Peanut Butter Patents Versus the New Economy: Does the Increased Rate of Patenting Signal More Invention or Just Lower Standards?*

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Abstract

The rate of patenting in the U.S. has exploded in the last half of the 1990s. It is widely believed that the increase in patent grants is at least partly a result of the apparent decline in examination standards. There has been little exploration, however, of the theoretical prediction that a decline in examination standards would itself induce an increase in dubious applications. We estimate a simultaneous equation model, in which the number applications depend on the perceived rigor of the examination process, amongst other things and patent grants depend on the number and quality of applications. We have a multi-dimensional panel, with data on the application and grant rates for each year, countries of origin, and jurisdiction of examination. We find that a 'loosening' of the grants standards by one percent increases applications by 8 percent in the full sample and by 3 percent in the Non-US sample. This result points to the importance of accounting for the endogenous application response particularly for the US case. Controlling for this effect, we find that application elasticity of grants is around 0.124 for the full sample and 0.145 for the Non-US one, and is declining over time in both. In addition countries whose patent applications are more likely to be successful in the US are more likely to be successful in other countries as well. These findings confirm that inventors respond to increased likelihood of success at the patent office by filing more applications, but also confirm earlier findings that the surge in patenting in the US in the last two decades appears to be driven to a significant extent by an increase in the underlying invention rate.

JEL Code (L10, O31, O34)

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Section 1: Introduction

United State Patent No: 6293874
User Operated Amusement Apparatus for Kicking the User's Buttocks
Inventor: Joe W. Armstrong, 306 Kingston Street, Lenoir, TN(US) 37771-2408
Abstract:
"An amusement apparatus including a user-operated and controlled apparatus for self-infliction of repetitive blows to the user's buttocks by a plurality of elongated arms bearing flexible extensions that rotate under the user's control…"[3]

The much maligned crustless peanut butter and jelly sandwich[4] is in good company. The US Patent and Trademark Office (USPTO) has been granting some improbable patents[5] that seem to suggest that one or more of three pillars of patents grants – non-obviousness, novelty and utility, has weakened. There is a perception, both in the popular press (Forbes, Summer, 2002) and amongst scholars in the area, that patent quality has declined concurrent with the explosion in patenting in the U.S. in the last two decades. Around this time, the US IPR regime underwent significant changes. The combined effect of the major law changes in the early 1980s[6] and the 1990[7] has been to broadened subject matter (software and business method patents), encourage university patenting, strengthen patent rights and make the USPTO more "customer-friendly".

It is a fundamental challenge to students of technological change to understand this historically unprecedented surge in patenting during the mid-1980s (Please refer to Appendix Graph 1(A) –(C)) and the dramatic law changes that seemed to have preceded this explosion. The establishment of the Court of the Federal Circuit (1982), the Bayh-Dole Act, broadening of

[3] USPTO database
[4] US Patent No. 6004596, "Sealed Crustless Sandwich" (1999). Chosen for its alliterative allure, the title of this paper refers also to a patent granted by the USPTO to the Smuckers company, and used by Smuckers as the basis for an infringement suit, on a peanut butter sandwich crimped at the edges so that the jelly does not run out (U.S. Patent 6,004,596, covering a "sealed crustless sandwich").
[5] US Patent No. 5616089. "Method of Putting" (1997) that outlines a "new method" of putting a golf ball; US Patent No. "Metal Wire Paper Clip Structure" that was granted for a "slightly elongated" paper clip.
[6] Bayh-Dole Act and establishment of the CAFC.
[7] Omnibus Act

patent subject matter (specially to include software), and pro-patent courts coincided with the increased rate of patent applications and grants in the US. This surge has continued through the late-1990s. In particular, we would like to know to what extent the increase during this period, represents an increase in the rate of invention, and to what extent it represents an increase in the number of patents per unit of invention. Early work on this topic (Kortum and Lerner, 1999, 2000) suggested that there has been at least some increase (till 1995) in the invention rate and law changes do not seem to have been the main source of this explosion. Thus these cannot be held responsible for the perceived decline in patent quality. But recent controversies about patents for apparently "obvious" inventions being granted by the PTO suggest a possibly significant increase in the patenting rate relative to the invention rate. There is extrinsic evidence that the "quality" of patents has declined, in the sense of an apparent increase in the rate of patents on "obvious" inventions, such as the "Sealed Crustless Sandwich" that inspired our title.

It is widely believed that the increase in patent grants is at least partly a result of the apparent decline in examination standards. Appendix Graphs 2(A) – (D) show what has happened to patent applications and grants to two jurisdictions – US and France. Of course, these numbers do not account for technology composition change and year effects, but they do provide us with a striking contrast. As we can see, the US has increased both, as a source and destination in the latter part of the 1990s. While grants were declining in France, they were on the rise in the US. This may have implications about grants standards in the US conditional on world inventiveness and constant examination standards in non-US countries.

