the 'cohort periods'). For instance, 'Year 1' is 1975 for the 1969–1974 analysis and 1985 for the 1979–1984 analysis. In each case, new firms are more active patentees in the later period. For instance, entities that had not patented in 1969 through 1974 represented 9% of the patents in 1978; while those that had not patented in 1979 through 1985 represented 14% of the patents in 1988. The late 1980s and early 1990s, rather than seeing a decrease in activity by new patentees, actually had increasing representation.

One possible explanation for this pattern is that it reflects the extent of merger activity and new firm formation during this period. Because the 1980s saw considerably more new firm formation and mergers than the 1970s, it may be that the increasing share of patents issued to new patentees simply reflects the greater economic and innovative activities by these entities. New firms may have been less likely to undertake patenting activities, but there were simply many more of them.

To at least partially address this possibility, we look at the evolution of patenting by firms that had already filed for patents in the two cohort periods. This analysis will not be influenced by shifts in merger activity or new firm formation. We divide the patentees in the two six-year periods into five quartiles, which range from the most to the least active firms in patenting. The quartiles are constructed, so that each has the same number of patents: thus, the

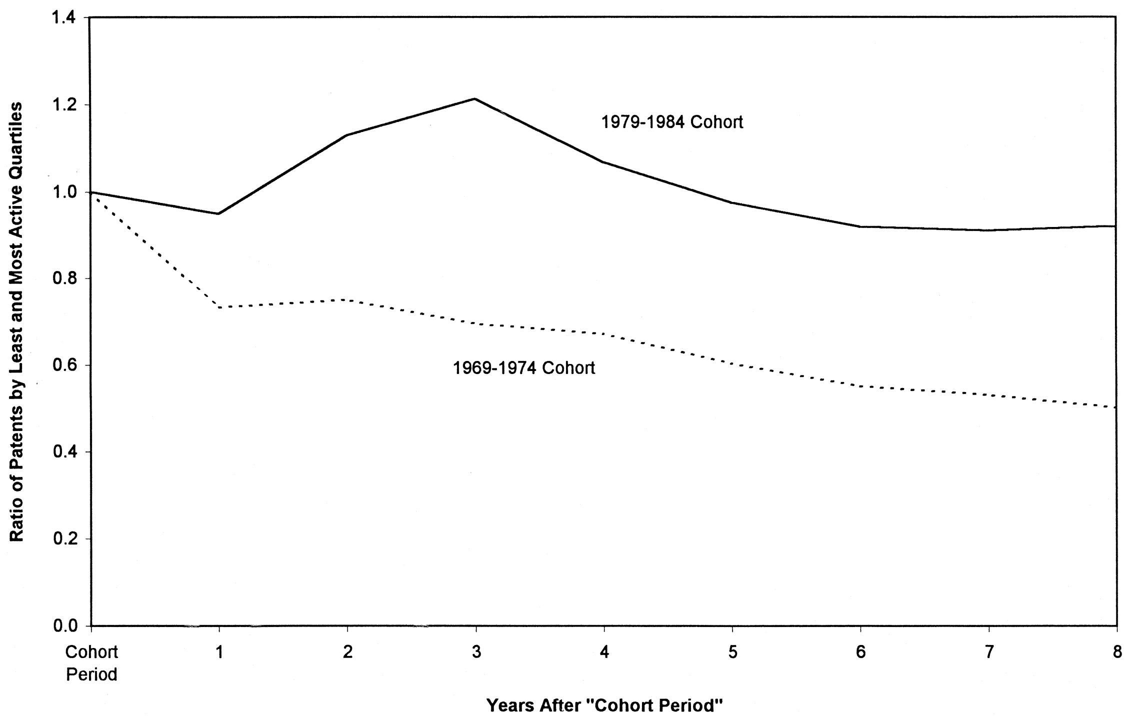

Fig. 11. Patenting by least experienced relative to most experienced.

