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Quantifying Changes in Innovation: Patenting Activity and IPR Regimes*

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Abstract

This paper develops a sequential application-grant framework to analyze how changes in patent regimes influence an inventor's propensity to patent. Using the two changes in the U.S. patent system during the mid-eighties and early nineties, we distinguish between increases in patenting activity due to (a) the lowered cost of patenting (friendly court hypothesis) and (b) lowered patent examination standards (regime laxity hypothesis). Results from the empirical models show that the patent surge of the mid-1980s can be partly attributed to the "friendly court hypothesis." The 1990s surge cannot be attributed to regime laxity and was a result of increasing world inventiveness.

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

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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, until 1985, the number of patent applications remained between 40,000 and 100,000, and the number of 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, when applications and grants surged by another 50 percent. Thus, in the 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 US intellectual property right (IPR) regime and have 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. Six 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; increasing patent value in certain fields; 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 because of increased resident patent applications, it would signal growing U.S. inventiveness. However, 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, we must ask whether or not there was a 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? Did this increase 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, we must consider whether the surge was due to the changing nature of innovative activity and shifting business practices. If the surge was due to a shift from basic to applied research or to changes in firm size, behavior, industry structure, or market concentration (Cohen & Levin, 1989; Kamien & Scchwartz, 1975; Mansfield, 1963, 1968; Scherer, 1965; Williamson, 1965), it would have had little to do with new knowledge creation. For example, in the semiconductor industry, 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

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

significant gain for applied research funding in comparison to basic research funding. Hence, one may rule out this explanation as the primary cause of the patent surge.

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 the 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, which led to increases in patent applications and 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 ushered in the "customer-friendly" era of the patent office. In this environment, inventors were viewed as clients who were paying to get a service. 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 it would, instead, denote some fundamental shifts in the underlying innovative capacity of countries.

1.1 Background

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

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. Their primary hypothesis, termed the "friendly-court hypothesis," proposed that the enormous increase in patenting was a result of US patent law changes. They compared this with two alternative explanations – 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 arguments. There has been an overall increase in patent applications from all sources, which can only be explained by the fertile technology hypothesis. Thus the explosion of patenting in the 1980s was a result of an increase in US and world inventiveness and was 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. When ruling out law change as the cause of the patent surge, the authors argue that if law change had caused the increase in applications and grants, 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 do domestic inventors.[7] If the law change altered the cost of US applications, it

[4] As the name suggests, the "fertile technology hypothesis" proposed that the recent patent surge occurred due to an increase in world inventiveness or to the 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, which 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 grow as a destination (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 the 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] Translation costs are one of the biggest costs in this process. For example, a French inventor has to incur the cost of translating all his documents into English before he can apply to the US.

would affect these two groups differently; domestic applications would show a greater increase than would foreign applications.

In addition, strong correlations between multi-country application decisions indicate that the action of applying to an inventor's home country and the action of applying to a foreign country are not independent. For a vast majority of patents, when an inventor has undertaken the patenting process in his domestic country, the costs of patenting in a second country are not prohibitive. Thus, if the 1980s 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 1990s 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 (whether the inventor applies for a patent or not) to determine her own response. The primary decision the principal has to make 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 who applies for a patent without knowing the quality of the invention. 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.[8]

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

[8] In most decision models, the principal observes both types of actions – for example 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 the expected quality of the invention, given the information.

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 a random variable V which is bounded between [0,∞), and denotes the intrinsic net quality of the invention.[9]

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 ($\underline{V}$).[10] 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., the 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 does not know the true quality of the invention. She tries to formulate the probability of observing a good versus a 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- θ), 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-μ) is the probability that the inventor is uninformed. The third node shows the

[9] The quality of the invention refers to the "importance" of the invention in the particular field and the market value of the invention. 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.
[10] 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.

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 probability is $(1-\delta)$ 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 one to calculate the probability of application at each grant node.[11] This, coupled with the examiner's grant probability, yields the expression for the probability of observing a grant: 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 $\mu=\delta=1/2$.[12] 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.[13]

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 her beliefs, decides whether or not to grant a patent. The patent examiner does not know the exact

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[11] The probability of observing an application is given by summing over all these application probabilities: 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 $\theta(1-\mu)\delta\gamma$.

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

[13] In this simple formulation we have not modeled the determinants of these probabilities. We could assume, for 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 are spent on a project, the greater the probability would be of observing a good signal. The empirical model includes this.

quality of the invention. After she observes an application, she uses the information conveyed by this "event" to construct posterior probabilities (Ω) that the invention is of high quality i.e. V=$\overline{V}$,[14] which is given by:

$$\Pr ob\{V = \overline{V} \mid Appli.\} = \Omega = \frac{\theta\mu + \theta(1 - \mu)\delta}{\theta\mu + (1 - \mu)\delta} \qquad (1)$$

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=$\overline{V}$ increases at a decreasing rate as θ increases.[15] 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=$\overline{V}$ given application increases.[16] 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.[17]

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) due to, for example, 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, such as the relative ease with which startups can raise venture capital if they have

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

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

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

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

some patents.[18] Increase in the first two factors will increase grant rates, but 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.[19] 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*). For example, 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.[20]

$$\text{Examiner's Decision: } \begin{cases} \textit{Grant Patent} & \textit{if} \quad \mathrm{Pr}ob\{V = \overline{V} \mid Appli.\} = \Omega \geq \Omega^* \\ \textit{Not Grant} & \textit{Otherwise} \end{cases}$$

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

Ω* is determined by the objective of the patent office. If the objective function is to maximize aggregate patent quality subject to certain constraints,[21] 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.

[18] This does not imply that there are no feedback effects from the 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.

[19] The examiner's decision problem is more complex than posited here – for example, instead of 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.

[20] 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.

[21] 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 to 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).[22] 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., it decreased the net cost of patenting. Hence, it shifted the net quality distribution to the right, as shown in Figure 1 below. If the gross quality distribution was unchanged but costs were lower, it would imply that this law change allowed more marginal inventors to apply for patents.

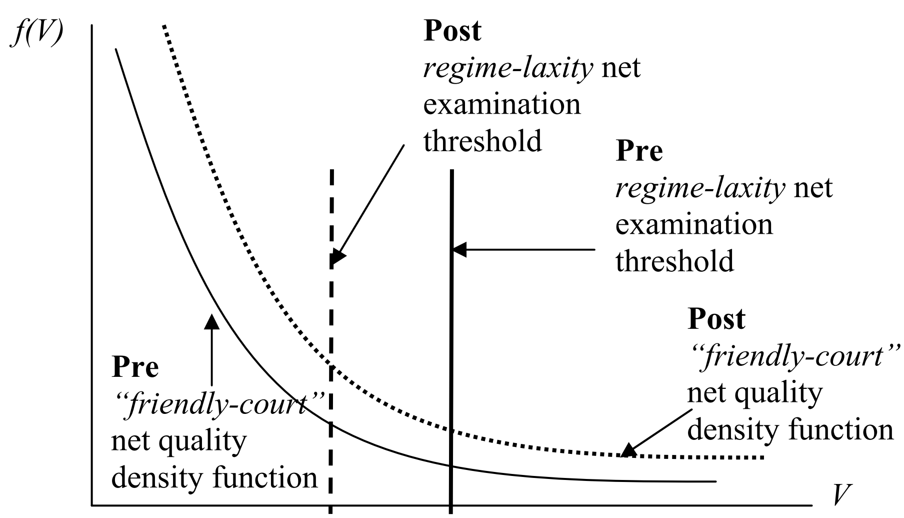

Figure 1

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

[22] 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.

more marginal) patents being granted, as shown in the figure above. Thus the effect of both these changes was to increase the 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 shift the net-quality density function to the right, leading to more applications and grants. In addition, a decline in examination standards and an increase in gross intrinsic quality would have the same observed effect on applications and grants. Hence, one needs to rely on other effects of the two regime shifts to separately identify the impact of law changes on patenting, distinct from the changes in patent behavior due 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, quality, and quality variance should be different for inventors with a low cost barrier (such as the English-speaking country inventors or large or informed inventors) and those with a high cost barrier (such as non-English-speaking country inventors or small or uninformed inventors).

