Version: October, 2005

The Patent Explosions: Quantifying Changes in the Propensity to Patent*

Paroma Sanyal**
Brandeis University
October 2005

Abstract

This paper develops a sequential application-grant framework to analyze competing explanations for the two U.S. patent surges during the mid-eighties and early nineties: (a) the 'friendly court' hypothesis argues that legislative changes in the 1980s lowered the cost of patenting and led to the increase in patenting activity and (b) the regime laxity hypothesis argues that the 1990s intellectual property regime shift lowered examination standards and caused the 1990s patent surge. Results from the empirical models reject the 'friendly court' hypothesis as the primary source of the eighties patent surge. The nineties surge can be attributed partly to the regime laxity hypothesis.

Key Words: Patents, Law Change, Sequential Decision Game
JEL Code: O31, O34

---

* I would especially like to thank Adam Jaffe for his help with this paper. Thanks also go to James Bessen, Mike Muerer, Mosahid Khan, Colin Webb and all participants of the NBER productivity seminar series, IIOC'05 and AEA meetings for valuable and constructive comments. I owe a special thanks to Bob Hunt and Avi Goldfarb for their suggestions. I would like to thank Prof. Sam Kortum and Dr. Dominique Guellec for generously sharing their data on EPO and WIPO patents. All errors are mine.
** Economics Department & IBS, MS 021, Sachar International Center, Brandeis University, 415 South Street, Waltham, MA 02454. Email: psanyal@brandeis.edu

1. Introduction

There has been an unprecedented surge in patent applications and grants in the United States (US) in the past two decades. For about 100 years, till 1985, applications remained between 40,000 and 100,000 patents and grants remained in the range of 20,000 to 70,000. Between 1985 and 1991 there was a dramatic increase in both applications and grants, with applications jumping by over 50 percent and grants rising by 35 percent (Appendix Figure 1(a))[1]. This was followed by another growth spurt between 1991 and 1998, where applications and grants surged by another 50 percent. Thus in a span of roughly 15 years between 1983 and 1998, applications and grants have more than doubled. These two patent surges, one in the mid-eighties and one in the early 1990s, have largely followed shifts in the U.S. intellectual property right (IPR) regime and has engendered discussion about the linkage between such institutional changes and patenting activity.

Although imperfect, patents are one of the best proxies available for measuring innovative activity. Hence changes in patenting behavior need to be carefully investigated to determine their exact ramification for a country's science, technology and innovation policy. For the two patent surges alluded to earlier, one must first understand the source of the increase and the underlying determinants before advocating policy prescriptions. Five potential sources have been identified in earlier literature (Kortum and Lerner, 1998; Hall, 2004; Sanyal and Jaffe, 2004): relative changes in resident and non-resident patenting, an increase in activity in new and fertile technology fields such as biotech and software, a shift of focus from basic to applied research, changing patenting incentives due to IPR regime shifts and an increase in real inventiveness of society. Depending on the relative importance of each of these factors, the policy lessons learned from the unprecedented patent surges would be different.

[1] The data for the figure is from two WIPO Industrial Property Statistics publications – "100 Years of Industrial property Statistics" and "25 Years of Industrial property Statistics".

First, if the increase occurred due to increased resident patent applications, it would signal growing U.S. inventiveness, while an increase due to rising non-resident applications would imply increased inventiveness in the rest of the world. From Appendix figures 1(b) and (c), one finds that both resident and non-resident applications and grants in the US have surged at roughly the same time, alluding to an increase in overall world inventiveness.[2] Second, was there any particular technology that spearheaded this increase? Specifically, did the introduction of new classes of patentable technology (like software and biotech) lead to a disproportionate increase in these fields, and hence lead to the surge? Kortum and Lerner (1998) argue that while these classes did contribute greatly to the overall increase, this contribution was not disproportionate. Other 'traditional' technology classes also displayed the same patterns of increase.

Third, was the surge due to the changing nature of innovative activity and shifting business practices, i.e. a shift from basic to applied research or changes in firm size, behavior, industry structure or market concentration, (Cohen & Levin, 1989; Kamien & Scchwartz, 1975; Mansfield, 1963, 1968; Scherer, 1965; Williamson, 1965) having little to do with new knowledge creation? For example, in the semiconductor industry for example, studies have shown that an important driver of patenting is the use of patents as deterrents in future litigation (Bessen and Hunt, 2004; Hall and Ziedonis, 2001; Cohen et. al, 2000). Hence, even without a change in the inventive potential of a country, one may observe increases in patent applications and grants. In addition, performance pressures and profit targets may shift a firm's focus from basic to applied research. However, there is little evidence to support exogenous business practice changes during this period and trends in R&D expenditures do not show any significant gain for applied research funding as opposed to basic research. Hence, one may rule out this explanation as the primary cause of the patent surge.

[2] However, the changes in non-resident magnitudes are more dramatic. The interesting point is that non-resident applications and grants, which had lagged behind the U.S. for decades, finally caught up in the last two decades.

Thus the two explanations I focus on in this paper are the legal changes in the IPR regime in the US and a change in the underlying inventiveness potential of countries. For my period of analysis, there were four major changes in the IPR regime - three during the early eighties and one during the early nineties. During the early eighties, three important institutional changes transformed the patenting environment. These were the establishment of the Court of Appeals of the Federal Circuit (CAFC), the passing of the Bayh-Dole Act[3] and the patentability of software and business method patents. This new regime was viewed as pro-patent and increased the rights of patent holders, consequently decreasing the net-cost of patenting, leading to increases in patent applications and hence grants. Thus following Kortum and Lerrner's (1998) '*friendly court hypothesis*' this eighties patent surge may be the effect of patent friendly US courts.

In addition, in the early nineties the Omnibus Act (1990) made the U.S. Patent and Trademark Office (USPTO) a user-fee funded entity and began the 'customer friendly' era of the patent office. In this environment, inventors were viewed as clients who were paying to get a service and there is evidence of declining examination standards during this period, which could have produced the sharp increase in grants during the nineties. I call this the *regime laxity* hypothesis. This paper focuses on these legal changes and investigates whether they were responsible for the patent explosion during the two periods under study. Any finding against these hypotheses would imply that the patenting increase was not a mere artifact of law changes, but denoted some fundamental shifts in the underlying innovative capacity of countries.

1.1 Background

The first systematic investigation into the possible explanations for the dramatic rise in patent applications and grants in the US during the mid-eighties was conducted by Kortum and Lerner in their 1998 paper. The primary hypothesis, termed the 'friendly-court hypothesis',

[3] The establishment of the CAFC and the Bayh-Dole Act was in 1982.

proposed that the enormous increase in patenting was a result of US patent law changes. They compared this with two alternative explanations – namely, the 'fertile technology hypothesis'[4] and the 'regulatory capture' hypothesis[5]. The authors argued that the patterns of application do not support the law change or regulatory capture argument. There has been an overall increase in patent applications from all sources that can only be explained by the 'fertile technology' hypothesis. Thus the explosion of patenting in the 1980s was a result of an increase in U.S. and world inventiveness and not a byproduct of US patent law changes[6].

This paper attempts to formulate, more fully, the exact ramifications of the pro-patent law changes of the 1980s and builds on the Kortum and Lerner findings.[7] When ruling out law change the authors argue that if law change had caused the patent surge, then the US would become more attractive as a destination and the increase in patenting "should be relatively uniform" across patentees and technologies. I consider an alternative explanation. Foreign inventors applying for patents in the US face a higher internal cost threshold than domestic inventors.[8] If the law change altered the cost of US applications, it would affect these two groups disproportionately – increasing domestic applications by more than foreign applications.

---

[4] The 'fertile technology hypothesis', as the name suggests, proposed that the recent 'patent surge' occurred due to increase in world inventiveness or arrival of newer technologies (e.g. biotech, software etc.) and was not an artifact of any legal change.

[5] The 'regulatory capture' hypothesis proposes that larger and more experienced patentees and domestic inventors were able to take advantage of the patent law change that led to an increase in patenting.

[6] The authors argue that if the legal change was responsible for the sudden increase in patent applications, then the US should increase as a destination for patents (not as a source) for both domestic and foreign patents. Thus the pattern of patent applications should show an increase in applications by both domestic and foreign inventors to the US, but little should change in the number of applications from US inventors to foreign countries or for non-US inventors in their domestic country. Thus if we compare, say, US and Germany, US and German applications to the US should increase, whereas US and German applications to Germany should remain roughly the same. Since this is not the case, they rule out the law change as a possible explanation.

[7] When ruling out law change the authors argue that if law change had caused the patent surge that the US would become more attractive as a destination and the increase in patenting "should be relatively uniform" across patentees and technologies. Let us consider why we may observe a different pattern. Foreign inventors applying for patents in the US face a higher cost threshold than domestic US inventors. Thus if the law change altered this threshold it would affect these two groups disproportionately – increasing domestic applications by more than foreign applications.

[8] Translation costs are one of the biggest costs in this process. For e.g., a French inventor has to incur the cost of translating all his documents into English before he can apply to the US.

In addition, strong correlations between multi-country application decisions indicate that the action of applying to an inventor's home country and a foreign country are not independent. For a vast majority of patents, the costs of patenting in a second country, when an inventor has undertaken the patenting process in his domestic country, is not prohibitive. Thus if the 1980's law changes made the US a more attractive destination, then marginal domestic inventors – who were not applying before, would now apply. They would then also apply to foreign countries since the incremental cost is small. For foreign patentees, the US law change may move some marginal patents over the quality-cost threshold and they too may patent more. Thus both the US and foreign countries may increase as a source for patents without any increase in inventiveness. Therefore this paper re-investigates the '*friendly court*' hypothesis in light of the above assumption and analyzes if it can indeed be ruled out as a major explanation for the 1980s patent surge.

In addition, this paper contributes to the existing literature by focusing on the 1990's IPR change and analyzing whether this was a possible cause for the nineties patent increase. It studies the impact of this change on patent volume and quality variance and investigates if the application and grant increases during this period were due to *regime laxity*. To study these issues, I model the patent application and grant process as an asymmetric information sequential decision game with heterogeneous inventors. This helps me identify the different factors impacting the grant rate for a patent office and make predictions about their signs. This model is then used to formulate hypotheses about the expected impact of IPR regime shifts on patent volume and quality variance in US and non-US jurisdictions.

2. Probability Structure of Patent Application and Grants

To model patent applications and grants, I use a simple sequential decision framework that provides useful insights about the probability distribution of patent applications and grants under asymmetric information. In this setup, the agents (inventors) have asymmetric information (some have superior information compared to others) and the principal (patent examiner) uses the information contained in the agent's actions (apply for a patent or not) to determine her own response. The primary decision the principal has to take is whether to grant or reject a patent. I assume that the examiner does not know the true quality of the invention, and formulates an expected quality depending on the prior probability of the invention being high quality and the conditional density function of the action of the agent, given the quality and the marginal likelihood of the action.