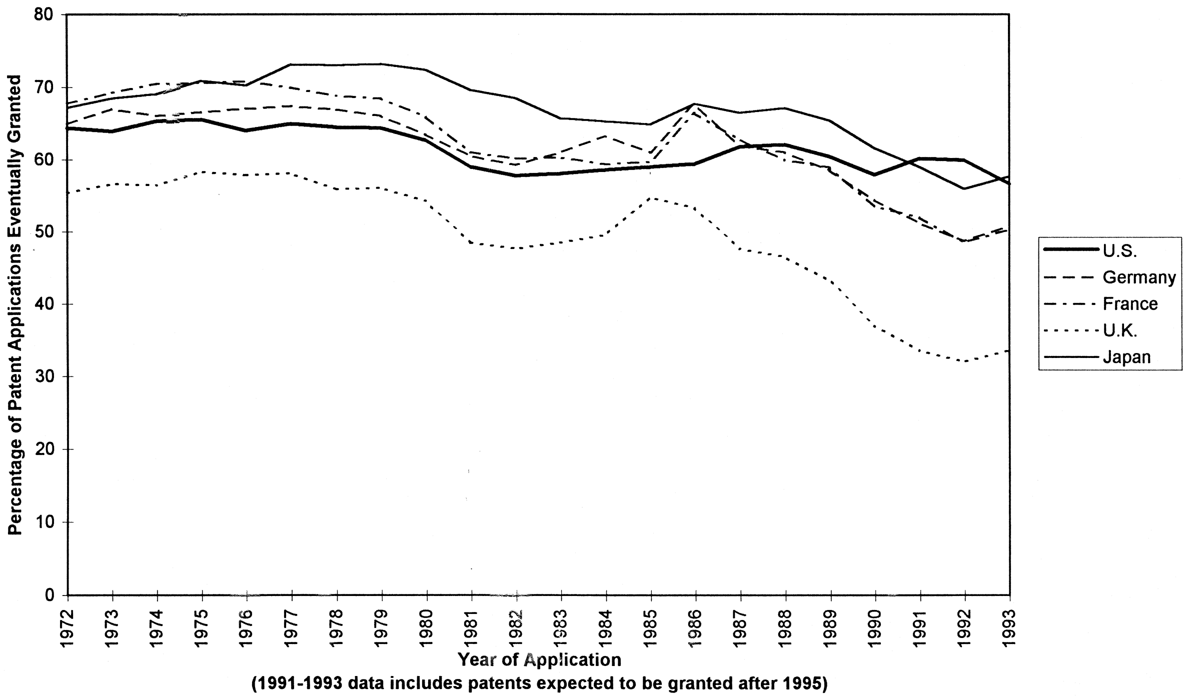

Fig. 12. US patents grants relative to applications by residence of inventor.

quartile containing the most active patentees has many fewer firms than the quartile with the least active patentees.

We then look in Fig. 11 at the ratio of patents in subsequent years by the quartile least active in patenting to the quartile most active. While the relative share of patenting by the least active quartile declined sharply in the 1970s, in the 1980s, the share actually increased. Thus, once again we see that the most marginal patentees appear not to have diminished during this period, but actually increased. This is inconsistent with the view that the large firms pushed for and exploited the change in the patent system to benefit themselves.

5.2. Comparing applications and grants

If the value of patenting is rising in the United States (as is predicted by the *friendly court hypothesis*), researchers will have an increasing incentive to seek patent protection even on inventions which are of questionable patentability. Under this scenario, such questionable applications will increase as a fraction of all patent applications. Assuming that patent examiners reject a constant fraction of questionable applications, we would expect to see a declining share of patent applications eventually granted. [15]

To examine this issue, we use US Patent and Trademark Office statistics on patents granted by country of inventor (dated by year of application) and on patent applications by country of inventor. We calculate, in each year from 1972 to 1993, the percentage of applications that had been granted by the end of 1995. [16]

Fig. 12 plots the percentage of patent applications eventually granted, by year of application and country of inventor. The 'application yield' has been

[15] We thank Mehmet Yorukoglu for suggesting that we examine this issue.

[16] For application years 1991, 1992, and 1993 we adjust upward the number of patents granted to account for an estimate of how many are likely to be granted after 1995. This estimate, which reflects the lag in the examination process, was based the application years of patents granted in 1993, reported in WIPO (1993).

fairly constant since the early 1980's for US inventors. There is little evidence of a decline since 1982, as predicted by the friendly court hypothesis. On the other hand, there has been a recent decline in the yield for foreign inventors. Since the friendly court hypothesis predicts a declining yield on patent applications from all sources, we find this second fact somewhat puzzling.

5.3. Patent renewals

Another source of evidence is from data on patent renewals. Public Law 96-517 required all US patents issued from applications filed after December 1980 to pay renewal fees at four, eight and twelve years after the issue date. (Alternatively, the patent holders can let the awards expire prematurely.) Such fees have been in force for over forty years in many European countries (Pakes and Simpson, 1989). The changing patterns of patent renewals might be helpful in distinguishing between our hypotheses.