There has been little exploration, however, of the theoretical prediction that a decline in examination standards would itself induce an increase in dubious applications. The increase in patent grants can be decomposed into (1) any change in the rate of invention; (2) any change in the likelihood of patent application, conditional on the rate of invention and/or the expected grant rate; and (3) any change in the likelihood of patent grant, conditional on the rate of applications. This paper focuses on the interplay between the second and third factors. We would like to estimate a model in which the number of patent grants depends on the number of applications, the quality of those applications, and the rigor of the examination process, and the number and average quality of applications depends on the (unobserved) rate of invention and the perceived rigor of the examination process. But present data constraints do not allow the estimation of all the parameters of interest. Therefore we try to segregate rate-of-invention and application-propensity effects by looking at applications and grants in various jurisdictions and comparing the results with the US.

The fundamental framework for analyzing this question is presented in Griliches (1979) and Griliches and Pakes (1984). Unobserved and unobservable new knowledge is produced by R&D and other inputs, and firms (and other institutions) make decisions about which new bits of knowledge merit patent applications. Trajtenberg, Henderson and Jaffe (1998) build on this foundation by noting that there is a distribution of quality or value of inventions; since patent applications are costly (in terms of lawyers' fees, inventor time, and possible loss of competitive advantage through disclosure), there will be a threshold quality, with inventions above this threshold deserving a patent application, and inventions below this threshold not. Changes over time in the attractiveness of the patent process can be thought of as shifting this threshold. Sanyal (2002) adds the final necessary piece to the model, which is the decision of the Patent Office as to whether or not to grant a given patent application. Changes in the examination standards will affect the number of patents granted conditional on applications, but will also affect the decisions to apply, since a change in the likelihood of success changes the threshold of invention quality necessary to justify an application.

Models based on the US data are limited by the fact that the USPTO does not publish detailed data on patent applications, making it difficult to model patent applications and grants simultaneously. But we believe that in studying the drivers of the patent explosion, one needs to incorporate two important factors, (a) the endogenous application response to patent grants and (b) the linkage between current patent applications and grants. Any law that changes inventors' perception of the IPR regime and/or the actual grant rate will affect the application propensity and hence the number of applications. In addition, if the number of applications themselves have implications for current grants. Using these above observations, we then compare the various relevant magnitudes for US and non-US data to understand the patent explosion phenomena.

This paper attempts to distinguish between the legal change and invention production function change arguments that are advanced as explanations for the patent explosion. We attempt to do this by exploiting the fact that while the US IPR regime was undergoing dramatic changes, for most of the OECD countries, there was no such change. This allows us, after making certain assumption, to potentially separate out the effects of changes in the patent office practices from a real increase in the invention rate.

Section 2: Motivating the Empirics

Modeling patent applications and grants entails recognizing the interplay of several decision processes. Though tautological, it is nonetheless useful to think of the rate of patent grants by a given jurisdiction as the product of: (1) the underlying rate of invention; (2) the propensity to apply for patents in the given jurisdiction, conditional on the rate of invention; and

(3) the propensity of the jurisdiction to grant patent applications it receives. In addition to this arithmetic or tautological relationship, there are potentially interesting behavioral links among these components of the patent creation chain. In particular, the propensity to apply should be affected by the propensity to grant, since a higher likelihood of grant increases the expected return to the patent application decision. Conversely, a higher propensity to apply implies that more of the applications being made are of marginal quality; this suggests that the propensity to grant is itself an inverse function of the propensity to apply. These behavioral interactions suggest the possibility of a feedback mechanism in which a decline in grant standards not only produces more grants conditional on the application rate, but actually induces an increase in the application rate itself.

The "peanut-butter patents" view is that the dramatic rise in patent applications and grants in the U.S. in the last two decades has been driven primarily by an increase in the propensity to apply and the propensity to grant. Within this view, it is unclear to what extent the increase in the propensity to apply is driven by factors external to the patent system (e.g., increasing competitiveness of world markets because of globalization), and to what extent the increase in the propensity to apply might in fact be an endogenous response to the increased propensity to grant. The alternative "new economy" view is that the increases are driven by a rise in the underlying invention rate. Of course these views are not mutually exclusive, it is possible and indeed likely that multiple factors are operating at the same time.

Section 2.1: Factors Affecting Patent Applications and Grants

A real increase in the invention rate could occur when "invention potential" factors change (Evenson, 1993). Perhaps the most important of these is research and development

(R&D) expenditure. The amount and composition of R&D, the share of federal, university and industry expenditures, the percentage of GDP spent on R&D, all have implications for the rate of invention (Cohen et al., 1997; Feller et al., 1998; Griliches, 1989; Jaffe, 1989; Klevorick 1994; Lichtenberg, 1984, 1987, 1988; Mansfield & Switzer, 1984; Mansfield, 1991; Mowery, 1997; Nelson, 1986; Sanyal, 2001). For example, it is likely that private financed research yields more patents than does similar expenditures on publicly-financed research, which tends in general to more focused on basic research. Thus, controlling for the total level of R&D expenditure in a country, we would expect the rate of patent applications to be lower the higher is the share of that total that is publicly financed.

Other factors that can affect the invention rate are increases in income, education, government quality and the legal environment of a country. Poor quality of governance, weak property rights and corruption can act as severe impediments to the innovation potential of a country. If inventers cannot be guaranteed property rights at least for some period of time, then their incentive to innovate declines. Various facets of the legal regime, even those unrelated to intellectual property, can affect the invention propensity. For example, immigration policy that allows large inflows of highly skilled scientists into a country may increase its invention rate. In all these cases, holding constant the grant standards, we expect an increase in patent applications and patent grants.