A patent application could be generated by an informed inventor who knows the invention quality or it could be generated by an uninformed inventor on the chance that he obtains a patent. Since the examiner does not know which type of inventor she is facing, she forms her beliefs about the quality of the invention, conditional on the type of event (application or non-application) that has occurred.[9]

2.1: Assumptions

In this model, the inventors and the examiners are risk neutral and act competitively. To make the model tractable I assume that the number of examiners can be generalized to one without loss of generality. The process of patent grant and application occurs in two sequential stages. In the first period, the inventor decides whether to apply for a patent. In the second period, the patent examiner decides whether the patent application should be granted or rejected. Inventors base their application decision on the realized net quality of the invention. When a firm or an individual invests in research, the net quality of the invention is not known, and hence this is characterized by

[9] In most decision models, the principal observes both types of actions – say buys and sales in a sequential trade model. She then gathers information from them. In this model, the patent examiner, in reality, does not observe the people who do not apply. But, for the setting up of the model, we assume that 'not applying' is an observable action. Formulating the patent application and grant problem in this manner, allows me to introduce learning into the model. Through repeated interaction with informed inventors, the examiner may eventually learn the informed inventors' information and can base her patent grant decision on this expected quality of the invention, given the information.

a random variable V which is bounded between $[0,\infty)$, and denotes the intrinsic net quality of the invention.[10]

Now consider two types of inventors – an informed and uninformed type. The informed inventor knows that the quality of invention can be either high ($\overline{V}$) or low ($\underline{V}$).[11] When he observes a 'good' signal (i.e. net quality is positive), he applies for a patent with probability 1. The uninformed inventor only knows the net quality distribution and not the actual realized value. Thus, he may apply even if he observes a bad signal (i.e. net quality signal is negative). We assume that there are no costs involved (other than forgone profits) in not applying for a patent after the invention occurs. In addition, the examiner, too, does not know the true quality of the invention. She tries to formulate the probability of observing a good versus bad invention from the applications that are occurring.

This application-grant structure is illustrated by a simple tree-diagram in Appendix Figure 2. Nature moves first and chooses the quality of the invention – i.e. high or low quality. This represents the first node. Let θ be the probability that the signal says invention is high quality and $(1-\theta)$, the probability that it says bad quality. The second node shows the fraction of inventors who learn about invention quality – i.e. who is informed and who is uninformed. This fraction is symmetric with respect to bad and good quality. Here μ is the probability that the inventor is informed and $(1-\mu)$ is the probability that the inventor is uninformed. The third node shows the application decision by the inventors. For the informed inventor, the probability of application is either one or zero depending on whether he has received a good or bad signal about invention quality. For the uninformed inventor, the application probability is δ and the non-application

---

[10] The quality of the invention refers to the 'importance' of the invention in the particular field and what the market value of the invention is. The probability of observing a good signal may depend on the amount of R&D expenditure of the application country, R&D expenditure by the individual inventor and other underlying 'inventiveness' factors. Hence in the empirical model I will include these as controls.

[11] Here 'high' quality implies that the intrinsic or gross value of the patent is greater than the sum of costs involved in patenting the invention and readying it for the market.

probability is (1-δ) irrespective of whether he received a good or bad signal about invention quality. The fourth node determines the patent grant probabilities.

2.2: Constructing Application and Grant Probabilities

The probability of application for the informed and uninformed inventor along with the probabilities of good or bad news and the probability of inventor type allows me to calculate the probability of application at each grant node.[12] This, coupled with the examiner's grant probability, yields the expression for the probability of observing a grant: $\text{Prob}\{Grant\} = \theta \mu \gamma + (1-\theta)(1-\mu)\delta\gamma$, and is obtained by summing over the probabilities of all grant nodes. To get a sense of what this grant probability means, let us start with diffuse priors on μ and δ. Let $\mu=\delta=1/2$[13]. The grant probability then simplifies to: $(3\theta +1)\gamma/4$. Thus the final grant probability is directly related to the probability of getting good news and the probability that the patent examiner decides to grant the patent.[14]

The primary variable of interest for this paper is γ, the probability of the patent examiner granting a particular patent. I formulate this as a standard Bayesian learning process, by which the examiner forms her posterior beliefs about the quality of the invention being high, and depending on that, decides whether or not to grant a patent. The patent examiner does not know the exact quality of the invention. After she observes an application, she uses the information conveyed by

---

[12] The probability of observing an application is given by summing over all these application probabilities: $\text{Prob}\{Application\} = \theta\mu + (1-\mu)\delta$. This along with the grant probabilities, allow us to construct the final probability of a patent being granted. In Appendix Figure 2, the expressions at the end of each final node signify the probabilities of being at that particular node. Hence, the probability that an informed inventor with a good quality invention is granted a patent is: $\theta\mu\gamma$, whereas this probability for an uninformed inventor is: $\theta(1-\mu)\delta\gamma$.

[13] This implies that the probability that an inventor is informed (μ) is half, and probability that an uninformed inventor is going to apply is also half.

[14] In this simple formulation we have not modeled the determinants of these probabilities. We could assume, foe instance that the probability of a good signal (θ) depends on the amount of R&D dollars that have been spent on the invention. The more R&D dollars that is spent on a project, the greater would be the probability of observing a good signal. The empirical model includes this.

this 'event' to construct posterior probabilities (Ω) that the invention is of high quality i.e. V=$\bar{V}$,[15]

which is given by: $$\Pr ob\{V = \bar{V} \mid Appli.\} = \Omega = \frac{\theta\mu + \theta(1-\mu)\delta}{\theta\mu + (1-\mu)\delta} \qquad (1)$$

This posterior probability varies positively with θ and μ and negatively with δ, i.e.

$\Omega'_\theta \geq 0$, $\Omega'_\mu \geq 0$, and $\Omega'_\delta \leq 0$. First, this implies that the posterior probability of V=$\bar{V}$ increases at a decreasing rate as θ increases[16]. A higher prior probability of a good signal implies a higher posterior probability that the invention is of high quality. Second, if the probability that the inventor is informed (μ) increases, the probability that V=$\bar{V}$ given application, increases.[17] Third, as the probability of application by an uninformed inventor increases, it becomes harder for the examiner to judge the quality of the patent by observing the application (increased δ introduces more noise). Thus Ω decreases as δ increases.[18]

Hence even without a change in application costs or grant standards, grant rates will change due to three factors, (a) change in the inventive capacity of a society (θ), leading to a change in the probability of getting a valuable innovation, (b) change in the proportion of informed or 'genuine' inventors (μ), say due to a stricter patent regime that better protects their property rights and (c) change in the likelihood of application by uninformed inventors (δ), which may be driven by exogenous factors like making it easier for startups to raise venture capital if they have some

---

[15] Thus she calculates: $\Pr ob\{V = \bar{V} \mid Appli.\} = \frac{\Pr ob\{V = \bar{V}\}\Pr ob\{Appli \mid V = \bar{V}\}}{\Pr ob\{V = \bar{V}\}\Pr ob\{Appli \mid V = \bar{V}\} + \Pr ob\{V = \underline{V}\}\Pr ob\{Appli \mid V = \underline{V}\}}$

[16] $\Omega'_\theta = \partial\Omega / \partial\theta = [\delta(1-\mu)(\mu + \delta(1-\mu))] / [\theta\mu + (1-\mu)\delta]^2 \geq 0$, $\Omega''_\theta < 0$

[17] $\Omega'_\mu = \partial\Omega / \partial\mu = \delta\theta(1-\theta) / [\theta\mu + (1-\mu)\delta]^2 \geq 0$, $\Omega''_\mu > 0 \ if \ \theta < \delta$ and $\Omega''_\mu < 0 \ if \ \theta > \delta$

[18] $\Omega'_\delta = \partial\Omega / \partial\delta = \theta\mu[\mu(\delta-\theta) - (1-\theta)] / [\theta\mu + (1-\mu)\delta]^2 \leq 0$,

patents.[19] Increase in the first two factors will increase grant rates, while an increase in the third factor will dampen grants rates, independent of a change in grant or examination standards.

After constructing the posterior beliefs about the quality of the invention, the patent examiner can either grant or dismiss the patent.[20] The US examiner judges the inventions on the twin principles of 'non-obviousness' and 'novelty'. In this model, a patent is granted if the posterior probability is greater than the examiner's pre-determined standard (Ω*), i.e. say the examiner finds that the posterior probability of the invention being of high quality is 0.7. But the standard says that she should grant a patent only if this probability is greater than or equal to 0.75. In this case the patent is not granted.[21]

Examiner's Decision: $\{Grant\ \ Patent\ \ if\ \ \Pr ob\{V = \overline{V} \mid Appli.\} = \Omega \geq \Omega^*$
$\{Not\ \ Grant\ \ Otherwise$

This implies: $\gamma = \begin{cases} 1 & if \quad \Omega \geq \Omega^* \\ 0 & otherwise \end{cases}$

Ω* is determined by the objective of the patent office. If the objective function is to maximize aggregate patent quality subject to certain constraints[22] – then Ω* will be set at a very high level. However, if the objective is to maximize the number of patents granted subject to some minimal quality requirement, then Ω* will be low. In the next section I use this model to study the two US IPR regime changes.

[19] This does not imply that there are no feedback effects from lowering of grant standards. In fact, I hypothesize that the largest effect on the application probability of uninformed inventors will come from lowering of grants standards, which in turn lowers the implicit cost of patenting.
[20] The examiner's decision problem is more complex than posited here – for example, instead to rejecting the application, she can send it back to the inventor and ask him to narrow his claims. But to keep the analysis simple, I assume that the examiner had only two decision options – grant or not grant.
[21] If the examiner knew the true quality of the invention, she could set a standard by which to grant the patent. However, the examiner does not know the true quality of the invention and has to formulate this standard a little differently.
[22] These constraints may be that the patent office has to grant a certain minimum number of patents to provide encouragement to inventors to innovate and patent their inventions and also help in technology diffusion.

3. Implications of the Model

The above model illustrates that there are two primary thresholds that an invention has to overcome before it becomes a granted patent – the cost-benefit threshold (from the inventor's side) and the 'novelty' and 'non-obviousness' threshold (from the examiner's side). Suppose *f(V)* denotes the density function of invention quality (net of costs).[23] I hypothesize that the two major law changes, altered these thresholds differently. The '*friendly court*' hypothesis suggests that the eighties law change made patents more valuable – i.e. decreased the net cost of patenting. Hence it shifted the net quality distribution to the right as shown in Figure 1 below.

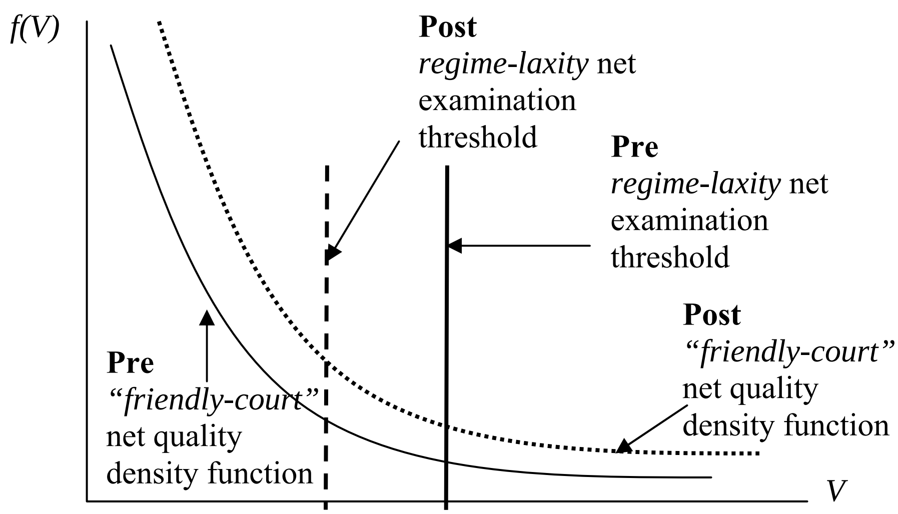


Figure 1

If the gross quality distribution was unchanged but costs were lower, this implies that this law change allowed more marginal inventors to apply for patents. The *regime laxity* hypothesis holds that during the 1990s, the objective function of the patent office changed and this relaxed the 'non-obviousness' constraint (Ω*), leading to lower valued (and thus more marginal) patents being

[23] We may think of this as being exponential or Pareto as there are a small number of very high quality inventions, some mid-quality inventions and quite a significant number of low quality inventions.

granted as shown in the figure below. Thus the effect of both these changes was to increase number of patent applications and grants.