First, 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[23] is stricter than the threshold that ES inventors face due to factors such as document translation costs. Thus, the US cost threshold may be non-binding for these inventors, and at the margin, their actions may not be affected by the US law change. Second, patents from 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

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

such uninformed inventors to apply. In the econometric 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 prove that this increase occurred partly as a result of the law change and not solely because of the changing invention production function? 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 will. In addition, the examiners' perceived beliefs about invention quality (Ω) would then be greater for ES than it would be for NES inventor patents. This would have the effect of more ES inventions crossing the legal threshold when compared with NES inventions. This implies that the grant rate of ES inventor patents would be greater than that of NES inventor patents during this period. Another implication of the lowered cost of patenting is the increase in the probability of application (δ) by uninformed inventors from all countries. 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 lower quality and 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 (1986 – 1992):

(a) *Impact on grant rate*

i. *Proportion of informed inventors and signal quality: impact similar in both periods*

ii. *Application probability of uninformed inventors: Less adverse impact after change*

(b) *Impact on patent quality and quality variance: unclear*

(c) *ES country versus NES country*

i. *ES grant rate increases by more than NES grant rate after change*

ii. *ES country patent quality lower than NES country patent quality after change*

iii. *ES country quality variance greater than NES country variance after change*

(d) *Marginal inventor grant rate should grow at a faster pace post-law change*

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) and the proportion of informed inventors (μ) 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 probability of application by uninformed applicants (δ) should increase, and we should see uninformed inventors having a greater impact on grant standards during the nineties. Granting of more marginal patents will decrease the average quality and increase the variance in patent quality. The result should be asymmetric between ES country inventors and NES country inventors. Thus, shifting the US legal threshold may have the following effects:

Regime Laxity Hypothesis (Post-1992):

(a) *Impact on grant rate*

i. *Proportion of informed inventors and signal quality: impact diminishes post -law change*

ii. *Application probability of uninformed inventors: Less adverse impact after change*

(b) *Impact on patent quality and quality variance*

i. *Patent quality should decline after law change*

ii. *Quality variance should increase after law change*

(c) *ES country versus NES country*

i. *ES grant rate increases by more than NES grant rate after change*

ii. *ES patent quality decreases less than that of NES patents after change*

iii. *ES quality variance increases less than that of NES patents after change*

In the following section I test 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 the "Patent Citations Database" at the National Bureau of Economic Research (NBER); the World Intellectual Property Organization (WIPO) 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 2002.[24] It comprises application and grant years, geographical distribution of these patents, technology classifications, forward and backward citations[25] 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 domestic and foreign application and grant rates.[26]Variables such as research and development spending and GDP are obtained 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 grant rates decline in the mid-eighties and increase during the early nineties, and the average rate is lower for ES countries when compared to NES countries throughout the sample period. This supports our assumption that, on average, the higher internal cost constraints of the NES country inventors lead to higher patent values. In addition, the 1980s law change seems to be rejected as the primary driver of the eighties patent

[24] Browyn Hall's updated database was used for this paper
[25] US citation only.
[26] There is considerable double counting in the WIPO data. Thus, for the empirical analysis, I use the cleaned data provided by Prof. Sam Kortum.

explosion. However, we cannot reject the hypothesis that the nineties changes were responsible for the nineties patent surge.

Next, I focus on examining the average quality and quality variance 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[27] 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[28] shed light on the technological roots of an invention and on patent scope, and 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[29] and calculate the coefficient of variation measure based on this. To compare across years and technology

[27] 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.

[28] "Backward" citations are those that a patent cites, whereas "forward" citations are counts of how many other patents have cited a particular patent.

[29] 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 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- a propensity that needs to be controlled for when using citations as quality measures in any estimation model.

fields, I adjust the citations using the fixed effects methodology outlined by Hall et al. (2001). The raw number of citations for each patent is purged of year, field, and year-field effects by dividing them by the year-field means.[30]

Prior to the empirical estimation, I present some basic graphs that shed light on the impact of the legal changes on patent quality. The friendly court hypothesis postulates that the quality should be lower and the variance higher for ES country patents compared to NES country patents. The regime laxity hypothesis implies that, compared to pre-1990 levels, the quality of NES patents should decrease and variance should increase compared to ES country patents. From Figures 3(a), I find that the average (adjusted) citations per patent are lower for NES countries as compared to ES countries throughout the sample period, rejecting the friendly court hypothesis. In addition, in keeping with the predictions of the regime laxity hypothesis, patent quality for both ES and NES shows a slight decline after the mid-1990s. Figure 3(b) shows that the variance is fairly similar and steady in the eighties and increases slightly in the nineties for both groups, thus rejecting the friendly hypothesis and weakly supporting the regime laxity hypothesis.

Last, we study whether the eighties law changes gave any advantage to the uninformed inventors, as the friendly court hypothesis would predict. From Figure 4 we find that this is not the case. If one defines uninformed inventors as individual inventors, then Figure 4 shows that there has been a sharp decline in the patent share of such inventors over the entire sample period, thus rejecting the friendly court hypothesis. In conclusion, the graphical evidence favors rejecting the friendly court hypothesis, and no definitive conclusion can be drawn about regime laxity.

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[30] Hall et al. (2001) point out that this rescaling of the citation intensities by the year-field means takes out both the real and artificial impacts 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

To further understand the impact of law changes on various dimensions of the patent application and grant processes and the implications for patent quality, I use the theoretical framework developed earlier to formulate the empirical model. First, I develop measures of signal quality, the 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 US 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 lower grant 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 19 OECD countries[31] and use the theoretical model to construct the constituents of the expected grant probability estimates at the country level.[32] 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.

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

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

[32] 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[33] is comprised of the proportion of informed inventors in a country (i_{it}); the 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 the mid-1980s and early 1990s and should also be increasing significantly over time. I estimate a panel data fixed effects model for nineteen countries (i is the source country) given by:

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

where:

- US grant rate (g_{it}) = Number of patents granted by USPTO to country i in year t / Number of applications to the USPTO from country i in year t
- Proportion of informed inventors ($i_{i,,t-s}$) = 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[34] in a given patent class for country i in year t-s.[35] This total excludes government patents.
- 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

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

[34] I use the assignee and 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 three 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.

[35] 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.

- Uninformed inventor application probability ($a_{i,t-s}$)[36] = Number of patents from assignees who had one USPTO patent in a given patent class for country i in year t-s / Number of domestic patent grants in country i in year t-s.
- Z_{it} = Control variables pertaining to country source i in year t, e.g., level and composition of R&D expenditure, level of wealth, technological distance from the US,[37] etc.
- η_i = Country fixed effects
- δ_T = Year fixed effects or Regime change measure, where T are year dummies.

Table 2(a) estimates the basic model (equation 3). We find that the results confirm the findings of the sequential game-theoretic model developed earlier, and all the coefficients have the predicted signs. I find that a 1 percent increase in the proportion of informed inventors increases USPTO grant rates by 0.023 percent, and a 1 percent increase in signal quality increases the grant rate by almost 0.03 percent. In addition, an increase in the application probability by uninformed inventors dampens the grant rate, and a 1 percent increase in the former leads to a 0.01 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 the US while an increase in the application probability of uninformed inventors dampens it. The

[36] 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.

[37] 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 eight IPC classes.[37] 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 use a country's patent application composition in 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.

specification also includes controls such as the application country's GDP, gross R&D expenditure, the size of the manufacturing sector, and technological distance of the country from the US. I find that as the technological distance between the application country and the US increases, the grant rate is adversely affected. This may imply that countries whose technology profile is very different from that of the US have greater difficulty obtaining US patents. Also, as expected, increasing R&D expenditure increases the number of patents granted. The GDP of the country and the size of its manufacturing sector have no significant impact on patent 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 for the mid-1980s and early 1990s. From the coefficient estimates we find that a majority of the year dummies are positive and significant throughout the sample period, implying that unobservable changes have a positive impact on the grant rate. Thus, based on this evidence, one cannot reject either the friendly court or the regime laxity hypotheses. However, this specification cannot distinguish between these two hypotheses and a real change in world inventiveness. To study this question further, in the next section, I investigate how these regime changes affect the slope coefficients.