Changes in a country's IPR regime are one of the key external factors that influence invention rate and application propensity (Lerner, 2002; Jaffe, 2000; Jaffe & Trajtenberg, 2002; Merges & Nelson, 1990; Ordover, 1991; Sakakibara & Branstetter, 1999; Scotchmer, 1991). But the issue is not a settled one. There is a huge body of literature by economists over the past fifty years that suggest that patent rights positively affects the invention rate in select industries only

(Mansfield, 1986; Levin et al., 1987; Cohen et al., 2000). The pharmaceutical and medical industries were found to be chief benefactors from patenting (Cohen et. al., 2000; Levin et. al, 1987: Mansfield, 1986)

The propensity to apply for patents is likely to be affected by changing patent grant standards, fees, legal costs, outcome of infringement cases or changing patent subject matter, can alter this variable. For example, if grant standards are lower or legal costs lowered then many more marginal inventions will enter the application stream leading to an increase in application propensity. A similar increase will occur if courts are perceived to be more patent friendly. Application propensity is also influenced by a host of market structure variables. Firm size, industry structure and concentration, market size and business environment can all affect how many inventions are patented (Cohen & Levin, 1989; Kamien & Scchwartz, 1975; Mansfield, 1963, 1968[8]; Scherer, 1965; Williamson, 1965). There is considerable evidence that the importance and use of patents vary by industry (Arora et. al, 2003; Levin, 1987). In the semiconductor industry for example, studies have shown that an important driver of patenting is litigation deterrent (Hall and Ziedonis, 2001; Cohen et. al, 2000). Recent studies on 'thicket-building behavior' of firms (Shapiro, 2001) document yet another source of increasing application propensity, without any change in the invention production function.

When looking at application propensities to foreign countries, the volume of bilateral trade, common language, common border and technology overlap may be important drivers. Another central factor would be the inventor's perception of the legal environment. If the inventor perceives that a country has lower patent grant standards, then all else remaining the same, he would be more likely to apply to that jurisdiction, because net present value of an

[8] (1963) The author found that during 1919-58 in petroleum refining and bituminous coal the largest four firms did most of the innovating, but this was not true for the steel industry. Thus it is not always the case that the largest firms are the greatest innovators.

investment in patent application is increased if the probability of grant rises (assuming that the value of the legal protection the patent conveys is not undermined by the lower standard for grant).

Given the rate of patent application, the propensity to grant patents is influenced primarily by IPR laws and patent office characteristics, over and above the number and quality of inventions that flow in. Griliches (1989) suggested that patent grants were heavily influenced by the inefficiencies and constraints of the USPTO. More recent work by Cockburn et. al. (2003) show that that patent examiner characteristics may have important implications for patent quality as inferred from litigation outcomes. But when doing an international comparison, such micro level data are hard to come by. So in the empirical part of the paper we will have to make certain simplifying assumptions about the patent regimes in various countries. The next section provides a simple theoretical model relating inventor behavior, country characteristics and patent regimes.

Section 2.2: Theoretical Motivation

This section investigates the underlying relationships between inventions, patent propensity and grant propensity. There are three decision stages in this model. In the first stage, the inventor decides to invest in R&D and this produces some inventions. In the next stage she decides whether to apply for a patent. This patent propensity is governed by the net value of the inventions, which includes amongst other factors, the grant propensity. The patent office is the final filter that these applications have to pass through before they are converted into patents. The patent office converts applications into grants according to some production function that includes as inputs, the number of patent applications and resources at the disposal of the patent authorities. The following discussion develops a simple model that explains the above processes.

Suppose there is a pool of identical risk-neutral inventors who want to participate in the invention 'game'. We model the invention and application decision in terms of a representative inventor 'k'[9]. Let $F(y,r,x)$[10] denote the distribution of potential innovations values. The uncertainty in the invention process is captured by the fact that *ex ante*, the inventor does not know the exact value of the invention that results from R&D investment, only the distribution of values (F). We represent the outcome of R&D as a random variable Y, that is drawn from $F(y,r,x)$. Thus y denotes the realization of Y. 'r' denotes the R&D dollars spent by the firm at time t. 'x' set of covariates that capture the 'invention potential' (Evenson (1993)) of both the individual inventor and the economic environment in which he is operating. For example, these covariates could embody factors like internal capability of the inventor, education, technological advancement of the country, past knowledge stock from which the inventor can draw, government support of research and so on.

In period t, inventor k invests in R&D (rd_t)[11] and obtains a single draw ($\tilde{y}_t$) from the invention value distribution $F(y,rd_t,x_t)$. We assume that the draws are independent across time and inventors. Let y_{t-1} be the value of the innovation obtained in the period before t. Following Telser (1982) we describe the $F(y_{t-1},rd_t,x_t)$ as the probability of failure to get values higher than the one in hand i.e. greater than y_{t-1}. This particular formulation combined with the independence assumption generates interesting characteristics of the invention process. First, having rd_t in the pdf allows for the accumulation of knowledge, which leads to increasing

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[9] Assume that there are k = 1….K inventors in the economy who satisfy i.i.d. We abstract away from patent tournaments and races since our primary aim is to model application and grant behavior at the country level. We will drop the 'k' subscript from the variables for notational convenience.