Statistics on renewal rates in the United States have recently been compiled and analyzed by Brown (1995). He finds that renewal rates have generally fallen in the 1990s. For instance, the percentage of US patents for which fourth year renewal fees were paid fell from 84% in 1991 to 79% in 1994. Of those eligible for an eighth year renewal, the fraction actually renewed fell from 74% in 1991 to 66% in 1994. Patents in the United States from other countries display a similar decline. [17]

Although the trends in patent renewals are unambiguous, the implications are not so clear-cut. It is unclear whether a strengthening in patent protection (such as the friendly court hypothesis suggests has occurred) will lead to an increase or a decrease in the renewal rate. As patents become more valuable due to strong enforcement, inventors will try to patent more marginal inventions, but they will also seek to renew patents on more marginal inventions.

The fertile technology hypothesis, on the other hand, predicts a decline in renewal rates as the faster flow of new inventions leads to a higher obsolescence rate, see Kortum and Lerner (1998). Thus, if anything, the evidence on declining renewal rates weakly favors the fertile technology hypothesis.

5.4. The R&D puzzle

In exploring what caused the unprecedented increase in US patenting—one indicator of research output—it is natural to ask what happened to research inputs. Our analysis of various dimensions of the patent data has led to a tentative conclusion that US patenting jumped due to improvements in the management or automation of the innovation process itself. We now subject that tentative conclusion to evidence on research effort.

As an analytical framework, we use a general equilibrium model, distilled from Kortum (1997). That model generates a baseline in which patenting is constant, while research effort and productivity grow at constant rates. The baseline captures the US trends in these three indicators of technological change prior to the mid-1980's. To reproduce the recent jump in patenting, along the lines suggested by the fertile technology hypothesis, we perturb the baseline by introducing a permanent positive shock to research productivity. The analysis of the model, performed by Kortum and Lerner (1998), makes a clear prediction: a permanent rise in research productivity leads to a transitory rise in patenting and generates a transitory period of higher research intensity (R&D/GDP).

Research intensity did rise rapidly, as expected, in the 1980s, but it has flattened in the 1990s even as patenting has continued to surge. Fig. 13 plots research intensity in France, Germany, Japan, the United Kingdom, and the United States. [18]

[17] The renewal rate began to decline after 1990, but the first year of decline is difficult to interpret because renewal fees rose by 70% effective in November 1990. The decline since 1991 is not likely due to changing renewal fees, since fees have been constant in real terms since 1990.

[18] The data on R&D expenditure (performed and financed by the business enterprises) are from OECD (1995) and Main Science and Technology Indicators (magnetic tape). The German data are for Unified Germany starting in 1991. Recent upward revisions to US R&D expenditures, as collected by the National Science Foundation, go some way toward resolving the R&D puzzle.