5.1.2: Effect of Law Changes on Observables

In Table 2(b), Column 1, I add two dummy variables denoting each of the law changes to the specification in equation 3.[38] I find that the coefficients on the observables are unchanged. The mid-1980s dummy is positive and significant, and the early-1990s dummy is negative and significant. This implies that the eighties change increased grant rates and the nineties change decreased it. To further explore this issue, I then interact the slope coefficients with these two law change dummies (for mid-1980s: D_{1986} and for 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

[38] Column 1 in Table 2(b) also contains year fixed effects, although some of these are not indentified when the law change dummies are included.

quality, and the probability of application by an uninformed inventor. The estimated equation in Table 2(b), Column 2 is given by:

$$g_{it} = \alpha + \sum_{K=1}^{3} \beta_K X_{i,t-s}^{K} + \delta D_{1986} + \sum_{K=1}^{3} \delta_K X_{i,t-s}^{K} D_{1986} + \theta D_{1992} + \sum_{K=1}^{3} \theta_K X_{i,t-s}^{K} D_{t=1992}$$
$$+ \sum_{M=1}^{m} \lambda_M Z_{it} + \sum_{t=1982}^{2000} \pi_t T + v_i + \varepsilon_{it} \qquad (4)$$

where: D_{1986} =1 if year >= 1986, 0 otherwise, and D_{1992} =1 if year >= 1992, 0 otherwise. The aggregate impact of the eighties and nineties changes on the slope coefficients are given by $(\beta_K + \delta_K)$ and $(\beta_K + \delta_K + \theta_K)$ respectively (if the coefficients are significant). From the theoretical framework we expect grant rates to increase after both law changes. To understand whether the increase is due to the law changes or increasing world inventiveness, we test the implications of the law changes outlined earlier. If the law changes were indeed responsible for the patent surges the following should hold:

H1: Impact of proportion of informed inventors and signal quality on grant rate

i. Impact similar pre- and post- mid-1980s law change

ii. Impact diminishes after 1990s law change

H2: Application probability of uninformed inventors has a less adverse effect on grant rate after each law change

From Table 2(b), Column 2, I find that the eighties and nineties law changes have different impacts on the slope coefficients. The nineties changes did not affect any of the slope coefficients, and the law change dummy is negative, rejecting the regime laxity hypothesis. The eighties changes, however, decreased the impact of informed inventors on grant rates (0.007 percent after the regime change as opposed to 0.11 percent before). Signal quality does not have an impact on grant rates in this model. The application probability of uninformed inventors has less of an adverse effect on grant rates after the eighties law change (-0.012 percent after the regime change as opposed to -

0.028 percent before).[39] The aggregate impact of the eighties law change is an increase of grant rates by 17.7 percent. The eighties changes seem to have loosened the link between the factors that should affect patent applications and observed patent grants and increased grant rates. Thus, we cannot reject the friendly court hypothesis as a possible explanation for the mid-1980s patent surge. From Table 2(a) and (b) there are indications that the eighties IPR regime change did have some impact on the patent grant rates, but the nineties regime laxity may not have significantly impacted grant rates. The next section studies the effect of IPR regime changes on patent characteristics and the variance in patent quality metrics to further investigate how the eighties and nineties law changes affected patenting.

5.2: Differences in Patent Quality and Quality Variance

5.2.1: Patent Quality Pre- and Post-Law Changes

Patent quality is measured by the number of citations received by a patent, purged of year and field effects. Since there is no apriori reason to believe that this has a linear relation to the explanatory variables, we add square terms for the regressors to equation (4) to allow for flexible functional form.

$$y_{it} = \alpha + \sum_{K=1}^{3} \beta_K X_{i,t-s}^K + \sum_{K=1}^{3} \gamma_K \left(X_{i,t-s}^K\right)^2 + \delta D_{1986} + \sum_{K=1}^{3} \delta_{1K} X_{i,t-s}^K D_{1986} + \sum_{K=1}^{3} \delta_{2K} \left(X_{i,t-s}^K\right)^2 D_{1986}$$
$$+ \theta D_{1992} + \sum_{K=1}^{3} \theta_{1K} X_{i,t-s}^K D_{1992} + \sum_{K=1}^{3} \theta_{2K} \left(X_{i,t-s}^K\right)^2 D_{1992} + \sum_{M=1}^{m} \lambda_M Z_{it} + \sum_{t=1982}^{2000} \pi_t T + v_i + \varepsilon_{it} \qquad (5)$$

In equation 5 above, y_{it} denotes patent quality (log(mean adjusted citations). D_{1986} captures the 1980s law changes, and D_{1992} captures the 1990s changes. If δ and θ are negative and significant, there is evidence that patent quality has been adversely affected by the two regimes shifts. The

[39] 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.

coefficients on the interaction terms between the law change dummies and the independent variables show whether these law changes affected the slope coefficients.

Results are presented in Table 3(a) and (b).

From the earlier theoretical framework, I expect the proportion of informed inventors and signal quality to have a positive impact on patent quality. An increase in the application probability of uninformed inventors is expected to lower quality. From Table 3(a) I find that, in line with the predictions, as the proportion of informed inventors increases by 1 percent, patent quality increases by 0.45 percent. However, the signal quality and uninformed inventor application probability variables have the wrong signs. This may be due to an omitted variables problem since law change dummies or the interactions are not included. In Table 3(b) I estimate a fuller model, correcting for this bias. The primary testable hypothesis from the earlier discussion on the effect of the law changes on patent quality holds that if regime laxity is responsible for the 1990s patent surge, then the following is true:

H3: Overall patent quality may be unchanged after the mid-1980s law change, but it should decline after the 1990s law change

In Table 3(b) I add the law change dummy in Column 1, but this does not affect the earlier coefficient estimates. In Column 2, when the interaction terms are added, I find that the slopes are significantly affected by the law changes.[40] The aggregate effect of the eighties law change is to decrease patent quality by 1.4 percent ,whereas the nineties changes increased quality by 1.09 percent. These findings, along with the earlier results about the eighties changes significantly

[40] A 1 percent increase in the proportion of informed inventors increases patent quality by .7 percent before the eighties law change, decreases patent quality by 0.09 percent between 1986 and 1992, and increases patent quality by 1.12 percent after the nineties law change. The aggregate effect of the two law changes is an increase of patent quality by 0.33 percent when the proportion of informed inventors increases by 1 percent. The signal quality has no effect before 1986, but it adversely affects quality between 1986 and 1992 and positively affects it after the nineties law change. Last, as the uninformed inventor probability increases, it decreases patent quality after the eighties change and increases quality after the nineties change.

increasing grant rates, point to the fact that the friendly court hypothesis was partly responsible for the patent surge. Regime laxity does not seem to be the primary cause of the nineties surge.

5.2.2: Quality Variance Pre- and Post-Law Changes

An additional implication of the sequential application-grant model shows that, if the law changes were primarily responsible for the two patent surges, then hypothesis H4 below should hold:

H4: Patent quality variance may be unchanged after the mid-1980s law change, but it should increase after the 1990s law change

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 the model in equation (5) with the coefficient of variation as the dependent variable. One would expect an increase in the proportion of informed inventors and an increasing quality signal to decrease variance. An increase in the probability of uninformed inventors should increase variance. In Table 4(a) a basic model excluding the law change interaction terms is estimated. First, in keeping with the findings from the theoretical framework, as the proportion of informed inventors increases, quality variance decreases, and an increase in the application probability of uninformed inventors increases the variance. The signal quality variable, however, has the opposite sign of that predicted by the model. The year dummies show a significant increase in variance during the nineties.

To explore the results further, in Table 4(b), Column (2), I estimate the full model. The results show that in aggregate the 1980s changes have increased variance by 0.4 percent, whereas the variance decreased by 0.21 percent after the nineties changes.[41] This supports the friendly court

[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.

hypothesis while rejecting the regime laxity one. In addition, a 1 percent increase in the proportion of informed inventors decreases the variance by 0.04 percent, and a 1 percent increase in signal quality and the application probability of uninformed inventors increases variance by 0.08 percent and 0.34 percent respectively. The increase in variance as the signal quality increases may imply that the variance is increasing due to very good quality patents rather than marginal ones. This result, coupled with an increase in quality during the nineties, provides further proof that regime laxity was not the primary cause for the nineties patent surge.