[10] F(y,r,x) is the cumulative density function and f(.) is the probability density function where:

$$\text{Prob}(Y \leq y) = F(y,r,x) = \int_0^y f(z,r,x)\,dz$$

[11] We assume that in each period, the inventor invests a constant amount r.

realizations of y.[12] Second, increasing y implies that the probability of 'failure' is a decreasing function of R&D expenditures.

After the realization of $\widetilde{y}_t$ (the value of the discovery by inventor k at time t), the inventor must decide whether to apply for a patent for the given invention. In our model, the decision is whether inventor *k*, in country *i*, should apply for a patent to a 'foreign' country *j*. If there were no resource constraints on the inventor, she could apply for a patent for every discovery[13]. Budget constraints imply that she must choose which discovery merits an application[14]. In a dynamic setting, this can be modeled as a sequential search process with recall[15] or as an optimal stopping rule problem.

Following Lippmann and McCall (1986)[16], we assume that the inventor behaves rationally under uncertainty and follows as optimal application policy. There are three variables ($\widetilde{y}_t$, β, C_t) that characterize the application decision[17]. $\widetilde{y}_t$ is the invention value in period t. β is the discount rate. C_t is the cost associated with applying for the patent. This would consist of R&D cost for the invention, patent office fees, lawyer's fees and transaction costs. These transaction costs are influenced by several factors. First they are positively related to grants standards (g_{ijt}) of a country, i.e. a decline in grant standards results in a decline in transaction costs. Second these transaction costs are also influenced by geographical factors like distance

[12] We need decreasing returns to R&D (r_t) to ensure the existence of an equilibrium. The independence assumption makes this possible (see Telser, 1982).
[13] Even in the absence of a budget constraint, a inventor may not apply for a patent if she wants to prevent disclosing her invention to her competitors.
[14] For simplification we assume one patent application per inventor in this model.
[15] In this paper we will not derive the existence of an equilibrium and the properties of the search process. In general search models have often been used in the R&D literature because they display properties desirable in R&D models, like stochastic success, diminishing returns etc. For a good discussion see Taylor (1995), Telser (1982), Lippman & McCall (1986).
[16] The authors develop this approach to model the liquidity of an asset, where the decision is whether the individual should hold out for a higher price or sell the asset today and convert it to cash.
[17] All decisions are made by inventor k in this model. So we drop the subscript k for notational convenience.

between countries and a common border. Greater distance increases transaction costs, whereas a common border decreases it.

Thus, if the patent is granted, the inventor obtains net profit Π.[18] A rational inventor wants to maximize the expected discounted profits. Suppose he decides to apply at time τ (t = 1.….τ). Then the discounted net profit that is associated with stopping time τ is given by:

$$\text{(1a)} \qquad \Pi(\tau) = \beta^{\tau} \hat{y}_{N(\tau)} - \sum_{t=1}^{\tau} \beta^{t} C_t$$

where: $\hat{y}_t = \max\{\tilde{y}_1, ...\tilde{y}_t.\}$ (recall is allowed). This is value of the invention for which the inventor decides to apply for a patent.

N(τ) is the random number of inventions that the inventor observes before deciding to implement the application rule τ[19].

Thus the inventor chooses an application rule τ* is a set of all application rules T such that:

$$\text{(1b)} \qquad E\Pi(\tau^{*}) = \max\{E\Pi(\tau), \tau \in T\} = V^{*}$$

where: V*[20] is the expected net value of the invention when the inventor implements the optimal application rule τ*.[21]

Using (1a) and (b) we can obtain a distribution of applications over time for the K inventors in the economy. Thus aggregating up from the inventor to the country level, we can

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[18] We assume that when the patent is granted, he can immediately sell the invention and make a positive profit.

[19] τ can be interpreted as the time between the first invention and the application. Thus it could serve as a measure of application lag. However, since we do not have micro data to measure this in any concrete way, we do not belabor this point.

[20] It can be shown that V* is equal to the inventor's reservation value for the patent.

[21] We assume the existence of an optimal application rule. Following Lippman and McCall (1986) it can be shown that given the assumption of constant cost, one invention in each period of time, invention values distributed as iid and recall, there will exists an optimal application rule τ*.

write an expression for the total number of applications (A_{ijt})[22] made by inventors in country *i* to country *j* at time *t*, if all inventors follow an optimal application rule.

$$\text{(2a)} \qquad A_{ijt} = f(\tilde{y}_{it}, C_{ijt})$$

where: $\tilde{y}_{it}$ is the 'aggregate' value on invention in country *i* and C_{ijt} is the cost that country *i* faces when it applies for a patent in country *j*.