This observation alone, however, does not allow one to distinguish between and the law change hypothesis and the effect an increase in underlying invention potential factors. An increase in the gross quality of patents or a decrease in cost would both shift the net-quality density function to the right leading to more applications and grants. In addition a decline in examination standards and increase in gross intrinsic quality would have the same observed effect as well. Hence, one needs to rely on other effects of the two regime changes to separately identify the effect of law changes as opposed to an increase in underlying invention potential of a country. I argue that if IPR regime change is the primary cause then the impact on patent volume and quality variance should be different for inventors with a low cost barrier (such as the English speaking country inventors) and those with a high cost barrier (or non-English speaking country inventors) and for informed and uninformed inventors.

Patent application probabilities will differ for inventors in the US and other English speaking (henceforth ES) countries when compared to non-English speaking (henceforth NES) countries. For the NES inventors, the cost of applying for a patent in the US is greater than that of ES inventors, i.e. their internal cost threshold[24] is stricter than what ES inventors face, due to factors such as document translation costs. Thus the US cost threshold maybe non-binding for these inventors. Any change in US patent law that affects this cost threshold, may differentially affect patent metrics produced by these two types of inventors. Also, uninformed inventors should increase as a proportion of application after the eighties law changes when compared to previous years due to lower costs making it worthwhile for such uninformed inventors to apply. In the econometric

[24] This internal cost threshold may be different due to several reasons. For e.g. a French inventor has to incur the cost of translating all his documents into English before he has to apply to the US. Also the lawyer's fees may be greater. Therefore the foreign threshold lies to the right of the domestic threshold.

specification I rely on these differences for identification. The next section discusses the implications of the '*friendly court*' hypothesis and the *regime laxity* hypothesis for patent grants and quality.

3.1 Effect of the 'Friendly Courts'

As discussed earlier, the pro-patent IPR regime of the 1980s can be interpreted as a decrease in the costs associated with patent protection. Viewed in this light, the implication of the '*friendly court*' hypothesis is to alter the probability distribution of the net quality of patents. If costs decrease, *f(V)*, the quality distribution (net of costs) shifts right and the probability of observing a good signal (θ) increases. This has a dual effect. From the inventor's side, it increases the number of applications. From the examiner's side, increase in θ implies an increase in Ω (the examiner's posterior probability that the invention is of high quality). So, in the new regime $\Omega \geq \Omega^*$ will occur more frequently, i.e. the invention will cross the legal threshold of acceptance more often. Hence, the number of patents applied for and granted will increase.

But how do we justify that this increase occurred partly as a result of the law change and not solely because of the invention production function changing? First, I argue that due to a higher internal cost threshold for the NES inventor, their observed net quality signal (θ) is lower than that of ES inventors. In terms of the model, this implies that the ES country applications will increase more than NES applications.[25] Another implication of the lowered cost of patenting is the increase in the probability of application (δ) by the uninformed inventor from all countries. However, one can argue that the ES application probability may increase more than the NES probability due to reasons outlined earlier. In this case, the examiners perceived beliefs about invention quality (Ω) would be greater for non-English speaking than English-speaking inventor patents. This would have

[25] This internal cost threshold may be different due to several reasons. For e.g. a French inventor has to incur the cost of translating all his documents into English before he can to apply to the US. Also the lawyer's fees may be greater. Therefore the foreign threshold lies to the right of the domestic threshold.

the effect of more NES inventions crossing the legal threshold than domestic or ES inventions. This implies that the growth rate of grants of NES inventor patents would be greater than that of ES inventor patents during this period.

In addition, a combination of a higher θ and higher δ for the ES country inventors implies that more marginal patents are going to come from these jurisdictions. Hence one may expect a wide variance in patent value for these jurisdictions when compared to NES countries. Thus we can derive several testable hypotheses, which if true, would lend credence to the law change explanation.

Implications for the 'Friendly Court' Hypothesis (1980 – 1990):

(a) ES inventor applications should increase by more than NES inventor patents.

(b) Grants of NES inventor patents increase more than the grants of ES inventor patents.

(c) Uninformed inventors should play a larger role, post law change.

(d) The variance in quality should be greater for ES country patents than NES country patents.

3.2 Effect of Regime Laxity

The *regime laxity* hypothesis postulates, that holding all else constant, the period after 1990 should display an even greater increase in patent applications and grants for all applicants due to declining grant standards. In terms of the model this implies that signal quality (θ) should have a smaller or negligible impact on grant probabilities during the nineties. In addition, if there are feedbacks from lower grant standards to application incentives, then the proportion of uninformed applicants should increase (conversely, μ should decrease) and thus we should see uninformed inventors having a greater impact on grant standards during the nineties. Granting of more marginal patents will increase the variance in patent quality and the result should be asymmetric between domestic or ES country inventors and NES country inventors. Thus shifting the US legal threshold may have the following effects:

Regime Laxity Hypothesis (Post – 1990):

(a) Grant probability for both ES and NES inventors will increase compared to previous years.

(b) Signal quality should have a smaller or negligible impact on grant probabilities and variance after the 1990s changes.

(c) The overall variance in patent quality should increase.

(d) Compared to pre-1990 levels, the variance of NES country's patents should increase more than that of ES country patents.

In the following section I test some of the above hypotheses to see whether the patent surges were indeed a result of these two regime changes.

4. Data and Graphs

4.1: Data

The data is primarily from NBER's (National Bureau of Economic Research) 'Patent Citations Database', WIPO (World Intellectual Property Organization) publications – "100 Years of Industrial property Statistics" and "25 Years of Industrial property Statistics, the European Patent Office (EPO), OECD's triadic patent family database and from the US Patent and Trademark Office. The NBER database is an exhaustive database containing all patents granted in the US from 1963 to 1998. It comprises application and grant years, geographical distribution of these patents, technology classifications, forward and backward citations[26] for each patent, measures of patent originality and generality and assignee codes that help in tracking assignees across years. I use this data to construct measures of patent quality variance and the proportion of informed inventors in a country. I use patent and inventor data from the OECD and EPO to construct measures of signal quality and application probability of uninformed inventors. The WIPO data contains information about patent applications and grants in all countries from 1883-2000. It is useful in comparing the

[26] US citation only.

domestic and foreign application and grant rate[27]. Variables such as research and development spending, GDP and the like come from OECD's Science and Technology Indicators. Summary statistics are shown in Appendix table 1.

This paper follows a two pronged approach when investigating the hypotheses postulated earlier. First, I graphically analyze the trends in foreign and domestic grants and applications and present some descriptive statistics. In addition, I present evidence of patent quality variance changes using citations as a quality measure. Second, I empirically investigate a subset of the theoretical predictions to analyze how much of the two patent surges can be attributed to IPR regime shifts.

4.2: Graphical Analysis

From Figure 1(b) in the appendix, it is evident that the increase in ES country patent applications is less than NES country patents. The total grants appear to follow the application patterns closely (Figure 1(c)). Thus contrary to the predictions of the two law change arguments, the ES countries have not gained after the 1980s IPR changes. The applications and growth for both ES and NES countries appear to have increased more after the nineties than a simple time trend would suggest. In addition, the growth rate of US applications to OECD countries is higher and increasing when compared to the US resident application growth rate (Figure 3(a)). From Figures 3(b) and (c) one observes that there are no dramatic differences between the applications and grant growth rate of ES and NES countries, as the law change argument would have predicted. In addition, grant rates are declining in the mid-eighties and increasing during the early nineties (Figure 3(d)). Taken in tandem, these graphs do not favor the 1980s law change as the primary driver of the eighties patent explosion. However, we cannot reject the nineties changes as a candidate for the nineties patent surge.

[27] There is considerable double counting in the WIPO data. Thus, for the empirical analysis I use the cleaned data provided by Prof. Sam Kortum.

Next, I focus on examining the variance in patent quality in different jurisdictions to better understand what is driving the patent surges. The literature suggests that while there are no perfect measures of patent quality, forward citations (Jaffe, 1986, Hall, Jaffe and Trajtenberg, 2001; Jaffe and Trajtenberg, 2002), stock market valuation (Lanjouw and Schankerman, 1999; Harhoff, Narin, Scherer and Vopel, 1999; Sampat,1998; Shane,1999, 2001; and Hall, Jaffe and Trajtenberg, 2004), patent renewal data (Lanjouw, Schankerman and Putnam, 1996) and the size of patent families, are all good indicators of quality. In this paper, when discussing patent quality I primarily focus on citations.

The use of citations[28] as a measure of patent quality was first proposed by Trajtenberg (1990), who argued that these contained rich information relevant to analyzing patent characteristics. Backward citations[29] shed light on the technological roots on an invention and patent scope, while forward citations help in analyzing patent quality and knowledge diffusion. Researchers have found that there is a positive relationship between the number of citations and patent quality implying that more fundamental or productive innovations are cited more frequently (Popp, 2002; Trajtenberg, 1990).Thus, I use forward citations as a metric of patent quality[30] and calculate the coefficient of variation measure based on this. To compare across years and technology fields, I used the fixed effects approach outlined by Hall et. al.(2001). The raw number

[28] Citations are references to related innovations that are contained in each patent document. They identify patent and non-patent prior art that are relevant to the current technology. Such citations are included in the patent document by the applicant and the patent examiner during the examination process.
[29] 'Backward' citations are those that a patent cites, whereas 'forward' citations are counts of how many other patents have cited a particular patent.
[30] However, when using this data one has to be careful about certain factors. First, citations have to be purged of year and field effects (Hall, Jaffe and Trajtenberg, 2001) before they can be used as quality measures. Second, it is not always true that more citations imply a greater market quality. More citations may also imply that competition has increased in the relevant market and there are more similar innovations. Hence the monopoly position of a firm may be eroded and hence market quality of the innovation may decline even with increased citation for the firm's patent. Based on a sample of 4,800 US manufacturing firms, Hall, Jaffe and Trajtenberg (2001) find that self-citations are worth about twice as much as citation by others, which hints at the above problem. Third, there may be country-wise differences in citing-propensity that need to be controlled for when using citations as quality measures in any estimation model.

of citations for each patent is purged of year, field and year-field effects by dividing them by the year-field means.[31]

Prior to the empirical estimation I present some basic plots of the citation coefficient of variation that shed light on the impact of the legal changes on patent quality. The '*friendly court*' hypothesis postulates that the variance should be greater for ES country patents than NES country ones, while the '*regime laxity hypothesis*' implies that compared to pre-1990 levels, the variance of NES country's patents should increase more than that of ES country patent. Figure 4 presents a plot for 5 major patenting countries, 2 in the ES group and 3 in the NES group. Variance is fairly steady in the eighties and increases in the nineties for both groups, thus rejecting the '*friendly court*' and weakly supporting the *regime laxity* hypotheses (Figure 4). However, as noted earlier, this alone is not sufficient to validate the *regime laxity* argument – the variance could be increasing if some patents granted are of extremely high value. Thus one needs to study the differences across ES and NES jurisdictions and this is done in the empirical analysis.

In addition, I graphically illustrate the assertion that the proportion of uninformed inventors would increase, especially for domestic inventors if the '*friendly court*' hypothesis is true. If one defines individual inventors as being 'uninformed' then from Figure 5, one finds that there is negligible difference during the eighties, rejecting the eighties law changes as a possible explanation for the eighties patent surge. In conclusion, the graphical evidence favors rejecting the '*friendly court*' hypothesis, while no conclusion can be drawn about the '*regime laxity*' one.

[31] Hall et al. (2001) point out that this rescaling of the citation intensities by the year-field means takes out both real and artificial impact of the citation generating process. Rescaling the citations by the year-field means removes any effects that are due to any particular technology field, macro-shocks and the interaction of the two. When comparing earlier and latter years, this fixed effects approach controls for the fact that there were many more patents to cite from in the later years, which would increase the number of citations and not reveal any information about patent quality. In addition, it also controls for the technology composition of a country's patent portfolio and makes comparison across countries meaningful.