5.3: Impact on English-Speaking Countries and Marginal Inventors

5.3.1: English-Speaking (ES) versus Non-English-Speaking (NES) 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 examination standards should give rise to more marginal applications and grants from ES countries as compared to NES countries after both regime changes. Thus, the following hypotheses should hold if the law changes were responsible for the patent surges:

H4: ES grant rate is greater than NES grant rate after both law changes

H5: Patent Quality

1. *ES country patent quality is lower than NES country patent quality after mid-1980s change*
2. *ES patent quality decreases less than that of NES patents after1990s change*

H6: Patent Quality Variance

1. *ES country quality variance is greater than NES country variance after change*
2. *ES quality variance increases less than that of NES patents after change*

To investigate this, I estimate a difference-in-difference model in Table 5 with the grant rate, patent quality, and the coefficient of variation as the dependent variables (Y_{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_i), and a law change dummy $D_{t=Law}$). This law change can be either the 1980s change or the 1990s change.

$$Y_{it} = \alpha + \beta_K \sum_{K=1}^{3} X^K_{i,t-l} + \varphi Eng_i + \sum_{m=1}^{2} \theta_m D_{t=1986\ or\ 1990} + \sum_{m=1}^{2} \mu_m \left(Eng_i * D_{1986\ or\ 1990} \right) + \varepsilon_{it} \qquad (8)$$

μ is the differences-in-differences in means between the two groups. From Table 5, one observes that, for the mid-1980s regime change, there is no significant difference between the grant rate, quality, and quality variance of ES and NES countries, thus rejecting the friendly court hypothesis as the primary source of the patent surge. After the 1990s law change, the grant rate for ES countries is lower, and the change in patent quality is higher when compared to NES countries. There is no effect on quality variance. These findings reject the regime laxity hypothesis as the primary driver of the 1990s surge.

5.3.2: Effect on Marginal Inventors

Earlier in the paper, it was argued that the law changes during the 1980s would have a greater impact on marginal (i.e., small or uninformed) inventors by decreasing the cost threshold. Therefore, if the friendly court hypothesis is true, then H7 should hold:

(e) H7: *Marginal inventor grant rate should grow at a faster pace after the mid-1980s change*

I test this hypothesis by using a difference-in-difference approach where the "treatment" is the 1980s law change and the "treated" are the marginal inventors (Mrg_Inv_j). I define marginal inventors as individual inventors[42] since they are likely to be less informed about the value of their innovation than corporate inventors. The outcome variable is the growth rate in patent grants for each inventor type *j* in country *i* in year *t* (Y_{ijt}). I estimate the following model for Table 6:

$$Y_{ijt} = \alpha + \beta_K \sum_{K=1}^{3} X_{i,t-l}^{K} + \varphi Mrg\_Inv_j + \theta D_{1986} + \mu(Mrg\_Inv_j * D_{1986}) + \varepsilon_{ijt} \qquad (9)$$

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 grant rate of marginal inventors is growing at a faster pace than that of more mainstream inventors, such as corporations. From Table 6, I find that the difference-in-difference estimate is not significant, thus rejecting the friendly court hypothesis as an explanation for the mid-1980s patent explosion.

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 develops a sequential application-grant framework to analyze how changes in patent regimes influence an inventor's propensity to patent. Using the two changes in the U.S. patent system during the mid-eighties and early nineties, it distinguishes between increases in patenting activity due to increasing world inventiveness and two patent regime changes, namely (a) the lowered cost of patenting (friendly court hypothesis) and (b) lowered patent examination standards (regime laxity hypothesis). It builds on the work by Kortum and Lerner (1998) by focusing on IPR regime changes as possible explanations for the patent surges in the mid-1980s and 1990s. During the early 1980s, the creation of the Court of Appeals of the Federal Circuit and its patent friendly

[42] There are four types of inventor categories for each country (Non-US Individuals, Non-US corporations, Non-US governments, and Unassigned). We classify the Non-US individuals and Unassigned as the marginal inventors.
[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.

stance, the passing of the Bayh-Dole Act, and an increase in the scope of patent subject matter vastly increased the probability of obtaining and protecting a patent in the US. These changes consequently decreased the net-cost of patenting. Changes in the early 1990s made the USPTO more customer-friendly and, arguably, lowered grant standards.

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 addition to IPR regime changes, such as changes in application costs or declining grant standards, I find that grant rates are influenced by three primary factors: (a) change in the inventive capacity of a society, leading to a change in the probability of getting a valuable innovation; (b) change in the proportion of informed or “genuine” inventors; and (c) change in the likelihood of application by uninformed inventors. From the empirical estimation I find that patent grant rates increase when the proportion of informed inventors and underlying invention quality increases, and it is adversely affected when the application probability of uninformed inventors increases.

This application-grant framework yields 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). I hypothesize that the two law changes altered these thresholds differently. The friendly court hypothesis suggests that the eighties law change made patents more valuable – i.e., it decreased the net cost of patenting. Hence, it shifted the net quality distribution to the right. 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, leading to lower valued (and thus more marginal) patents being granted. The effect of both these changes was to increase the 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 of increase in underlying invention potential factors on patenting.

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, or changes in the application probability of uninformed inventors. Following Kortum and Lerner (1998), I call this the friendly court hypothesis. From the theoretical framework, I hypothesize that, if the mid-1980s law changes were 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.

From the empirical model we find that the aggregate impact of the eighties law change is an increase in grant rates by 17.7 percent. The change also loosened the link between the factors that should affect patent applications and observed patent grants and increased grant rates. These law changes also decrease patent quality by 1.4 percent and increase variance by 0.4 percent. However, ES and NES countries are not significantly different, and marginal inventors do not have greater role after the law change. Thus, the evidence on the eighties law change in mixed. Overall, I find that the eighties patent surge was a combination of increased world inventiveness and the IPR regime changes.

The regime laxity hypothesis implies that signal quality and the proportion of informed inventors should have a smaller or negligible impact on grant rates during the nineties. Granting of more marginal patents will decrease the average quality and increase the variance in patent quality. The result should be asymmetric between ES country inventors and NES country inventors. After the 1990s law change, ES grant rates should increase by more than NES grant rates, ES patent quality should decrease less than that of NES patents, and ES quality variance should increase less than that of NES country patents.

From the empirical estimation I find that, for grant rates, the nineties changes do not affect any of the slope coefficients, and the law change dummy is negative. Patent quality increases by 1.09 percent and variance decreases by 0.21 percent after the 1990s law change. In addition, quality variance increases as the signal quality increases, which may imply that the variance is increasing due to very good quality patents rather than marginal ones. After the 1990s law change, the grant rate for ES countries is lower, and the change in patent quality is higher when compared to NES countries, which is contrary to the hypotheses from the theoretical framework. These results provide proof that regime laxity was not the primary cause of the nineties patent surge and that there was a genuine increase in world inventiveness. In conclusion, the patent surge of the mid-1980s can be partly attributed to the friendly court hypothesis. The 1990s surge cannot be attributed to regime laxity and was a result of increasing world inventiveness.

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. – “Exploring the Patent Explosion”, NBER Working Paper # 10605, 2004.

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)

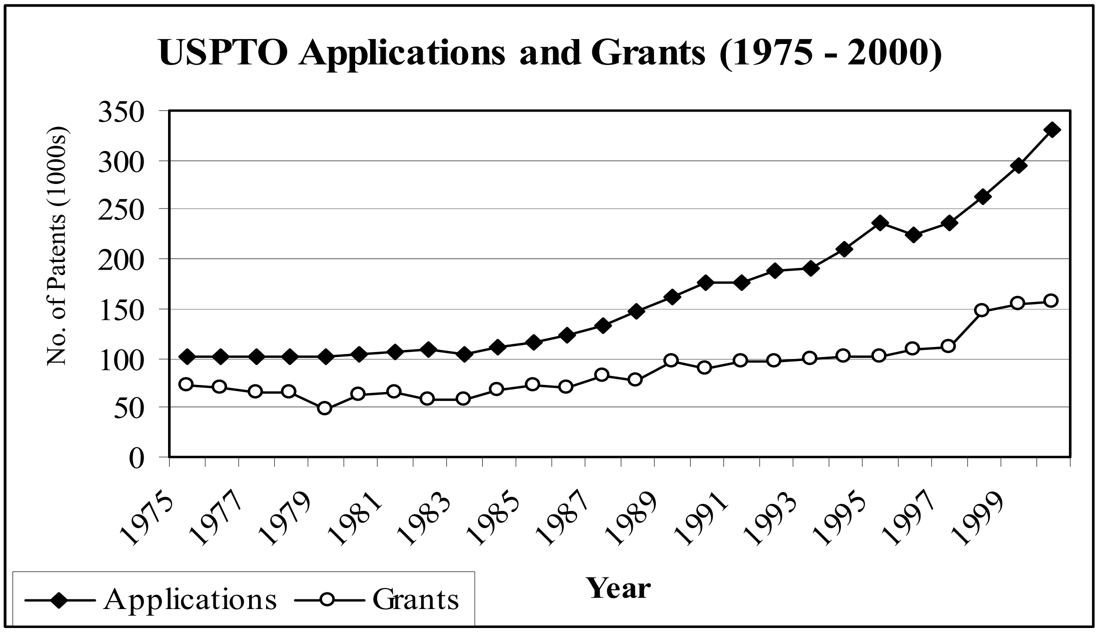


Figure 1(b)