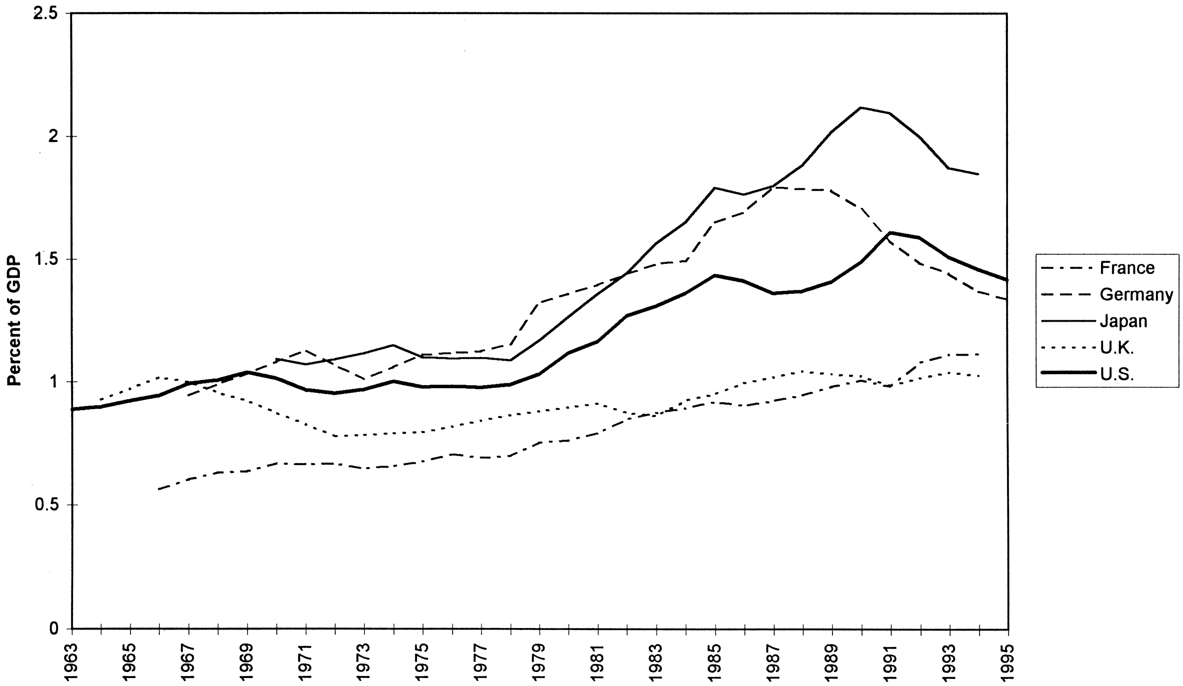

Fig. 13. R&D relative to GDP (financed and performed in business enterprises).

In the 1990s, research intensity has been either flat or declining, after having risen sharply in the 1980s. The United States is not an outlier in this respect: research intensity has declined less than in Germany, but more than in France and the United Kingdom. For all countries but the United States, the pattern in Fig. 13 is strikingly similar to the pattern of source-country effects in Fig. 6. In contrast, US R&D intensity has dipped even as the United States has become a more potent source of patents.

Research intensity in the United States began to increase about five years before patenting started to rise. Twelve years later, research intensity began to decline as patenting continued to rise. If a shock to research productivity has driven the increase in patenting, then, the behavior of research intensity in the past few years is anomalous. Alternatively, the behavior of research effort is evidence against the view that the continued rise in patenting is driven by a jump in research productivity.

What about the other variant of the fertile technology hypothesis, that the management of R&D has improved? As Rosenberg and Spencer note, ''Firms are restructuring, redirecting and resizing their research organizations as part of a corporate-wide emphasis on the timely and profitable commercialization of inventions combined with the rapid and continuing improvement of technologies in use'' (1964, p. 4). In the most natural formalization, however, there is no analytical distinction between an improvement in technological opportunities and an improvement in the management of research. In either case, we should see a rise in research spending.

6. Conclusion

We began with the puzzle of why patenting in the United States by US inventors has suddenly risen so much. Our initial conjecture, which we termed the friendly court hypothesis, was that the upswing resulted from changes in the legal environment for patents in the United States. We also considered two competing views, which we identified as the fertile technology and regulatory capture hypotheses. We explored several different dimensions of the patent data in search of evidence to either support or challenge the different hypotheses.

The key findings that emerge from our analysis are as follows.

- The recent surge in domestic patenting is particular to the United States.
- Foreign patenting in the United States has increased since 1985, but was also increasing prior to that.
- Patenting abroad by US inventors has risen roughly in parallel to US domestic patenting.
- Decomposing international patenting patterns show that the United States has not become a more attractive destination for patents.
- The recent increase in patenting was experienced broadly across the spectrum of different technologies.
- The growth of biotechnology and software patenting alone does not explain a large fraction of the overall increase.
- Compared to earlier periods, in the late 1980s, new and less established patentees are more aggressively exploiting the patent system.
- The fraction of domestic patent applications eventually granted by the US Patent and Trademark Office has declined very little.
- The fraction of eligible patents that are renewed at the US Patent and Trademark Office has declined recently.
- The intensity of research effort has not risen at the same time that patenting has surged.

We seek to determine which explanation is consistent with all these facts. We question the simple variant of the friendly court hypothesis, since it suggests that the United States would show up as a more attractive destination and that the percentage of patent applications granted would fall. We question the regulatory capture hypothesis, since the share of patenting by smaller firms has recently increased, rather than fallen. We question the view that technological opportunities have driven the jump in patenting, since it is not highly concentrated in particular technologies.

By a process of elimination, our analysis leads us to conclude that the increase in patenting has been driven by changes in the management of innovation, involving a shift to more applied activities. Looked at from the bright side, the jump in US patenting both at home and abroad seems to indicate a real burst of innovation. The one piece of evidence to temper this rosy picture is that research investment has flattened in the 1990s.

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