5. Empirical Methodology & Results

Graphical analysis did not yield very clear outcomes. To better understand the impact of law changes on various dimensions of the patent application and grant processes and implications for patent quality I use the theoretical framework developed earlier to formulate the empirical model. First, I develop measures of signal quality, proportion of informed inventors in a country and the probability of application for an uninformed inventor. This allows me to model the impact of observed variables and unobservables on U.S. patent grant rates and test whether unobserved changes in legal standards have led to increased grants. Second, the sequential decision model predicts increases in the variance of patent quality if the law changes have led to declining grants standards and consequently increased the number of marginal patents. I use the coefficient of variation of citations to investigate the impact of law changes on quality variance.

5.1: Model Using the Sequential Application-Grant Probability Framework

5.1.1: Explaining USPTO Patent Grant Rates

I first calculate the observed USPTO grant probabilities (i.e. grant rates) for 18 OECD countries[32] and use the theoretical model to construct the constituents of the expected grant probability estimates at the country level.[33] I argue that the observed US grant probability (G_{it}) can be disaggregated into two parts: an expected grant rate (O_{it}) and unobservable grant propensity as seen from the equation below.

$$G_{it} = \alpha + \beta O_{it} + \sum_{K=1}^{k} \gamma_n Z_{it} + \sum_{t=1982}^{1998} \delta_t T + \lambda t + \eta_i + \varepsilon_{it} \qquad (2)$$

[32] Austria, Australia, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Japan, Luxembourg, Netherlands, New Zealand, Norway, Switzerland, Sweden, United Kingdom. Belgium and Luxembourg are treated as one country.

[33] There will be aggregation problems in this measure since we are ignoring technology classes, inventor type etc. when adding up to the country level. However, for now, we shall ignore this bias.

where: Z_{it}s are control variables, T is a year dummy, t is a time trend, η_i are the country fixed effects and ε_{it} is the error term. From the theoretical model we know that the expected grant rate[34] comprises proportion of informed inventors in a country (i_{it}), inventive capacity of a society or signal quality (S_{it}) and the likelihood of application by uninformed inventors (a_{it}). After controlling for these and other variables of interest, the year fixed effects (δ_T) can be interpreted as unobervables that impact the grant rate. I interpret this as the unobserved grant propensity associated with a change in the patent regime. If the '*friendly court*' and the *regime laxity* hypotheses are true then this regime change variable should show structural breaks around mid-1980s and early 1990s and should also be increasing significantly over time. I estimate a panel data fixed effects model for non-US countries (i is the source country) given by:

$$g_{it} = \alpha + \beta_1 i_{i,t-s} + \beta_2 S_{i,t-s} + \beta_3 a_{i,t-s} + \sum_{M=1}^{m} \gamma_M Z_{i,t-s} + \sum_{t=1982}^{1998} \delta_t T + \lambda t + \eta_i + \varepsilon_{it} \qquad (3)$$

Where:

- Log US grant rate (g_{it})[35] = Log (Number of patents grant by USPTO to country i in year t / Number of applications to the USPTO from country i in year t)
- Log Proportion of informed inventors ($i_{i,,t-s}$) = Log (Number of assignees who had two or more USPTO patents in a given patent class for country i in year t-s) / Number of total assignees[36] in a given patent class for country i in year t-s[37]). This total excludes government patents.

[34] Expected Grant Rate (O_{it}) = $\Pr ob\{V = \overline{V} \mid Appli.\} = \Omega_{it} = \frac{\theta_{it}\mu_{it} + \theta_{it}(1-\mu_{it})\delta_{it}}{\theta_{it}\mu_{it} + (1-\mu_{it})\delta_{it}}$ where: $\mu_{it} = I_{it}$, $\theta_{it} = S_{it}$ and $\delta_{it} = A_{it}$

[35] Let 'g_{it}' be the proportion of granted patents for country i in year t. Since this quality is between zero and 1, we transform the dependent variable using a logit transformation that guarantees that the predictions will also range between 0 and 1. The logit transformed dependent variable will then be: log ($g_{it}/(1-g_{it})$). The marginal effects are given by: $\delta g/\delta x = \beta e^{\beta x}(1-s)/(1+e^{\beta x})$ where 'x' is an independent variable in levels and $\delta g/\delta x = \beta x^{(\beta-1)}(1-s)/(1+x^{\beta})$, when x' is an independent variable in logs

[36] I use the CUSIP numbers from the NBER patent database to identify assignees that had two or more patents in the previous year. Alternatively we can use assignees with 3 or more patents and the results are stronger. A one year lag is used because while updating her beliefs this is the patent examiner's information set.

[37] An alternate definition of informed inventors could be that these are the big corporations and all individual inventors are uninformed. This definition shall be used for sensitivity analysis.

- Signal that says invention is high quality ($S_{i,t-s}$) = Number of triadic patent families for country i in year t-s / Number of applications to the home country i in year t-s
- Log of Uninformed inventor application probability ($a_{i,t-s}$)[38] = Log (Total number of domestic patent grants in country i in year t-s / Total number of applications in country i in year t-s).
- Z_{it} = Control variables pertaining to country source i in year t, for e.g., level and composition of R&D expenditure, level of wealth, technological distance from the US[39] etc.
- η_i = Country fixed effects
- δ_T = Year fixed effects or Regime change measure, where T are year dummies.

Results from table 2(a) lend support to the predictions from the sequential game-theoretic model developed earlier and all the coefficients have the predicted signs. From the basic model (column 1) I find that a 1 percent increase in the proportion of informed inventors increase USPTO grant rates by 0.06 percent, while a 1 percent increase in signal quality increases the grant rate by almost 0.5 percent. In addition, increase in the application probability by uninformed inventors dampens the grant rate and a 1 percent increase in the former leads to a 0.03 percent decline in the latter.

Thus, there is evidence that increasing world inventiveness (as captured by the signal quality variable) along with a rise in the number of informed inventors positively impacts patent grants in

[38] This is an imperfect proxy for the real probability. We assume that uninformed inventors probability is determined by their success in getting a patent in their home country. Hence as the resident patent grant rate increases, the probability of uninformed inventor application to the US increases as well.

[39] We use the EPO data to construct the technological distance index for each country. These data are disaggregated by source countries and IPC classes. We have the application and grant counts by country for each of the 8 IPC classes.[39] The range of this dataset is from 1977-2000. The technology overlap index (Jaffe, 1986) was created by using:

$$TECH_{ij} = \frac{\sum_k f_{ik} f_{US,k}}{\sqrt{\sum_k f_{ik}^2 \sum_k f_{US,k}^2}} \text{ and } f_{ik} = \frac{Applications \text{ in } IPC_k}{Total\ Applications} \text{ for country i}$$

where: i, j = country, k = IPC Class (A - H)
This index is bound between zero and one and is calculated for 1979 – 2000, to allow for lags. If two countries have identical technology compositions, then the index takes the quality 1. If the vectors f_i and f_j are orthogonal then this index is zero. Ideally we would have liked to use a country's patent application composition to its domestic jurisdiction to pick up the universe of patentable inventions - not just the important ones that are applied for through the EPO. But in the absence of such data, the EPO patent class data serves as a good proxy.

the US, while an increase in the application probability of uninformed inventors dampens it. When controls such as the composition of gross R&D expenditure (GERD) and technological distance of the country from the US are added to the basic specification (column 2), the explanatory variables remain largely unchanged. One interesting finding is that as a greater percentage of gross R&D expenditure comes from universities, it has a dampening effect on grant rates. This may be attributed to the nature of research in universities, which tends to be more fundamental and basic and may result in a smaller number of patent applications and hence grants.

After controlling for these observed effects, I test the year dummies, or the regime change variable for structural breaks. A Wald test rejects the hypothesis of no change. In addition, for the period between 1985 and 1989, year unobservables have a positive impact on the grant rate. Hence, one cannot reject the '*friendly court*' hypothesis based on this evidence. The post-1990 years show a negative impact on grant rates, rejecting the predictions of the *regime laxity* hypothesis. However, the specification in table 2(a) does not address how these regime changes affected the slope coefficients, and the next section studies this issue.

5.1.2: Effect of Law Changes on Observables

To further investigate the proposed hypotheses, I interact the slope coefficients with the two law change dummies (for mid 1980s: D_{1986} and early 1990s: D_{1992}) to explicitly account for the impact of the '*friendly court*' hypothesis and the *regime laxity* hypothesis on the proportion of informed inventors, signal quality and the probability of application by an uninformed inventor. The estimated equation in table 2(b) is given by:

$$g_{it} = \alpha + \sum_{K=1}^{3} \beta_K X_{i,t-s}^{K} + \gamma D_{t=1986} + \sum_{K=1}^{3} \delta_K X_{i,t-s}^{K} D_{t=1986} + \varphi D_{t=1992} + \sum_{K=1}^{3} \theta_K X_{i,t-s}^{K} D_{t=1992}$$
$$+ \sum_{M=1}^{m} \gamma_M Z_{it} + \sum_{t=1982}^{1998} \phi_t T + v_i + \varepsilon_{it} \qquad (4)$$

where: D_{1986} =1 if year > 1985, 0 otherwise and D_{1992} =1 if year > 1991, 0 otherwise. The impact of the eighty's and 1990's changes will be given by $(\beta_K + \delta_K)$ and $(\beta_K + \delta_K + \theta_K)$ respectively (if the coefficients are significant).

From Table 2(b), I find that the 1980s and 1990s law changes have different impacts on the slope coefficients. The eighties changes did not affect any of the slope coefficients and year dummies are negative.[40] The 'customer-friendly' approach of the 1990's, however, increased the impact of informed inventors on grant rates (0.253 as opposed to 0.103), rejecting the *regime laxity* argument. Signal quality does not have an impact on grant rates in this model and the application probability of uninformed inventors has the same a negative influence in both regimes. Thus from table 2(a) and (b) there are indications that the IPR regimes change did not contribute significantly to any of the patent surges. The next section studies quality variances to further investigate these two hypotheses.

5.2: Modeling Variance in Patent Quality

5.2.1: Quality Variance in the Two Regimes

An additional implication of the sequential application-grant model was an increase in patent quality variance after both the law changes for Non-English speaking as well as English-speaking country inventors. To measure the variance in patent quality I use the coefficient of variation of citations that have been purged of year and field effects. To account for the two law changes (mid-1985 and early-1990), I estimate a model similar to that in table 2(b) with the coefficient of variation as the dependent variable. Since there is no apriori reason to believe that this has a linear relation to the explanatory variables, this model also includes square terms for the regressors to allow for flexible functional form.

[40] The post-law change coefficients are obtained from estimating the linear combination of the coefficients: $\hat{\beta}_k + \hat{\delta}_K D_{t=lawchangeyear}$. The post law change slope coefficients for 1980s changes are insignificant.

$$V_{it} = \alpha + \sum_{K=1}^{3} \beta_K X_{i,t-s}^{K} + \sum_{K=1}^{3} \gamma_K \left(X_{i,t-s}^{K}\right)^2 + \delta D_{t=law} + \sum_{K=1}^{3} \phi_K X_{i,t-s}^{K} D_{t=law} + \sum_{K=1}^{3} \theta_K \left(X_{i,t-s}^{K}\right)^2 D_{t=law}$$
$$+ \sum_{t=1982}^{1995} \varphi_t T + \lambda t + v_i + \varepsilon_{it} \qquad (5)$$

where: D_{law} =1 if year > 1985, 0 otherwise for the eighty's changes and D_{law} =1 if year > 1991, 0 otherwise for the 1990s changes. If δ is positive and significant, there is evidence of patent quality variability being adversely affected (increasing) by the two regimes shifts.