We know that $\tilde{y}_{it}$, the random draw of the invention value is a determined by R&D (rd_{it}) and other 'invention potential' factors x_{it}. Thus we can rewrite (2a) as:

$$\text{(2b)} \qquad A_{ijt} = f(rd_{it}, x_{it}, C_{ijt})$$

As mentioned before x_{it} are the 'invention potential factors'. These consist of resources (gdp_{it}), factors related to government quality (gq_{it}), federal R&D ($rdgov_{it}$), R&D of foreign country to capture possible spillovers (rd_{jt}), technological capability and so on. As discussed before, the cost function comprises of application fees, grant standards (g_{ijt})[23] and other transaction costs (tc_{ijt}). The primary transaction cost variables used are bilateral trade volume (tr_{ijt}) and a technology overlap index ($tech_{ijt}$). Thus 2(a) can be written as:

$$\text{(2b)} \qquad A_{ijt} = f(rd_{it}, rdgov_{it}, gdp_{it}, gq_{it}, rdgov_{jt}, tr_{ijt}, g_{ijt}, tech_{ijt})$$

To impose a structure to the above equation we use a simple functional form:

$$\text{(2c)} \qquad A_{ijt} = D(r_{it}^{\theta_1+\theta_2 t})(rdgov_{it}^{\alpha_1}.r_{jt}^{\alpha_2}\, gdp_{it}^{\alpha_3}.tr_{ijt}^{\alpha_4})e^{(std_j . g_i tech_{ijt})}$$

where: $\theta_1+\theta_2 t$ is the time varying R&D elasticity. A positive θ_2 implies a rising elasticity over time, while decreasing values imply a decline in elasticity.

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[22] We can think of the economy comprising 1,…K inventors of varying resource sizes being i.i.d. distributed. Aggregating over the applications that these inventors make to country j, gives us the total number of patents applied for by country I in country j.

[23] For our purpose, the fees are subsumed in the grants standards.

Taking logs on both sides we get:

$$\text{(2d)} \quad \begin{aligned} \ln A_{ijt} &= \ln D + \theta_1 \ln r_{it} + \theta_2 t.\ln r_{it} + \alpha_1 \ln rdgov_{it} + \alpha_2 \ln r_{jt} + \alpha_3 \ln gdp_{it} \\ &+ \alpha_4 \ln tr_{ijt} + g_i + std_{jt} + tech_{ijt} \end{aligned}$$

This is the basic equation we shall use to estimate the applications equation.

Next we model the grant propensity. Let G_{ijt} be the total number of patents granted by country *j* to country *i* at time *t*. It depends on the number of applications (A_{ijt}) and a vector of variables (w_{jt}) that comprise resources of country *j* (gdp_{jt}), and the technological proximity of the applying and granting country ($tech_{ijt}$). Thus we can write:

$$\text{(3a)} \quad G_{ijt} = g(A_{ijt}, w_{jt}) \text{ or } G_{ijt} = g(A_{ijt}, gdp_{jt}, tech_{ijt})$$

To model the grant propensity we use a one-factor Cobb-Douglas function:

$$\text{(3b)} \quad G_{ijt} = \lambda(w_{jt}) e^{vt} A_{ijt}^{\delta_1 + \delta_2 t}$$

where: $(\delta_1 + \delta_2 t)$ denotes the time varying elasticity of granting applications. $\delta_2 > 0$ implies that the elasticity is increasing over time and viceversa.

$\lambda(w_{jt}) e^{vt}$ is the scale parameter and w_{jt} is allowed to develop over time at rate '*v*'.

Taking logs on both sides and substituting for w_{jt} (where this consists gdp (gdp_{jt}) government rd (rd_{jt}) and the technological proximity ($tech_{ijt}$) of the granting country, we can rewrite 3(b) as:

$$\text{(3c)} \quad \ln G_{ijt} = \ln \gamma(w_{jt}) + vt + (\gamma_1 + \gamma_2 t) \ln A_{ijt}$$

Or $$\text{(3d)} \quad \ln G_{ijt} = \ln \gamma + \ln gdp_{jt} + \ln rd_{jt} + \ln tech_{ijt} + vt + \gamma_1 \ln A_{ijt} + \gamma_2 t \ln A_{ijt}$$

Thus the two equations that are used as a basis for the estimation are the application equation 2(d) and the grant equation 3(d).

Section 3: Data and Estimation Techniques

Section 3.1: Data Sources and Variables

The data for the models comes from several sources. The majority of the data are from OECD and the NBER. The EPO patent application and grant data, by IPC (International Patent Classification), come from the OECD Patent database. The bilateral applications and grants data are from the OECD website – the original data was collected by WIPO (World Intellectual Property Organization). The US grant data are from the NBER dataset (Hall et. al, 2001). Most of the explanatory variables and instruments are from the OECD – "Main Science and Technology Indicators", 2003. These include, GDP, Gross R&D expenditure, by country, the amount and share of R&D that was financed and/or performed by industry, a similar breakdown for university R&D, number of full-time R&D personnel, industrial employment and export shares in electronics, pharmaceuticals and aeronautics. These will serve as the major explanatory variables in the empirical model.

The variables relating to the political environment of a country – like government quality and index of property rights, are from the Inter Country Risk Guide and World Bank datasets. These indices range from 0 - 10, with 10 being the highest rating. The bilateral trade data are from the NBER trade dataset (Blonigen, 1999). This consists of the volume of bilateral exports and imports by 4 digit SIC code. For this paper we have not made use of the SIC disaggregation. Our bilateral trade variable is the total volume of trade between countries, by year (in US dollars). Appendix Table 1(A) and (B) show the summary statistics for the primary variables used in the estimation models.