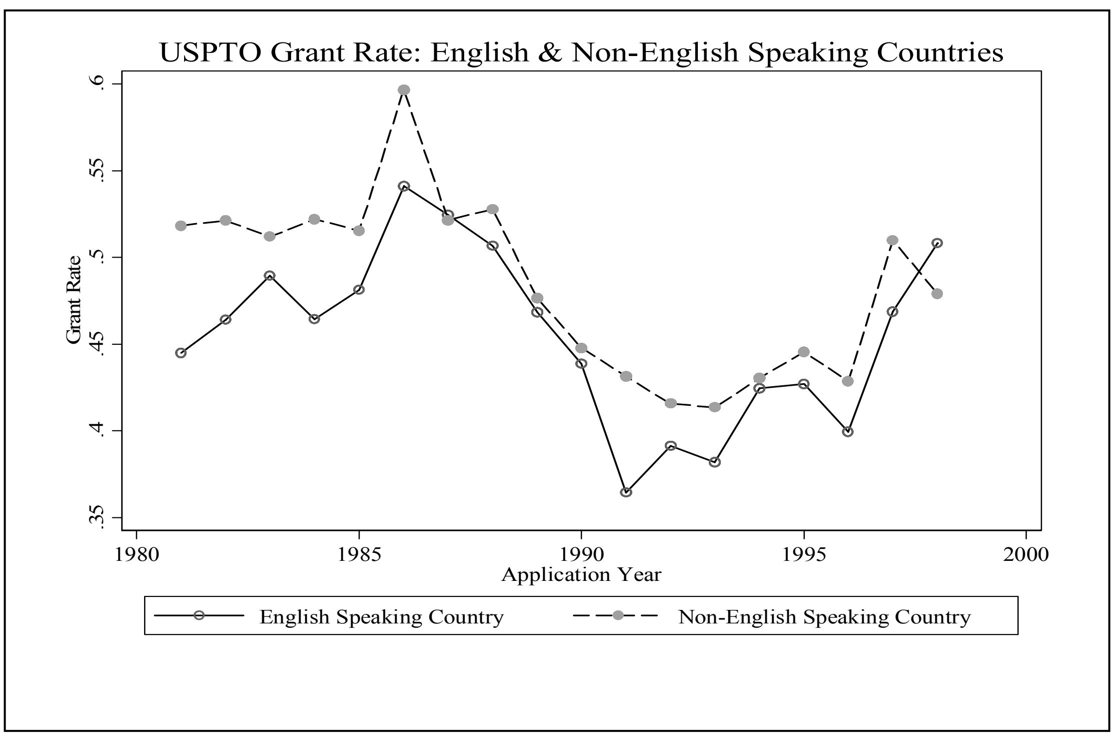


Figure 2: Probability Structure of Patent Grants and Applications

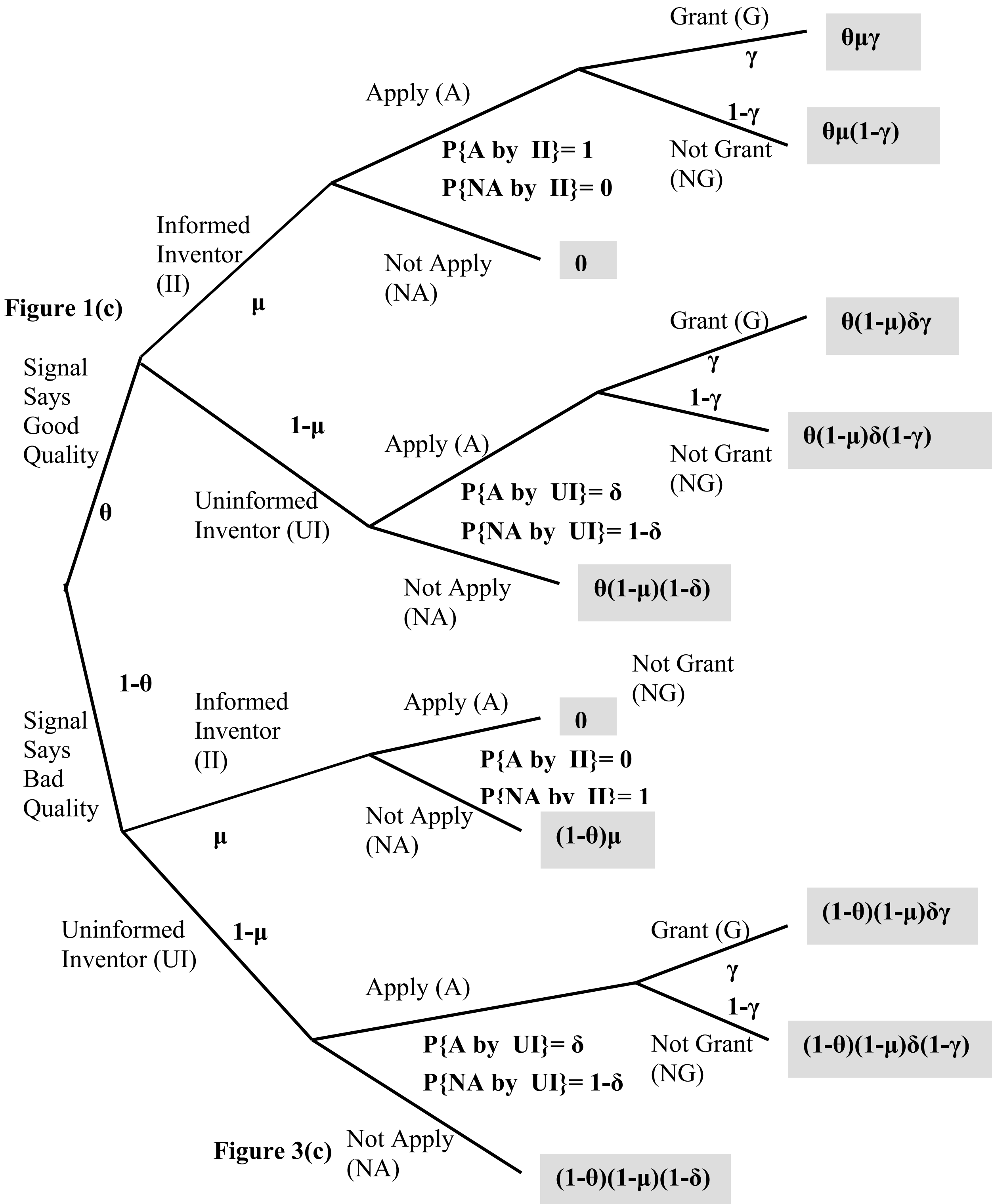


Figure 3(a)