From table 3(a) column 1, one observes that the 1980s changes have little impact on variance while the 1990's increase it,[41] thus rejecting the '*friendly court*' hypothesis while supporting the *regime laxity* one. I find that the flexible functional form is a good fit although two of the three coefficients do not have the expected signs. One would expect an increase in the proportion of informed inventors and an increasing quality signal to decrease variance, while the increase in the probability of uninformed inventors should increase it.

I find that a one percent increase in the proportion of informed inventors increases the coefficient of variation by 0.107 percent, while a one percent increase in signal quality decreases the coefficient of variation by 0.03 percent[42]. Taken together, this may imply that the patent quality variance during this period is increasing due to very good quality patents rather than marginal ones. In addition, increase in the application probability by uninformed inventors decreases variance. This probability is calculated as the domestic grant rates in each country. If standards have not changed in the OECD countries but domestic grants rates are increasing, this may signal an increase in inventiveness and lead to very high quality applications to the US – which may increase variance. This is preliminary evidence world inventiveness may have been increasing during this period and

[41] However, there is no way to know whether the variance increase is due to some very high quality patents or some very low quality patents. For sensitivity analysis I control for the mean lagged citation intensity and generality – the results remain unchanged.

[42] For the pre-law change regime, $\delta \ln Y/\delta \ln X = (\beta_K + 2\gamma_K X_{mean}) (X_{mean}/Y_{mean})$ if both coefficients are significant. For the post law-change: $\delta \ln Y/\delta \ln X = [(\beta_K + \phi_K) + 2(\gamma_K + \theta_K) X_{mean}] (X_{mean}/Y_{mean})$ if all coefficients are significant

the patent surge, especially the mid-eighties one cannot be attributed to the pro-patent stance of the courts.

In addition to the level effect, the law changes may have altered how the explanatory variables influence the variance before and after the regime change. Columns 2 and 3 show the impact of the law changes on the slope coefficients. I find that the results in the model are driven by the 1990s changes. After controlling for observable influences and unobserved year effects, the regime change in the 1980's decreased overall variance thus rejecting the '*friendly-court*' hypothesis. The 1990's changes increased variance supporting the *regime laxity* hypothesis. Slope coefficients behave the same way as in column 1, except for the signal quality variable. I find that signal quality decreases variance only after the 1990s law change contrary to the predictions and invalidating the *regime laxity* hypothesis

5.2.1: Impact on English Speaking Countries

Next, I test whether the law changes impacted ES and NES countries differently. As discussed earlier, when applying to the US, the internal cost-threshold of ES countries is lower than that of NES countries. Coupled with this, the pro-patent stance of courts and lower examinations standards should give rise to more marginal applications and grants from these countries as compared to NES ones after both regime changes. This should increase the post-law change variance of ES countries. To investigate this, I estimate a difference-in-difference model in table 3(b) with the coefficient of variation as the dependent variable (V_{it}), K explanatory variables ($X^{k}_{i,t-l}$) that comprise the lagged quality of signal quality, proportion of informed inventors and probability of application of uninformed inventors, an English dummy (Eng_{it}) and a law change dummy (Law_{it}). This law change can be either the 1980's change or the 1990's change.

$$V_{it} = \alpha + \beta_K \sum_{K=1}^{3} X^{K}_{i,t-l} + \varphi Eng_{it} + \theta Law_{it} + \mu(Eng_{it} * Law_{it}) + \varepsilon_{it} \qquad (6)$$

μ is the differences-in-differences in means between the two groups. If this is positive and significant then the regulatory changes increased variance of the English-speaking countries compared to the other group. From table 3(b), one observes that for the mid-1980's regime change the difference-in-difference estimates is insignificant, implying that the quality variance of ES countries was not significantly different from that of NES countries after this regime change. In addition, variance actually declined after the 1990's changes, leading to the rejection of both hypotheses as an explanation of the two patent surges.

5.3: Effect on Small Inventors

Earlier in the paper, it has been argued that the law changes during the 1980s would have a greater impact on small or uninformed inventors, by decreasing the cost threshold. Therefore the marginal inventors would be more likely to apply for patents in the new regime, if the '*friendly court*' hypothesis is true. I test this hypothesis by using a difference-in-difference approach where the 'treatment' is the 1980s law change ($ProPat_t$) and the 'treated' are the individual inventors ($Small_{jt}$). The outcome variable is the share of patents granted to individual inventors ($Patsh_{ijt}$). I estimate the following model for table 4(a):

$$Patsh_{jit} = \alpha + \varphi Small_{jt} + \theta \Pr oPat_t + \mu(Small_{jt} * \Pr oPat_t) + \sum_{t=1971}^{1998} \delta_t T + \lambda t + v_i + \varepsilon_{jit} \quad (7)$$

where: 'j' is the type of inventor.

As before μ is the differences-in-differences in means between the two groups (big companies[43] and small individual inventors). If this is positive and significant then the regulatory changes increased the patent share of individual inventors compared to the other group, and the patent explosion may thus be partly attributed to the 1980's law changes. From table 4(a) column

[43] To compute the number of patents going to companies in each country we can either add up by assignee country or by inventor country. In the empirical model we use both definitions to test the sensitivity of our results.

1[44], I find that while the law changes increased overall patent shares, the differences-in-differences estimate is negative and significant, rejecting the '*friendly court*' hypothesis as an explanation for the mid-1980s patent explosion.

In addition, I also estimate the same model as 3(a) with the coefficient of variation as the dependent variable, to study the impact of the 1980s law changes on patent quality spreads for small inventors. If the law change argument is true then smaller inventors should experience a greater variation in patent quality compared to the larger firms and μ would be positive and significant. Overall, variance increases after the mid eighties and decreases for small inventors. However, I find that the differences-in-differences coefficient is insignificant, thus rejecting the '*friendly-court*' hypothesis as a possible explanation for the patent increase.

6. Conclusion

This paper contributes to the existing literature on the drivers of patent applications and grants by investigating possible drivers on patent grant rates and their associated impact on patent volume and quality. It builds on the work by Kortum and Lerner (1998) by focusing on the 'friendly-court' hypothesis as a possible explanation for the patent surge in the mid-1980s. In addition, it adds a necessary piece to the literature by focusing on the 1990 changes in the US IPR regime as well. During the early 1980s, the creation of the Court of Appeals of the Federal Circuit and its patent friendly stance, the passing of the Bayh-Dole Act and increase in the scope of patent subject matter vastly increased the probability of obtaining and protecting a patent in the US, and consequently decreased the net-cost of patenting. Changes in the early 1990s made the USPTO more customer-friendly and had adverse impacts on grant standards.

[44] I test the sensitivity of the results by using an alternative counting scheme for the number of patents granted in each country.

I argue that if the 1980s changes were responsible for the mid-eighties patent surge then one should observe increased patent grants which cannot be explained by observed factors such as increase in the proportion of informed inventors in the economy, increase in inventiveness as evidenced by signal about invention quality and changes in application probability of uninformed inventors. Following Kortum and Lerner (1998), I call this the 'friendly court' hypothesis. If this is indeed responsible for the increased patent grants, one should also observe an increase in the variance of patent quality for English-speaking countries. In addition, grant share of small inventors should increase after law change relative to corporations. Overall, I tend to reject the '*friendly court*' hypothesis as the primary cause of the eighties patent explosion.

I find evidence of increases in world inventiveness (as captured by the signal quality variable) positively influencing patent grant rates. In addition, increase in the proportion of informed inventors increase grants rates while an increase in the probability of application by uninformed inventors decrease grants rates. Small inventors or English-speaking countries are not at a special advantage nor does patent quality variance increase after the 1980s law changes. Based on this evidence, I reject the '*friendly court*' hypothesis as the primary cause of the patent explosion, providing additional evidence in support of the Kortum and Lerner argument (1998).

In addition, if the *regime laxity* hypothesis was responsible for increased grants during the 1990s, one should observe positive and significant impacts of year unobservables on grant rates. Also, patent quality variance should increase further and the variance for non-English speaking countries should increase compared to the pre-law change levels. Here, the empirical evidence is more mixed. I find that the *regime laxity* hypothesis is rejected based on the patent grant rate and the English versus non-English speaking country variance models. In addition, increase in the proportion of informed inventors has a stronger impact on the grant rate after the 1990s and variance decreases as signal quality increases post-regime change. However, there is also evidence that these IPR changes increased overall quality variance. Therefore I argue that the patent surge of the 1990s may be have been cause by both, an increase in the proportion of informed inventors producing very high quality patents (leading to an increase in the quality variance) and the customer-friendly patent regime. The '*friendly court*' hypothesis can be largely rejected as a primary explanation for the mid-eighties patent surge, as well. Evidence from the variance equations points to changes in unobserved invention potential factors as possible drivers of this surge.

References

Barton, John H. – "Reforming the Patent System", *Science, Vol. 287, pp. 1933-34, March 2000..*

Bessen, J. & Hunt, R. – "An Empirical Look at Software Patents" *Working Paper No. 03-17/R, Boston University School of Law, March 2004.*

Cohen, W. M & Nelson, R. R. & Walsh, J. P. - "Patenting their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or not)", *NBER Working Paper #7522, 2000.*

Cohen, W. M. & Levin, R. C. - "Empirical studies of Innovation and Market Structure", *in R. Schmalensee & R. Willig ed. Handbook of Industrial organization, vol. II, Chapter 18, 1989.*

GAO – "Patent Policy – Recent Changes in Federal Law Considered Beneficial", *Report to the Chairman, Subcommittee on Courts, Civil Liberties and the administration of Justice, Committee on the Judiciary House of Representatives, GAO/RCED-87-44, April 1997*

Griliches, Zvi – "Patent Statistics as economic Indicators*", Journal of Economic Literature, Vol. 28, 1990, pp. 1661 – 1707.*

Hall, Browyn H., Jaffe, Adam B. & Trajtenberg Manuel – "the NBER Patent Citation Data File: Lessons, Insights and Methodological Tools", *NBER Working Paper # 8498, 2001.*

Hall, B. & Ziedonis, R. - "The Patent Paradox Revisited: An Empirical study of Patenting in the US Semiconductor Industry, 1979 - 1995", *Rand Journal of Economics, 2001, vol. 32(1), pp. 101-128.*

Harhoff, D., Scherer, F. M., Narin, F. & Vopel, K (1999) - "Citation Frequency and the Quality of Patented Inventions," *Review of Economics and Statistics, August, pp. 511-515.*

Jaffe, Adam – "The US Patent System in Transition: Policy Invention and the Invention Process", *Research Policy, Vol. 29, 2000, pp. 531 – 557.*

Jaffe, A. B. - "The US Patent System in Transition: Policy Innovation and the Innovation Process", *Research Policy , 2000, vol. 29, pp. 531 - 55.*

Jaffe, A. B. - "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Quality", *American Economic Review, 1986, vol. 76, pp. 984-1001.*

Jaffe, A. B. & Trajtenberg, M. - "Patents, Citations and Innovations: A Window on the Knowledge Economy", *Cambridge, MA, MIT Press, 2002.*

Kamien, M. I. & Schwartz, N. L. - "Market Structure and Innovation: A Survey", *Journal of Economic Literature, 1975, vol. 13, no. 1, pp. 1-37.*

Kortum, Samuel & Lerner, Josh – "Stronger Patent Protection or Technological Revolution: What is Behind the Recent surge in Patenting?", *Carnegie-Rochester Conference Series on Public Policy, Vol. 48, 1998, pp. 247 – 304.*

Lanjouw, Jean O., Pakes, Ariel & Putnam, Jonathan – "How to Count Patents and Quality Intellectual Property: Uses of Patent renewal and Applications Data", *NBER Working Paper # 5741, 1996.*

Lanjouw, Jean O. & Schankerman, Mark – "The Quality of Ideas: Measuring Invention with Multiple Indicators", *NBER Working Paper # 7345, 1999.*

Mansfield, E. & Switzer, L. - "Effects of Federal Support on Company financed R&D: The Case of Energy", *Journal of Management Science, 1984.*

Merges, R. P. – "Patent Law and Policy", *Charlottesville: Michie Company, 1992*

Popp, David – "Induced Innovation and Energy Prices", *American Economic Review, Vol. 92, no. 1, pp. 160 – 180, 2002.*

Sakakibara, Mariko & Branstetter, Lee – "Do stronger Patents Induce More Inventions? Evidence From the 1988 Japanese Patent Law Reforms", *RAND Journal of Economics, vol. 32, no. 1, Spring 2001, pp. 77-100*

Sampat, B. N. & Ziedonis, A. A. – " Cite Seeing: Patent Citations and the Economic Quality of Patents", mimeo.