In our larger dataset we have 28 OECD countries[24]. But due to data constraints, the final sample consists of 21 of them[25]. Also, the entries for Belgium and Luxembourg were merged into a single entry for the patent data, in order to use the trade dataset, which did not distinguish between the two. For the OECD (WIPO) dataset, our range is 1994-2000[26]. The application and grant data are by priority year[27]. There is considerable double counting in the data and thus we used a cleaner version of the OECD data.[28] There is also considerable truncation in the data, in the latter years. But for basic estimation purposes we assume that the truncation is uniform across countries and technology classes[29] and use the whole range. These data are not broken down by IPC classes. Appendix Graphs 2 (a) and (b) shows US, French and German Applications & grants to US and Germany.

We also use the EPO data to construct the technology overlap index for each country pair. These data are disaggregated by source countries and IPC classes. We have the application and grant counts by country for each of the 8 IPC classes.[30] The range of this dataset is from 1977-2000. The technology overlap index (Jaffe, 1986) was created by using:

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

where: i, j = country, k = IPC Class (A - H)

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[24] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Japan, Korea (South), Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Switzerland, Sweden, Turkey, UK, US.

[25] Czech Republic, Hungary, Italy, Korea, Mexico, Poland, and Turkey were dropped.

[26] The introduction of lags in the grant equation imply that we can actually use variables from 1995-2000.

[27] This is the date of the first filing. Our choice of this as the appropriate date stems from the fact that patents arrive through different sources – through PCT filings, the EPO of are applied directly to individual countries, and the priority year provides the most consistent application date. However, a problem with this date is that it masks variation of application dates to different countries.

[28] The cleaned data was provided by Prof. Sam Kortum.

[29] This assumption may not be a good one and we plan to explore this issue in further revisions of this paper.

[30] A: Human necessities (includes pharmaceuticals), B: C: Chemistry, D: Textiles, E: F: G: Physics includes computers), H: Electrical

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 value 1. If the vectors f_i and f_j are orthogonal then this index is zero. Ideally we would have liked to use a country's patent application composition to its domestic jurisdiction to pick up the universe of patentable inventions - not just the important ones that are applied for through the EPO. But in the absence of such data, the EPO patent class data serves as a good proxy.

Section 3.2: Operationalizing the Above Model

We estimate a simultaneous equation model with two main equations - an application equation and a grant equation (where patent grants are endogenous) for the OECD and EPO (European Patent Office) data, estimate application propensities from the EPO data and then use that to measure grant propensities from the US grant data..

First, we look at bilateral applications and grants, contrasting US and Non-US endogenous application response to grant standards and the effect of applications on grants. We want to investigate whether the application and grant responses are different when only non-US source and destination countries are considered as opposed to all 21 OECD countries. The idea is that any change in the US patent regime will probably affect (1) US applications to other jurisdictions, (2) Non-US applications to the US (3) US grants to US applications and (4) US grants to Non-US applications. For example, if grant standards are loosened in the US, marginal inventions from the tail of the invention distribution will now be lucrative enough to patent. So applications to the US may rise without any change in the invention production function. A lowering of grant standards will also increase the grants. Thus past grant rate should be a good indicator of the 'tightness' of a regime and a higher grant rate should induce a higher application response. In addition, if standards are declining over time, then the application elasticity should be increasing.

On the other hand, US IPR change should not affect (or have a much smaller effect) (1) Non-US applications to Non-US countries and (2) Non-US grants to Non-US countries. We exploit this fact to study whether the increase in patenting is a pure artifact of the change in US patent practice or whether there is some evidence of a real increase in the invention rate. If applications increase *solely* because of change in the patent regime in the US, then this increase in applications should have no effect on grants for non-US source and destination countries: If the underlying invention production function is unchanged, then any increased application propensity can only be due to more marginal patents entering the application stream. With unchanged grant standards outside the US, such an application increase should not result in rapidly increasing grants. If we do find that for the non-US source and destination countries, applications have a positive effect on grants similar to sample where the US in included - it may be, with some disclaimers, interpreted as evidence to support the Kortum and Lerner (1998) hypothesis about the increase in the world inventiveness. In addition, falling application elasticities ($\gamma_1 + \gamma_2.t$, where γ_2 is negative) over time would support our claim as well.

To further investigate the issue, we use these data to estimate US grant propensities. We estimate the US model for applications and grants and the residual from the grant equation is interpreted as the grant propensity. Again, all else equal, the US grant propensity for Non-US countries, should not affect Non-US applications and grants to Non-US countries, if the patent explosion was solely due to US law change. Lowering of grant standards may attract marginal patents to the US, but would not have a similar effect in other jurisdictions. If we find that US grant propensity affects Non-US grants positively, it is further evidence of increase in world invention rate. Last we use the EPO data to investigate the applications and grants trends by country, to identify any biases that the OECD data may have[31].