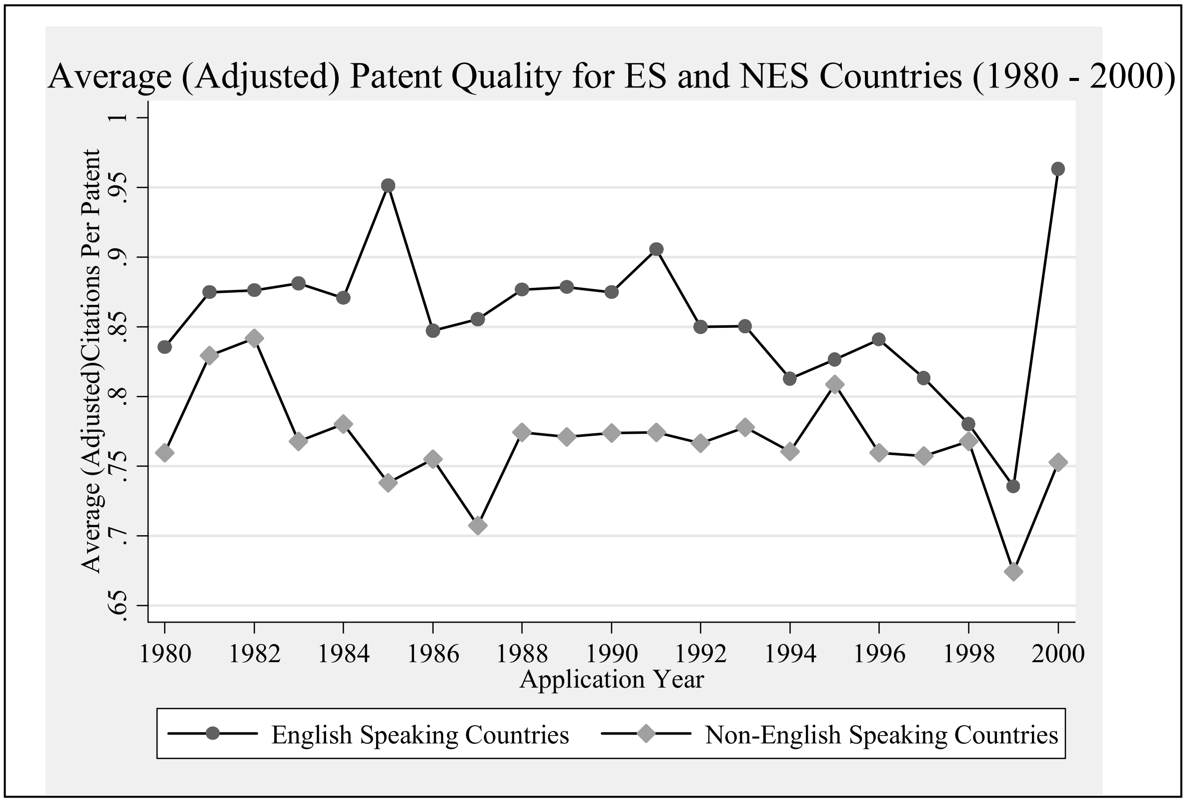


Figure 3(b)

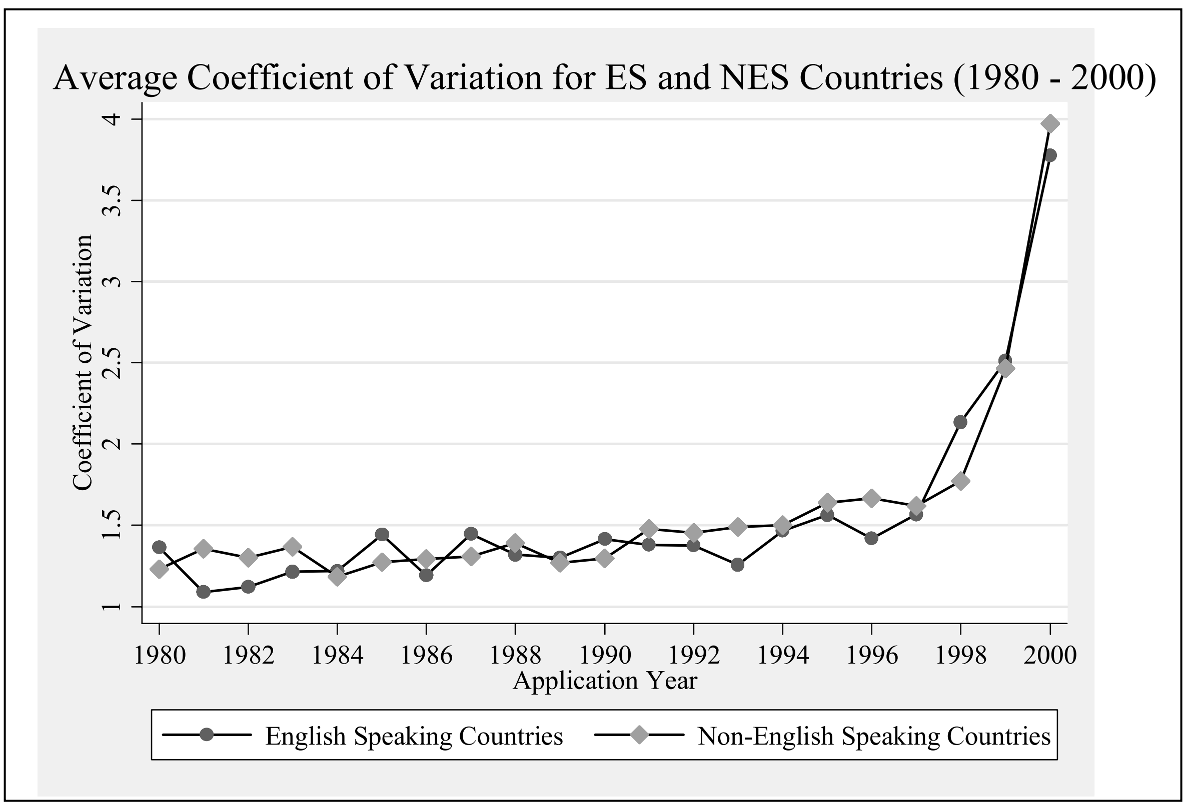
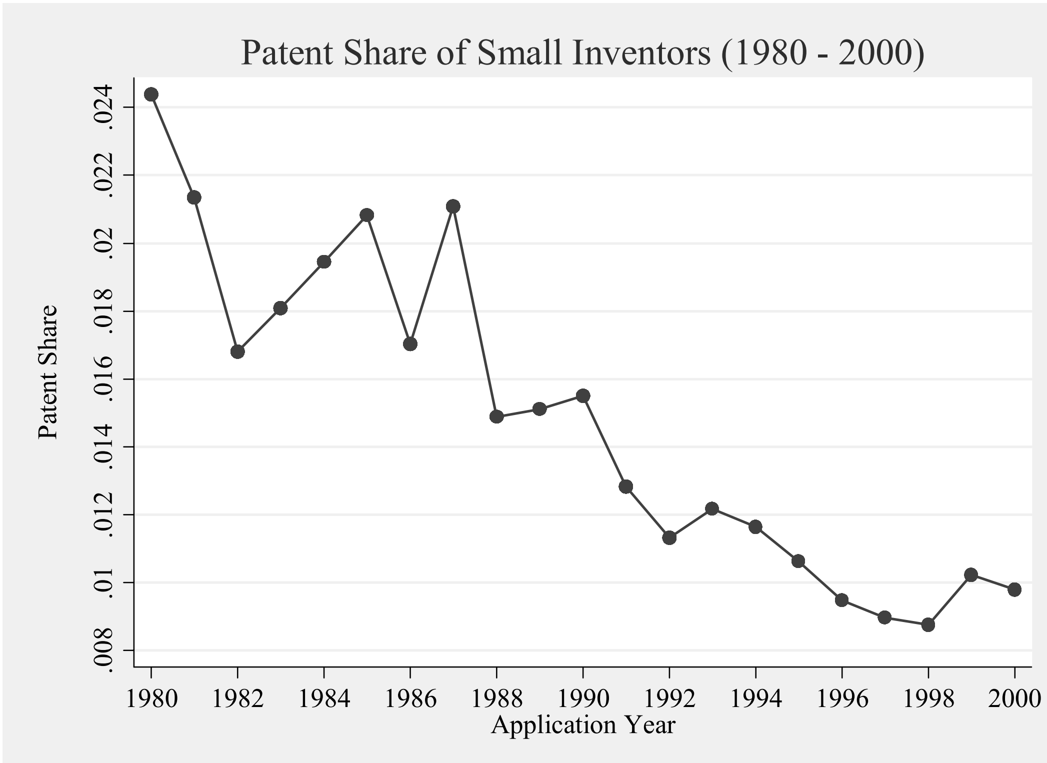