Sanyal, P. & Jaffe, A. B. (2004) – "Peanut Butter Patents Versus the New Economy: Does the Increased Rate of Patenting Signal More Invention or Just More Lawyers?" *Working Paper.*

Sanyal, P. (2002) – "Understanding Patents: The Role of R&D Funding Sources and the Patent Office", *Economics of Innovation and New Technology, December, vol. 12, no. 6, pp. 507 – 52.*

Scherer, F. M. - "Firm Size Market Structure, Opportunity and the Output of Patented Inventions", *American Economic Review, 1965, vol. 55, no. 5, pp. 1097-1125.*

Shane, S. (2002), "Selling University Technology: Patterns from MIT", *Management Science, vol. 48, no. 1, pp. 122 – 137.*

Shane, S. (1999), "Technological Opportunities and New Firm Creation," *Management Science, vol. 47, no. 2, pp. 205 – 220.*

Trajtenberg, Manuel (1990) – "A Penny for your Quotes: Patent Citations and the Quality of Innovations", *Rand Journal of Economics, Vol. 21, pp. 127 – 187.*

Williamson, O. E.(1965) - "Innovation and Market Structure", *Journal of Political Economy, vol. 73, no. 1, pp. 67-73.*

APPENDIX FIGURES

Figure 1(a)

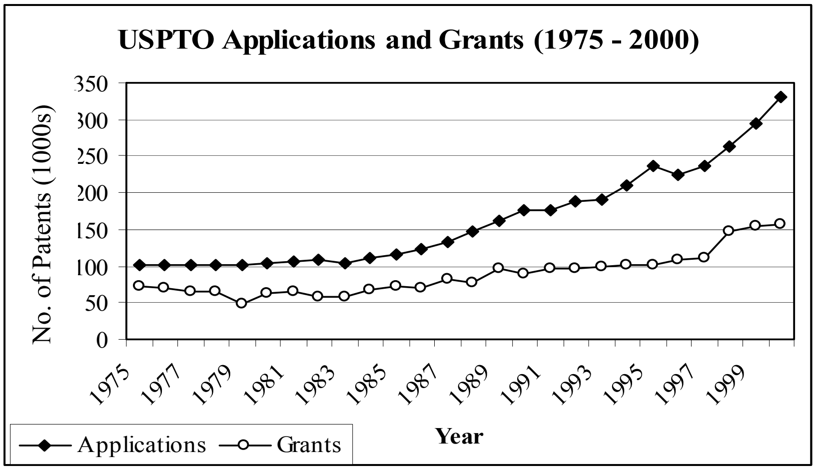


Figure 1(b)

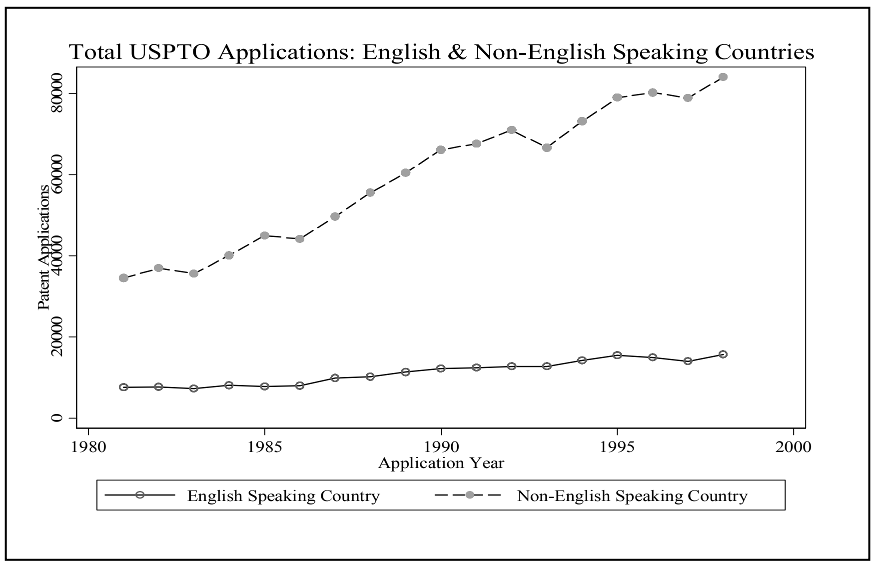


Figure 1(c)

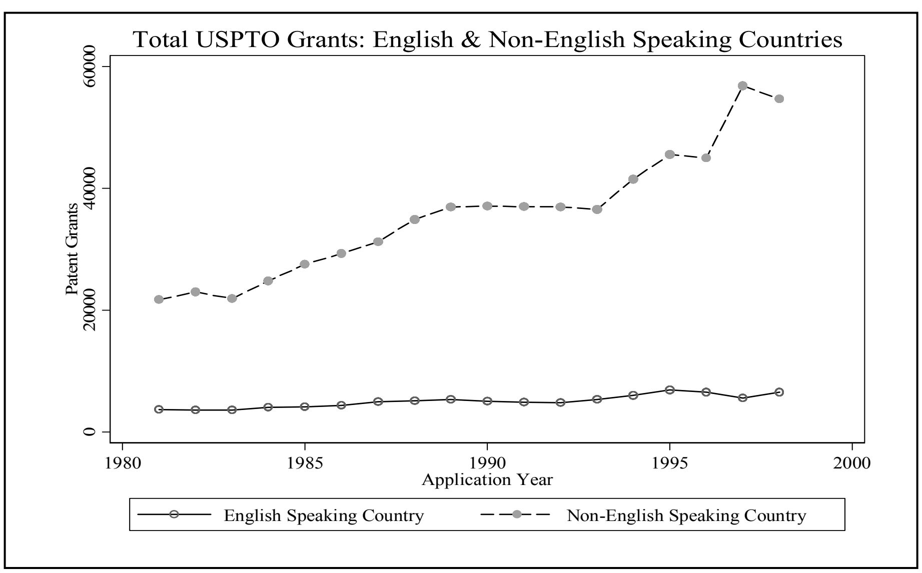
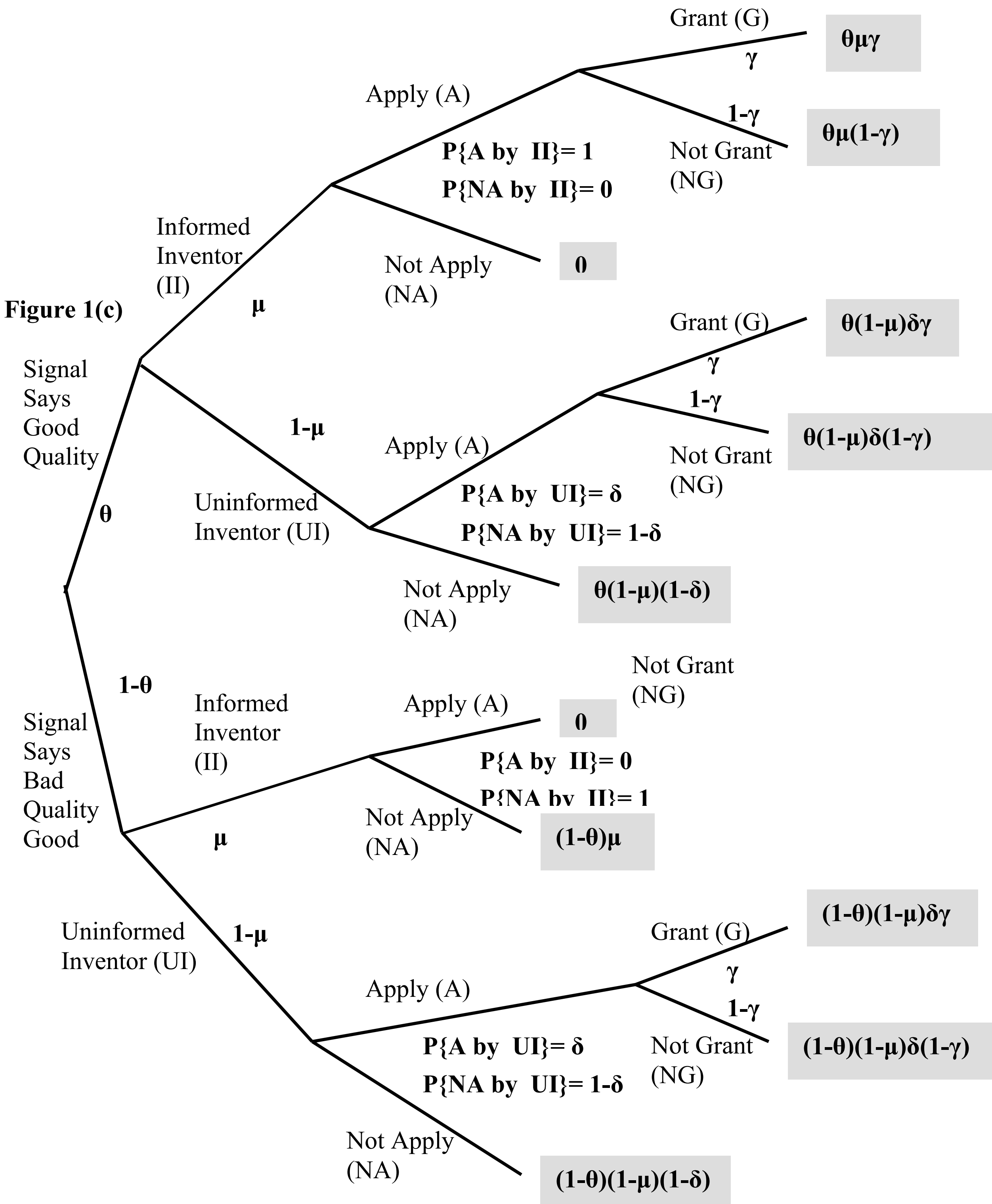


Figure 2: Probability Structure of Patent Grants and Applications



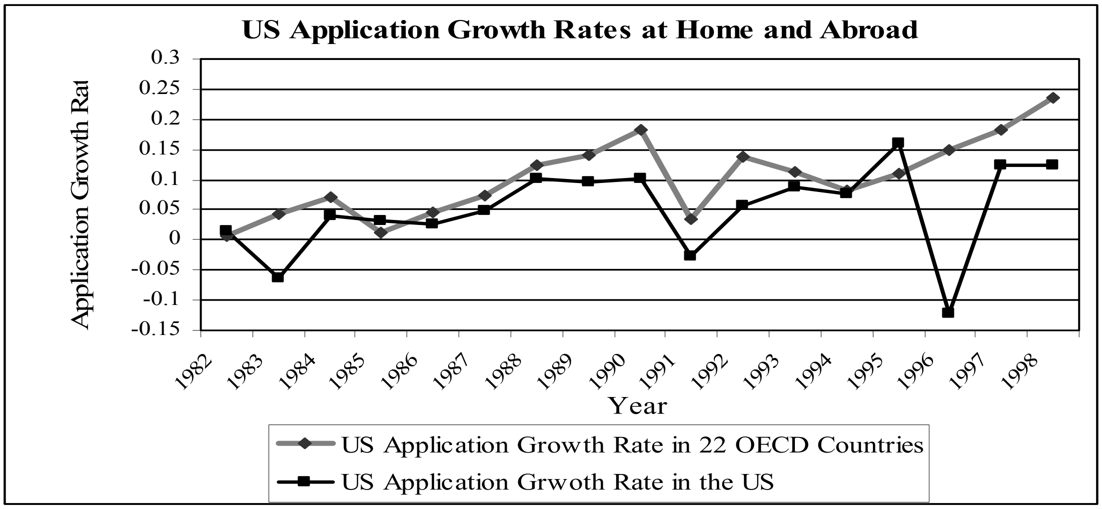


Figure 3(a)