Section 4: Results

Section 4.1: Estimation & Basic Results

Our primary aim in this paper is to control for the endogenous application response to patent grants and then investigate the effect of increasing applications on grants. We employ a fixed effects instrumental variable panel data regression to estimate the equations[32] below which are derived from 2(c) and 3(d)(with the appropriate lags and dummies):

$$\ln A_{ijt} = \ln D + \theta_1 \ln rd_{it} + \theta_2 t \ln rd_{it} + \alpha_1 \ln rdgov_{it} + \alpha_2 \ln gdp_{it} + \alpha_3 \ln rd_{jt} + \alpha_4 \ln tr_{ijt} + \gamma_1 g_{ij,t-2}$$
$$+ \gamma_2 gq_{it} + \gamma_3 tech_{ijt} + PairDum + YeaDum + SourceDum + DestinationDum + \varepsilon_{ijt}$$

$$\ln G_{ijt} = \ln \gamma + \phi_1 \ln gdp_{jt} + \phi_2 tech_{ijt} + vt + \gamma_1 \ln A_{ijt} + \gamma_2 t \ln A_{ijt} + \sum_{n=1}^{3} \delta_n A_{ij,t-5} + PairDum$$
$$+ YearDum + SourceDum + DestinationDum + \eta_{ijt}$$

where: applications depend on the past grant rate (as a proxy for the 'toughness' of the regime), GDP, R&D, source and destination country political climate, technology proximity and trade. Grants depend on current applications (instrumented), lagged applications, destination country R&D (proxy for the absorption rate), technological proximity, technological advancement of the source country (share of aeronautics exports used as a proxy) and other source and destination country characteristics.

Table 2(A) provides the results for the basic model for all 21 countries. The patent applications and grant data exclude domestic applications and grants in all countries. First, we find a very strong positive response of patent applications to lagged grant rates. These grant rates

[31] Kortum et al. point out that in the OECD data all patents applied through the EPO were designated as being applied to all EPO countries irrespective to whether the patentee had designated all countries or not.
[32] We performed the Durbin-Wu-Watson test to check for endogeneity.

are calculated for each country pair for each year. For each source country it picks up the country specific technology composition of applications and their associated success rates in various destinations[33]. A one percent change in lagged grant rates increases patent applications by 8 percent, evaluated at the mean of the sample[34]. This is strong evidence that lowering of grant standards will attract more applications.

In addition, we find that business expenditure on R&D by the source country positively affect applications. The time varying elasticity of R&D is 2.4, evaluated at the midpoint of the sample period[35]. This implies that for every one percent increase in business expenditure on R&D during 1997, applications increased by 2.4 percent. The coefficient on the interaction term of time and R&D is positive implying an increasing R&D elasticity over time. Increase in the percentage of government financed R&D has a negative impact on patent applications. This supports existing evidence that since the government conducts more basic R&D and the goal is to increase the "public" knowledge base, such research, by necessity is associated with fewer patents.

Technological proximity has a negative impact on applications. This may be due to fears of crowding out in countries that already invent the same kinds of technologies domestically. One counterintuitive finding is the negative impact of source country legal regime on patenting. One hypothesis is that inventors in countries with secure legal and property right regimes are less inclined to seek patent protection elsewhere – although this is not a satisfactory explanation as inventors must apply for patents in each country they seek protection in. The market size of the

[33] We do not use the overall grant rate for a destination country because this would mask the technology composition effect. For example the average grant rate for the US (destination) in 0.465 in 1994, whereas for Japan it was 0.560 and for UK it was 0.290. Thus each country would be interested in what happened to its specific grant rate taking into account its technology composition.

[34] $\delta\ln(App)/\delta(grant\ rate) = 0.235$. Grant rates are ratios, if converted to percentages, the coefficient would be 0.0024. Thus the marginal effect is: $\delta(App)/\delta(grant\ rate) = 0.0024 * Apps$. Mean on applications = 3277

[35] The total effect is: $\delta\ln(App)/\delta\ln(rd) = \theta_1 + \theta_2.t$, where $\theta_1 = 0.57$, $\theta_2 = 0.031$ and t=4 (mid sample period)

destination country (as measured by GDP) has no impact on applications hinting at the fact that patent protection is sought for other reasons than capturing foreign markets. Finally, transaction costs, as embodied in destination country property rights and the volume of export between countries do not seem to play a significant role in explaining bilateral application numbers.

Controlling for application response to grant rates, we find that current grants are positively affected by current applications. The time varying applications elasticity is 0.124[36], implying that every one percent increase in applications increases grants by slightly over 0.12 percent. This could be attributed to two reasons: lowering of grant standards or increase in world inventiveness. However, the small magnitude is evidence against lowering standards. Also, the negative coefficient on the interaction term[37] between applications and grants imply that the application elasticity is declining over time, evidence against the lowering standards argument.

In addition, lagged applications have a positive elasticity (although nowhere close to one), pointing to the time it takes for applications to pass through the system. We hypothesize that the gross R&D expenditure of the source country is an indicator of invention quality of that country, and hence the positive significant coefficient is expected. Patent office resources of the destination country (proxied by GDP) have a positive impact of patent grants, while the R&D of the destination country has little impact. Last, technological proximity has a strong positive influence on grants.