Figure 4: Patent Share of Small Inventors



APPENDIX TABLES

TABLE 1

SUMMARY STATISTICS

Dependent Variables	**Obs**	**Mean**	**SD**	**Min**	**Max**
US Grant Rate	300	0.475	0.118	0.043	0.917
Log(Citations)	300	0.958	1.838	-23.026	2.488
Log(Generality)	300	-1.691	2.983	-23.026	-0.585
Coefficient of Variation	300	1.655	0.707	0.699	5.375
Explanatory Variables (Lag 2 Yrs)					
Prop. of Inf. Inv. in the Ctry.	300	0.319	0.230	0	1
Signal Quality	300	0.063	0.066	0	0.386
Uninf. Inv. Application Prob.	300	0.086	0.123	0	1
Control Variable					
Technological Distance – Lag 2	300	0.750	0.090	0.446	0.926
Log (Real GDP)	300	12.536	1.107	10.485	14.984
Log (Real GERD)	300	8.356	1.407	5.295	11.405
Size of Manufacturing Sector	300	20.205	4.498	10.710	33.680

<u>TABLE 2(A)</u>
EXPLAINING PATENT GRANTS RATES

Dependent Variable: US Grant Rate	Coefficient (1)	Elasticity (2)
Explanatory Variables (Lag 2 Yrs.)		
Proportion of Informed Inventors in the Country	0.034 (0.005)***	0.023 (0.004)***
Signal Quality	0.236 (0.115)**	0.031 (0.015)*
Uninformed Inventor Application Prob.	-0.044 (0.007)***	-0.008 (0.001)***
Controls		
Technological Distance – Lag 2	-0.106 (0.046)**	0.168 (0.073)***
Log (Real GDP)	-0.020 (0.016)	-
Log (Real GERD)	0.021 (0.011)**	0.365 (0.201)*
Size of Manufacturing Sector	-0.006 (0.008)	
Year Dummies		
Year = 1983	0.122 (0.044)**	0.012 (0.004)**
Year = 1984	0.126 (0.041)***	0.012 (0.004)**
Year = 1985	0.133 (0.038)***	0.014 (0.004)***
Year = 1986	0.218 (0.074)***	0.023 (0.008)***
Year = 1987	0.130 (0.028)***	0.014 (0.003)***
Year = 1988	0.138 (0.043)***	0.016 (0.005)***
Year = 1989	0.075 (0.015)***	0.008 (0.002)***
Year = 1990	0.045 (0.038)	-
Year = 1991	0.027 (0.023)	-
Year = 1992	0.000 (0.023)	-
Year = 1994	0.028 (0.006)***	0.004 (0.001)***
Year = 1995	0.071 (0.014)***	0.009 (0.002)***
Year = 1996	0.056 (0.001)***	0.007 (0.002)***
Year = 1997	0.133 (0.009)***	0.018 (0.001)***
Year = 1998	0.090 (0.010)***	0.012 (0.001)***
Year = 1999	0.053 (0.018)***	0.007 (0.002)***
Year = 2000	-0.018 (0.012)	-
Constant	0.668 (0.136)	
Adjusted R Square	0.411	
Rho	0.704	
Observations	300	

Note: A fixed effects model has been used to estimate the equations. Standard errors are robust and clustered by the G7 countries. There are 19 OECD countries and 20 years (1981 – 2000). * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 2(B)
EFFECT OF LAW CHANGE ON PATENT GRANT RATES

Dependent Variable: US Grant Rate	**Basic Model (1)**	**Law Change Interactions (2)**
Explanatory Variables (Lag 2 Yrs.)		
Proportion of Informed Inventors in the Country	0.034 (0.005)***	0.164 (0.046)***
Signal Quality	0.236 (0.115)**	0.057 (0.124)
Uninformed Inventor Application Prob.	-0.044 (0.007)***	-0.159 (0.023)***
Controls		
Technological Distance – Lag 2	-0.106 (0.046)**	-0.116 (0.021)***
Log (Real GDP)	-0.020 (0.016)	-0.006 (0.037)
Log (Real GERD)	0.021 (0.011)**	0.020 (0.009)**
Size of Manufacturing Sector	-0.006 (0.008)	-0.008 (0.006)
Law Change Dummies		
Mid-1980 Law Dummy	0.096 (0.030)***	0.125 (0.021)***
Early-1990 Law Dummy	-0.218 (0.074)***	-0.232 (0.046)***
Law Change Interactions		
Mid-1980 Law Dum.* Percent of Informed Inv. in the Country – Lag 2 Yrs		-0.154 (0.013)***
Mid-1980 Law Dum.*Signal Quality – Lag 2 Yrs.		0.164 (0.165)
Mid-1980 Law Dum.* Log (Uninformed Inv. Application Prob.) – Lag 2 Yrs.		0.095 (0.012)***
Early-1990 Law Dum*Percent of Informed Inv. in the Country – Lag 2 Yrs		0.001 (0.055)
Early-1990 Law Dum *Signal Quality – Lag 2 Yrs.		-0.007 (0.202)
Early-1990 Law Dum* Log (Uninformed Inv. Application Prob.) – Lag 2 Yrs.		0.107 (0.115)
Constant	0.790 (0.092)***	0.628 (0.391)*
R Square	0.411	0.414
Rho	0.704	0.697
Observations	300	300

Note: A fixed effects model has been used to estimate the equations. Standard errors are robust and clustered by the G7 countries. All specifications contain year dummies. There are 19 OECD countries and 20 years (1981 – 2000). * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 3(A)
EXPLAINING PATENT QUALITY

Dependent Variable **Log(Mean Adj. Citations)**	**Coefficient** **(1)**	**Elasticity** **(2)**
Explanatory Variables (Lag 2 Yrs.)		
Prop. of Inf. Inv. in the Country	4.832 (1.306)***	0.448 (0.243)*
Prop. of Inf. Inv. in the Country Squared	-5.381 (3.256)*	
Signal Quality	-13.937 (3.285)***	-0.709 (0.179)***
Signal Quality Squared	20.705 (3.394)***	
Uninf. Inv. Application Prob.	-0.029 (0.487)	0.021 (0.006)***
Uninf. Inv. Application Prob. Squared	1.377 (0.395)***	
Controls		
Technological Distance – Lag 2	-4.611 (1.108)***	-3.457 (0.831)***
Log (Real GDP)	1.638 (0.298)***	1.638 (0.298)***
Log (Real GERD)	-0.685 (0.182)***	-0.685 (0.182)***
Size of Manufacturing Sector	0.069 (0.017)***	1.401 (0.378)***
Year Dummies		
Year = 1983	-0.130 (0.037)***	
Year = 1985	-0.290 (0.100)***	
Year = 1986	-0.378 (0.110)***	
Year = 1987	0.059 (0.240)	
Year = 1988	0.244 (0.368)	
Year = 1989	0.725 (0.432)*	
Year = 1990	0.288 (0.412)	
Year = 1991	0.843 (0.485)*	
Year = 1992	0.816 (0.571)	
Year = 1993	0.883 (0.596)	
Year = 1994	0.512 (0.542)	
Year = 1995	0.643 (0.538)	
Year = 1996	0.556 (0.621)	
Year = 1997	0.762 (0.616)	
Year = 1998	0.518 (0.553)	
Year = 1999	-1.096 (0.157)*	
Year = 2000	0.340 (0.592)	
Constant	-13.436 (1.900)*	
R Square	0.154	

Note: A fixed effects model has been used to estimate the equations. Standard errors are robust and clustered by the G7 countries. All specifications contain year dummies. There are 19 OECD countries and 20 years (1981 – 2000). Obs=300. * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 3(B)