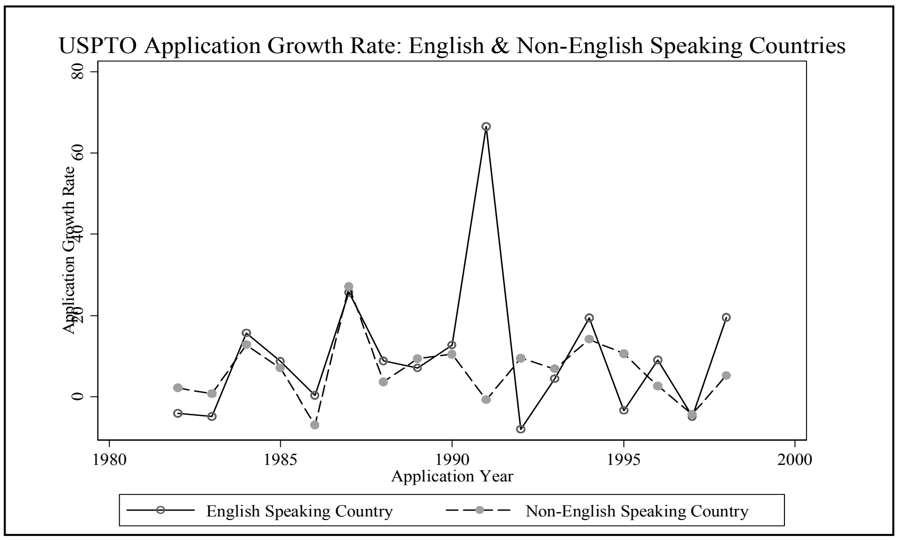
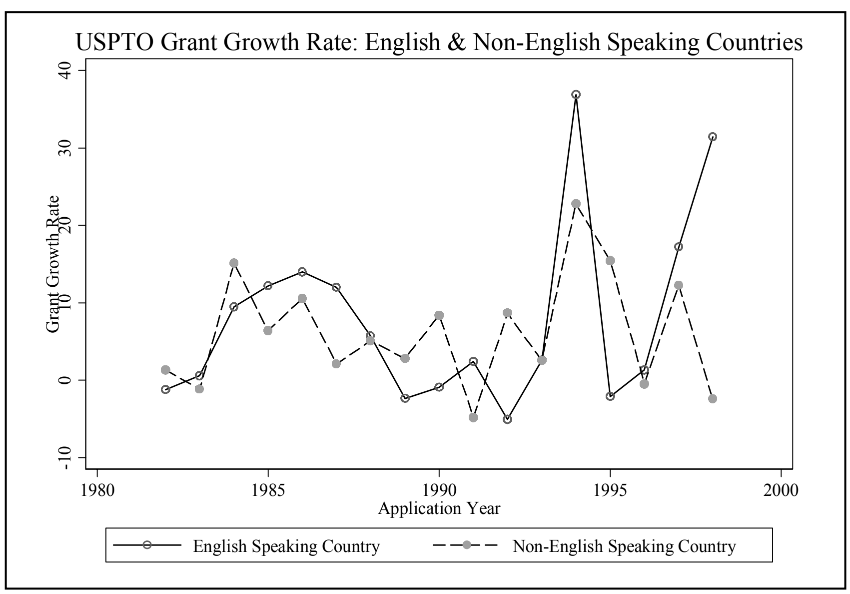


Figure 3(b)

Figure 3(c)



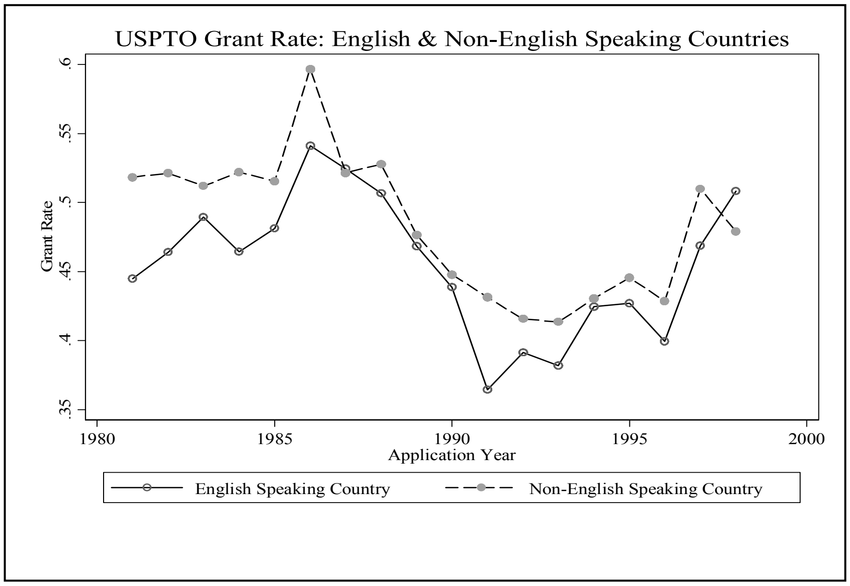


Figure 3(d)

Figure 4

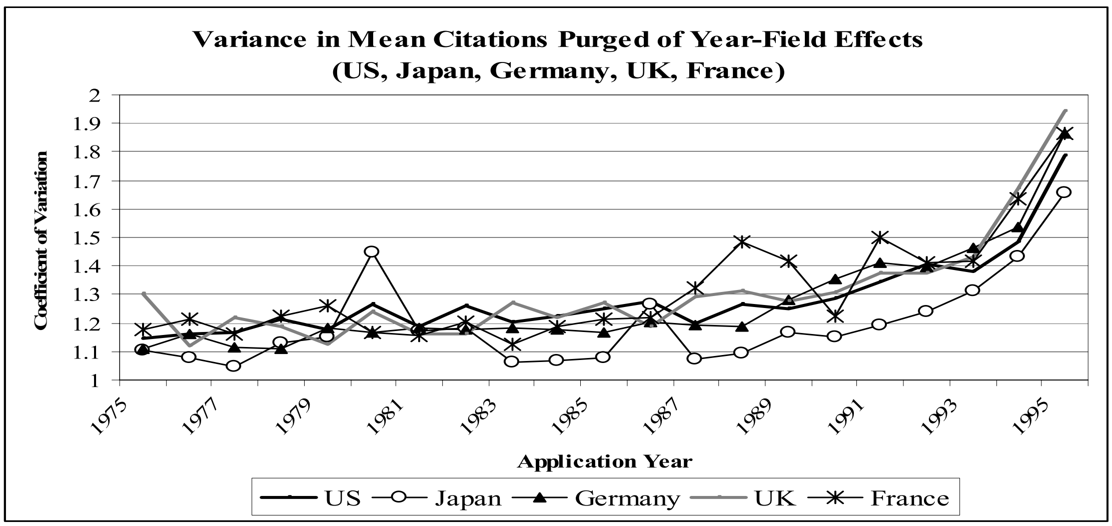
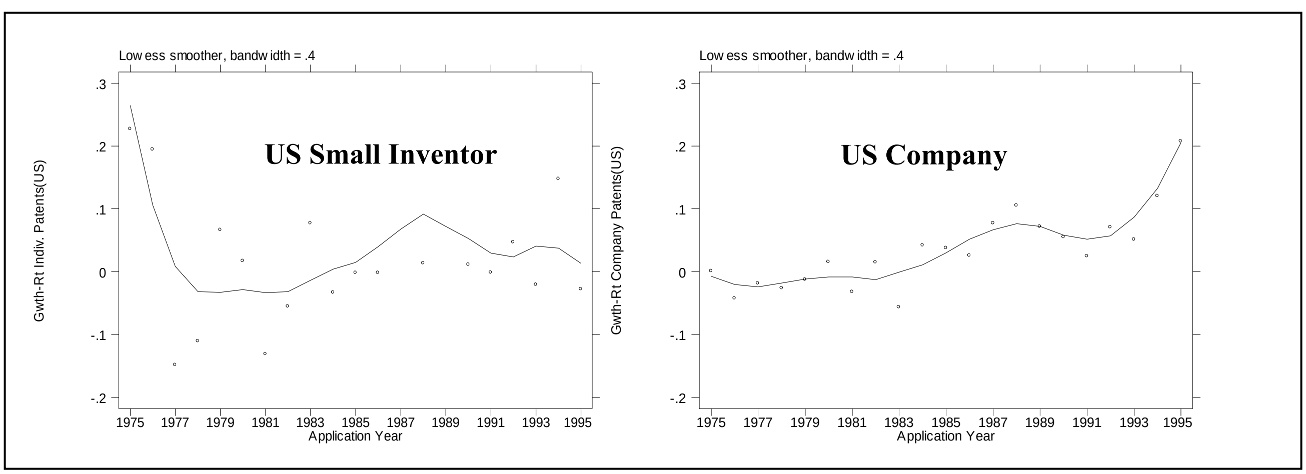


Figure 5: Growth Rate of Patents Granted to US Small Inventors and US Companies



Appendix Tables

Table 1
Summary Statistics

Dependent Variables	**Obs**	**Mean**	**SD**	**Min**	**Max**
Log(US Grant Rate) – 18 OECD Countries (1981-98) (Table 2)	282	-0.763	0.251	-1.759	-0.172
Coefficient of Variation - 18 OECD Countries + US (1981-95) (Table 3)	289	1.334	0.316	0.828	3.728
18 OECD Countries + US (1971-98): Table 4					
Grant Share By Inventor Type (Assignee Ctry)	1274	0.511	0.300	0.016	1
Grant Share By Inventor Type (Inventor Ctry)	1274	0.513	0.317	0.016	1
Coefficient of Variation	1274	1.410	0	0	12.35
Explanatory Variables (1981 – 1995)	**18 OECD Countries + US**				
Prop. of Inf. Inv. in the Ctry. (Lag 1 Yr.)	289	0.121	0.069	0	0.455
Prop. of Inf. Inv. in the Ctry. Sq.(Lag 1 Yr.)	289	0.019	0.024	0	0.207
Signal Quality (Lag 2 Yrs.)	289	0.079	0.235	0.001	3.75
Signal Quality Squared (Lag 2 Yrs.)	289	0.061	0.836	0.000001	14.063
Uninf. Inv. Application Prob. (Lag 1 Yr.)	289	0.439	0.253	0	1
Uninf. Inv. Application Prob. Sq. (Lag 1 Yr.)	289	0.257	0.254	0	1
Explanatory Variables (1981 – 1998)	**18 OECD Countries**				
Log (Prop. of Inf. Inv. in the Ctry)–Lag 1 Yr.	282	-2.194	0.524	-3.912	-1.304
Signal Quality – Lag 2 Yrs.	282	0.070	0.084	0.002	1
Log(Uninf. Inv. Application Prob.) – Lag 1 Yr.	282	-1.053	0.758	-4.321	0
Log (R&D Personnel)	282	10.42	1.279	7.737	13.42
% GERD from Business	282	58.92	10.96	25	77.7
% GERD from Academia	282	23.28	5.700	12.83	50.6
Technological Distance – Lag 2	282	0.898	0.069	0.636	0.990

TABLE 2(A)
EXPLAINING PATENT GRANTS RATES

Dependent Variable: Log(US Grant Rate)	**BASIC MODEL (1)**	**SENSITIVITY ANALYSIS (2)**
Explanatory Variables		
Log (Prop. on Informed Inventors in the Country) – Lag 1 Yr.	0.060 (0.033) *	0.072 (0.035) **
Signal Quality – Lag 2 Yrs.	0.484 (0.149) **	0.444 (0.152) **
Log(Uninformed Inventor Application Probability) – Lag 1 Yr.	-0.033 (0.018) *	-0.050 (0.019) **
Controls		
Log (R&D Personnel)	0.093 (0.074)	0.106 (0.087)
% GERD from Business	-	0.001 (0.003)
% GERD from Academia	-	-0.008 (0.004) *
Technological Distance – Lag 2	-	-0.268 (0.217)
Year Dummies		
Year = 1982	-0.018 (0.046)	-0.009 (0.049)
Year = 1983	-0.005 (0.045)	-0.001 (0.046)
Year = 1984	0.009 (0.043)	0.002 (0.045)
Year = 1985	0.027 (0.041)	0.014 (0.044)
Year = 1986	0.199 (0.041) **	0.180 (0.043) **
Year = 1987	0.046 (0.040)	0.035 (0.041)
Year = 1988	0.065 (0.039) *	0.050 (0.041) *
Year = 1989	-0.035 (0.039)	-0.043 (0.040)
Year = 1990	-0.071 (0.038) *	-0.074 (0.038) **
Year = 1991	-0.139 (0.038) **	-0.138 (0.039) **
Year = 1992	-0.195 (0.038) **	-0.188 (0.038) **
Year = 1993	-0.184 (0.038) **	-0.180 (0.038) **
Year = 1994	-0.106 (0.039) **	-0.103 (0.040) **
Year = 1995	-0.082 (0.040) **	-0.076 (0.046) **
Year = 1996	-0.113 (0.041) **	-0.109 (0.042) **
Year = 1997	0.011 (0.041)	0.022 (0.042)
Time Trend	-0.012 (0.005) **	-0.012 (0.005) **
Constant	21.44 (8.439) **	20.93 (8.786) **
R Square	0.414	0.414
Observations	289	289

Note: A fixed effects model has been used to estimate the equations. There are 18 OECD countries and 17 years (1981-1998). '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 2(B)
EFFECT OF LAW CHANGE

Dependent Variable: Log(US Grant Rate)	**(1)**
Explanatory Variables	
Log (Prop. on Informed Inventors in the Country) – Lag 1 Yr.	0.103 (0.045) **
Signal Quality – Lag 2 Yrs.	0.040 (0.912)
Log(Uninformed Inventor Application Probability) – Lag 1 Yr.	-0.049 (0.030) *
Law Change Interactions	
Mid-1980 Law Dum.*Log(Prop. on Inf. Inv. in the Country) – Lag 1 Yr.	-0.075 (0.041) *
Mid-1980 Law Dum.*Signal Quality – Lag 2 Yrs.	0.069 (0.902)
Mid-1980 Law Dum.* Log(Uninf. Inv. Application Prob.) – Lag 1 Yr.	-0.013 (0.028)
Early-1990 Law Dum*Log (Prop. on Inf. Inv. in the Country) – Lag 1 Yr.	0.150 (0.042) **
Early-1990 Law Dum *Signal Quality – Lag 2 Yrs.	-0.145 (0.492)
Early-1990 Law Dum* Log(Uninf. Inv. Application Prob.) – Lag 1 Yr.	0.007 (0.032)
Controls	
Log (R&D Personnel)	0.163 (0.091) *
% GERD from Business	0.003 (0.004)
% GERD from Academia	-0.006 (0.004)
Technological Distance – Lag 2	-0.334 (0.222)
Year Dummies	
Year = 1982	-0.012 (0.050)
Year = 1983	-0.023 (0.047)
Year = 1984	-0.023 (0.053)
Year = 1985	-0.027 (0.050)
Year = 1986	-0.051 (0.098)
Year = 1987	-0.213 (0.098) **
Year = 1988	-0.204 (0.094) **
Year = 1989	-0.310 (0.105) **
Year = 1990	-0.350 (0.092) **
Year = 1991	-0.419 (0.104) **
Year = 1992	-0.136 (0.050) **
Year = 1993	-0.131 (0.055) **
Year = 1994	-0.074 (0.049)
Year = 1995	-0.062 (0.045)
Year = 1996	-0.110 (0.043) **
Year = 1997	-0.042 (0.041)
Constant	8.816 (15.40)
R Square	0.409
Observations	282

Note: A fixed effects model has been used to estimate the equations. There are 18 OECD countries and 17 years (1981-1998). And Observations = 282. This equation has a negative time trend, but it is not significant. '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 3(A)
EXPLAINING VARIANCE IN PATENT QUALITY

Dependent Var.: Coefficient of Variation	BASIC MODEL (1)	MID-1980 LAW CHANGE (2)	EARLY-1990 LAW CHANGE (3)
Explanatory Variables			
Prop. of Inf. Inv. in the Ctry. – Lag 1 Yr.	2.295 (0.844) **	-0.157 (1.709)	2.117 (0.950) **
Prop. of Inf. Inv. in the Ctry. Sq.– Lag 1 Yr.	-4.348 (2.073) **	5.977 (6.904)	-4.257 (2.572) *
Signal Quality – Lag 2 Yrs.	-0.565 (0.274) **	1.629 (3.784)	2.374 (1.819)
Signal Quality Sq.– Lag 2 Yrs.	0.160 (0.073) **	-9.568 (34.06)	-9.474 (8.184)
Uninf. Inv. Application Prob. – Lag 1 Yr.	-0.715 (0.346) **	-0.532 (0.528)	-1.021 (0.425) **
Uninf. Inv. Application Prob.Sq – Lag 1 Yr.	0.468 (0.308)	0.271 (0.501)	0.728 (0.382) **
Mid-1980s Law Change			
Mid -1980's Law Change Dummy	-0.057 (0.067)	-0.643 (0.141) **	-
Mid-1980 Law Dum.* Prop. of Inf. Inv. in the Ctry – Lag 1 Yr.	-	3.099 (1.911)	-
Mid-1980 Law Dum.* Prop. of Inf. Inv. in the Ctry Sq. – Lag 1 Yr.	-	-11.60 (7.253)	-
Mid-1980 Law Dum.*Signal Quality – Lag 2 Yrs.	-	-2.264 (3.780)	-
Mid-1980 Law Dum.*Signal Quality – Lag 2 Yrs. Squared	-	9.748 (34.06)	-
Mid-1980 Law Dum.* Uninf. Inv. Application Prob. – Lag 1 Yr.	-	-0.247 (0.506)	-
Mid-1980 Law Dum.* Uninf. Inv. Application Prob. Sq. – Lag 1 Yr.	-	0.292 (0.500)	-
Early-1990s Law Change			
Early -1990's Law Change Dummy	0.190 (0.070) **	-	0.654 (0.145) **
Early-1990 Law Dum* Prop. on Inf. Inv. in the Ctry. – Lag 1 Yr.	-	-	-0.006 (1.239)
Early-1990 Law Dum* Prop. on Inf. Inv. in the Ctry. Sq. – Lag 1 Yr.	-	-	0.395 (3.256)
Early-1990 Law Dum *Signal Quality – Lag 2 Yr.	-	-	-3.016 (1.796) *
Early-1990 Law Dum *Signal Quality Sq. – Lag 2 Yrs.	-	-	9.661 (8.178)
Early-1990 Law Dum* Uninf. Inv. Application Prob. – Lag 1 Yr.	-	-	0.725 (0.506)
Early-1990 Law Dum* Uninf. Inv. Application Prob. Sq. – Lag 1 Yr.	-	-	-0.542 (0.497)
R Square	0.460	0.458	0.493

Note: A fixed effects model has been used to estimate the equations. There are 18 OECD countries plus US and 15 years (Due to truncation sample is limited to 1995). Obs = 282. This equation has a negative time trend, but it is not significant. It also includes a positive and significant constant term and year dummies. '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 3(B)

DIFFERENCE BETWEEN ENGLISH-SPEAKING AND NON-ENGLISH SPEAKING COUNTRY VARIANCE

Dependent Var.: Coefficient of Variation	MID-1980 LAW CHANGE (1)	EARLY-1990 LAW CHANGE (2)
Explanatory Variables		
Prop. on Inf. Inv. in the Country – Lag 1 Yr.	2.402 (0.851) **	2.399 (0.843) **
Prop. on Inf. Inv. in the Country Sq. – Lag 1 Yr.	-4.566 (2.085) **	-4.560 (2.069) **
Signal Quality – Lag 2 Yrs.	-0.595 (0.276) **	-0.661 (0.278) **
Signal Quality Sq. – Lag 2 Yrs.	0.167 (0.073) **	0.182 (0.074) **
Uninf. Inv. Application Prob. – Lag 1 Yr.	-0.703 (0.346) **	-0.643 (0.346) *
Uninf. Inv. Application Prob. Sq. – Lag 1 Yr.	0.444 (0.309)	0.397 (0.310)
Treated Group and Treatment		
English Speaking Country Dummy (Treated)	0.036 (0.117)	0.035 (0.111)
Mid -1980 Law Change Dum.(After Treatment Period)	0.062 (0.071)	-
Early-1990 Law Change Dum.(After Treatment Period)	-	0.896 (0.071) **
Difference-in-difference Estimates		
Mid -1980's Law Change Dummy* English Dummy	-0.061 (0.060)	-
Early 1990's Law Change Dummy* English Dummy	-	-0.111 (0.063) *
Observations	284	284

Note: A fixed effects model has been used to estimate the equations. There are 18 OECD countries plus US and 15 years (1981-1995). Obs = 282. Since there is considerable truncation in the data after 1996, I limit my estimation sample to 1995. All specifications contain year dummies. '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 4(A)

EFFECT OF 1980 LAW CHANGES ON GRANT SHARE OF SMALL INVENTORS

	SHARE OF PATENT GRANTS (BY INVENTOR COUNTRY) (1)	SHARE OF PATENT GRANTS (BY ASSIGNEE COUNTRY) (2)
Small Inventor Dummy (Treated)	-0.483 (0.012) **	-0.423 (0.013) **
Mid-1980 Law Change Dummy (Treatment)	0.075 (0.037) **	0.077 (0.040) *
Small Inventor Dummy * Mid-1980 Law Change Dummy	-0.139 (0.018) **	-0.141 (0.019) **
Country Fixed Effects	Yes	Yes
Year Dummies	Yes	Yes
Time Trend	-0.0001 (0.002)	-0.0001 (0.002)
Constant	1.018 (4.505)	1.087 (4.918)
Fraction of Variance Due to FE	0.006	0.008
R Square	0.764	0.689
Observations	1248	1248

Note: A fixed effects model has been used to estimate the equations. There are 18 OECD countries plus US and 29 years (1970 – 1998). This updated data is from Bronwyn Hall's updated patent database.'*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 4(B)

EFFECT OF 1980 LAW CHANGES ON PATENT QUALITY VARIANCE OF SMALL INVENTORS

Dependent Variable: Coefficient of Variation	(1)
Small Inventor Dummy (Treated)	-0.065 (0.031) **
Mid-1980 Law Change Dummy (Treatment)	1.117 (0.147) **
Small Inventor Dummy * Mid-1980 Law Change Dummy	0.070 (0.045)
Country Fixed Effects	Yes
Year Dummies	Yes
Time Trend	0.001 (0.006)
Constant	-0.850 (11.36)
Fraction of Variance Due to FE	0.063
R Square	0.340
Observations	1217

Note: A fixed effects model has been used to estimate the equations. There are 18 OECD countries plus US and 29 years (1970 – 1998). This updated data is from Bronwyn Hall's updated patent database.'*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.