EFFECT OF LAW CHANGE ON PATENT QUALITY

Dependent Variable: ***Log(Mean Adj. Citations)***	**Basic Model** (1)	**Law Change Interactions** (2)
Explanatory Var. (Lag 2 Yrs)		
Prop. of Inf. Inv. in the Country	4.832 (1.306)***	2.874 (1.620)*
Prop. of Inf. Inv. in the Country Squared	-5.381 (3.256)*	-2.544 (0.712)***
Signal Quality	-13.937 (3.285)***	-6.662 (7.965)
Signal Quality Squared	20.705 (3.394)***	-21.509 (79.393)
Uninf. Inv. App. Prob.	-0.029(0.487)	2.287(0.175)***
Uninf. Inv. App. Prob. Squared	1.377 (0.395)***	-4.097 (0.672)***
Law Change Dummies		
Mid-1980 Law Dummy	0.059 (0.240)	0.863 (0.003)***
Early-1990 Law Dummy	0.757 (0.330)**	0.066 (0.154)
Law Change Interactions (Lag 2 Yrs.)		
Mid-1980 Law Dum.*Prop. of Informed Inv. in Country		0.780 (0.957)
Mid-1980 Law Dum.*Prop. of Inf. Inv. in Country Squared		-3.860 (1.737)**
Mid-1980 Law Dum*Signal Quality		-11.230 (4.159)***
Mid-1980 Law Dum*Signal Quality Squared		63.692 (73.199)
Mid-1980 Law Dum.*Uninf. Inv. App. Prob.		-4.873 (0.215)***
Mid-1980 Law Dum.*Uninf. Inv. App. Prob. Squared		7.928 (1.731)***
Early-1990 Law Dum*Prop. of Inf. Inv. in Country		4.144 (2.012)**
Early-1990 Law Dum*Prop. of Inf. Inv. in Country Squared		-3.618 (1.851)**
Early-1990 Law Dum*Signal Quality		-1.995 (0.956)**
Early-1990 Law Dum*Signal Quality Squared		-9.438 (0.515)***
Early-1990 Law Dum*Uninf. Inv. App. Prob.		4.541 (0.436)***
Early-1990 Law Dum*Uninf. Inv. App. Prob. Squared		-8.087 (0.559)***
Adjusted R-Square	0.070	0.052

Note: Fixed effects model. Standard errors are robust and clustered by the G7 countries. All specifications contain year dummies and controls. There are 19 OECD countries and 20 years (1981 – 2000). Obs=300. * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 4(A)
EXPLAINING VARIANCE IN PATENT QUALITY

Dependent Variable Log(Mean Adj. Citations)	Coefficient (1)	Elasticity (2)
Explanatory Variables (Lag 2 Yrs.)		
Prop. of Inf. Inv. in the Country	-0.614 (0.281)**	-0.118 (0.054)**
Prop. of Inf. Inv. in the Country Squared	0.848 (0.560)	
Signal Quality	3.050 (0.891)***	0.084 (0.023)***
Signal Quality Squared	-6.679 (2.363)***	
Uninf. Inv. Application Prob.	0.441 (0.207)**	0.038 (0.018)**
Uninf. Inv. Application Prob. Squared	-0.176 (0.445)	
Controls		
Technological Distance – Lag 2	-0.417 (0.007)***	-0.189 (0.005)***
Log (Real GDP)	0.097 (0.125)	
Log (Real GERD)	-0.044 (0.072)	
Size of Manufacturing Sector	-0.018 (0.021)	
Year Dummies		
Year = 1983	-0.072 (0.040)*	
Year = 1985	0.104 (0.065) *	
Year = 1986	0.069 (0.091)	
Year = 1987	0.136 (0.0280 ***	
Year = 1988	0.149 (0.016)***	
Year = 1989	-0.050 (0.127)	
Year = 1990	0.076 (0.049)	
Year = 1991	0.072 (0.049)	
Year = 1992	0.047 (0.116)	
Year = 1993	0.034 (0.091)	
Year = 1994	0.138 (0.089)	
Year = 1995	0.242 (0.069)***	
Year = 1996	0.255 (0.040)***	
Year = 1997	0.230 (0.043)***	
Year = 1998	0.500 (0.055)***	
Year = 1999	1.152 (0.005)***	
Year = 2000	2.564 (0.021)***	
Constant	1.045 (0.550)***	
R Square	0.832	

Note: Fixed effects model. Standard errors are robust and clustered by the G7 countries. There are 19 OECD countries and 20 years (1981 – 2000). Obs=300. * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 4(B)
EFFECT OF LAW CHANGE ON PATENT QUALITY VARIANCE

Dependent Variable: Coefficient of Variation	**Law Change** (1)	**Law Change Interactions** (2)
Explanatory Var. (Lag 2 Yrs)		
Prop. of Inf. Inv. in the Country	-0.614 (0.281)**	-1.157 (0.180)***
Prop. of Inf. Inv. in the Country Sq.	0.848 (0.560)	1.846 (0.177)***
Signal Quality	3.050 (0.891)***	-2.259 (0.310)***
Signal Quality Squared	-6.679 (2.363)***	45.117 (14.283)***
Uninf. Inv. App. Prob.	0.441 (0.207)**	0.172 (0.558)
Uninf. Inv. App. Prob. Squared	-0.176 (0.445)	-0.634 (0.771)
Law Change Dummies		
Mid-1980 Law Dummy	0.136 (0.028)***	-0.101 (0.119)
Early-1990 Law Dummy	-0.089 (0.144)	0.055 (0.104)
Law Change Interactions (Lag 2 Yrs.)		
Mid-1980 Law Dum.*Prop. of Informed Inv. in Country		0.897 (0.448)**
Mid-1980 Law Dum.*Prop. of Inf. Inv. in Country Squared		-1.066 (0.662)*
Mid-1980 Law Dum*Signal Quality		7.122 (0.311)***
Mid-1980 Law Dum*Signal Quality Squared		-56.569 (15.009)***
Mid-1980 Law Dum.*Uninf. Inv. App. Prob.		-0.470 (0.697)
Mid-1980 Law Dum.*Uninf. Inv. App. Prob. Squared		1.350 (1.342)
Early-1990 Law Dum*Prop. of Inf. Inv. in Country		-0.632 (0.291)**
Early-1990 Law Dum*Prop. of Inf. Inv. in Country Squared		0.292 (0.098)***
Early-1990 Law Dum*Signal Quality		-2.107 (0.820)***
Early-1990 Law Dum*Signal Quality Squared		5.359 (2.874)*
Early-1990 Law Dum*Uninf. Inv. App. Prob.		0.900 (0.388)**
Early-1990 Law Dum*Uninf. Inv. App. Prob. Squared		-0.961 (1.229)
Adjusted R-Square	0.857	0.857

Note: Fixed effects model. Standard errors are robust and clustered by the G7 countries. All specifications contain year dummies. There are 19 OECD countries and 20 years (1981 – 2000). Obs=300. * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 5

DIFFERENCE BETWEEN ENGLISH-SPEAKING AND NON-ENGLISH SPEAKING COUNTRIES

Dependent Variable:	**US Grant Rate**	**Log(Mean Citations)**	**Coefficient of Variation**
	(1)	(2)	(3)
English-Speaking Country Dummy (Treated)	0.010 (0.023)	0.136 (0.138)	0.032 (0.034)
Mid-1980 Law Dummy (Treatment)	0.167*** (0.008)	0.261*** (0.087)	-0.209* (0.108)
Early-1990 Law Dummy (Treatment)	-0.207*** (0.021)	-1.205*** (0.117)	0.069 (0.077)
English-Speaking Country Dummy * Mid-1980 Law Dummy	0.015 (0.041)	0.085 (0.138)	0.017 (0.052)
English-Speaking Country Dummy * Early-1990 Law Dummy	-0.032* (0.017)	0.338* (0.196)	-0.122 (0.089)
R-Square			

Note: Random effects model. Standard errors are robust and clustered by the G7 countries. All specifications contain year dummies and all explanatory and control variables, and the law change dummies and interactions in the earlier models. Col. 1 is based on the specification in Table 2B, col. 2. Col. 2 is based on Table 3, col. 2. Col. 3 is based on Table 4, col. 3. There are 19 OECD countries and 20 years (1981 – 2000). Obs=300. There are 4 English-speaking countries (Australia, Canada, Ireland, UK). * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.

TABLE 6

DIFFERENCE IN GRANT RATE BETWEEN SMALL AND LARGE INVENTORS

Dependent Variable:	**Log(US Grant Rate)**
	(1)
Small Inventor Dummy (Treated)	0.004* (0.002)
Mid-1980 Law Dummy (Treatment)	0.142** (0.063)
Small Inventor Dummy * Mid-1980 Law Dummy	-0.004 (0.003)
Adjusted R-Square	

Note: Random effects model. Standard errors are robust and clustered by the G7 countries. The above specification contains year dummies and all explanatory and control variables, and the law change dummies and interactions from Table 2B, col. 2. There are 19 OECD countries and 20 years (1981 – 2000). There are 4 types of inventor categories for each country (Non-US Individuals, Non-US corporations, Non-US governments, and unassigned). We classify the Non-US individuals and unassigned as the marginal inventor patents. Obs=1493. * denotes 10% level of significance, ** denotes at least a 5% level of significance & *** denotes at least a 1% level of significance.