Tables 2(B)-1 and 2, provide sensitivity analysis for the basic model. From Table 2(B)-1, we observe that factors like a common border, technological advancement (as measured by percentage of exports attributed to aeronautics and commercial energy use of the source country)

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[36] The total effect is: $\delta \ln(\text{Grants})/\delta \ln(\text{Apps}) = \gamma_1 + \gamma_2.t$, where $\gamma_1 = 0.152$, $\gamma_2 = -0.007$ and t=4 (mid sample period)

[37] We estimate an applications equation, predict log(applications) and interact this with time and include it as a regressor in our instrumental variable regression to capture the time varying elasticity of applications. The standard error on this term is corrected for forecast errors.

positively affect applications (columns (i) – (iii)). The property rights index of the source country also has a positive impact on applications, as a stronger regime provides better rewards for invention activities (column (iv)). The response the lagged grant rates remains unchanged in all specifications and most other regressors behave as before. From Table 2(B)-2, we find that destination country property rights index (column(i)) and stability of the destination country (column (iv)) positively affects grants. Again transaction cost variables (like sharing a common language or engaging in high volumes of trade) have little influence on grants. Once again the application elasticities are robust in all specifications.

Section 4.2: Non-US Source and Destination Country Results

As discussed earlier, if the patent explosion in the US is a result of lowering standards, then we should expect to observe differential application response to grants and different application elasticities. When we compare the basic model to the Non-US source and destination model (Table 3(A)), these magnitudes are not dissimilar. The application response to grants is a little weaker (0.159 as opposed to 0.235) implying that a lowering of grants standards in the US would attract more applications than a similar loosening elsewhere. A one percent increase in past grant rates increases applications by 3 percent for Non-US source and destination countries. Most other variables behave as before, with the R&D elasticity being stronger than the full model. The only surprise is the significant negative impact of destination country GDP of patent applications.

From the grant equation, the time varying application elasticity is 0.145, which is higher than the full model. Thus the results in the full model were not driven by US data and as discussed earlier this implies that the surge in patenting in the US cannot be an artifact of US law change alone. Other regressors behave as in the full mode. Table 3(B) provides sensitivity analysis for the Non-US model. As before we find that sharing a common border and technological progress increases patent applications – the first due to decreased transaction cost and the latter due to increased inventiveness. For grants, a common language has no impact, whereas stronger property rights in the source country increase the number of patents granted to that country.

The above results highlight the important fact that US law change alone was not responsible for the increased patenting observed in the late 1990s. However, it may be possible that the aggregate effects are masking individual country variation. To investigate this issue further, Table 3(C), provides a similar analysis for some major countries. In this case, we consider four jurisdictions, US, UK, France and Germany, and study the application response to grants and application elasticities. For the US destination, neither coefficients of interest are significant. For the other three countries we find that the endogenous application response and the grant response to applications is even stronger. In fact, for every one percent increase in applications in these countries, grants increased between 2 and 3 percent. If we hold that grants standards in these jurisdictions have remained unchanged during our sample period, then it stands to reason that there is one primary channel through which such an effect would occur. An increase in world inventiveness would produce more quality inventions, which in turn would increase the number of applications that could cross the grants standard threshold (standards remaining unchanged). This finding is further support for our hypothesis of increased invention rate.

To further investigate this increased inventiveness story, we model the effect of US grants propensities in non-US applications and grants. If our hypothesis is correct, then the US grants propensity should have a negligible impact on non-US grants to non-US countries. In the application equation, this propensity may have a negative impact implying some crowding out issues. For example, consider a resource constrained inventor who must choose one jurisdiction in which to apply. If the US grant propensity increases, he or she is more likely to favor the US as a destination. This will decrease the number of patents applied for in non-US countries. In the grant equation, a positive coefficient on the US grant propensity would rule out the US law change story. A positive coefficient implies that a country with a high US grant propensity also has greater number of grants in Non-US jurisdictions. If standards remain unchanged in these countries, then it signifies that increased patenting in the US by these countries is not an artifact of the law change – some underlying invention rate and /or the quality of inventions has increased.

To study this, we first estimate the basic regression from Table 3(A) for the US destination only. The residuals from the grants equation are interpreted as US grant propensity for non-US applications. In Table 4(A) we estimate the same basic model as in table 3(A) with this grant propensity added. We find that the US grant propensity has a significant negative effect on applications. This implies that when applying to Non-US destinations, Non-US countries take US grants rates into account. All other coefficients remain unchanged. However, we find that the US grant propensity has no impact on Non-US grants to Non-US countries. This implies that, say, a country with a high US grant propensity have equal chances of obtaining a patent from a Non-US country as one with a low US grant propensity. This result does not allow us to rule out the law change argument. However we believe that this aggregate estimation masks the true effect of US grant propensities. Therefore we estimate a country-wise model for UK, Germany and France to study this issue further.

Table 4(B) shows the country-wise results. Two things stand out immediately. First, US grant propensity has a negative impact on patent applications in other jurisdictions – as observed earlier. Second, the US grant propensity has a significant positive impact on Non-US grants, the elasticity varying between 0.33 and 0.47. Therefore for every one percent increase in US grant propensity for a Non-US source country, the Non-US grants increase by 0.4 percent on average. This evidence favors the invention rate change argument, as discussed earlier.

Section 4.3: EPO Results

There is concern however, that that there is some measurement error in the applications data from the OECD (Eaton et. al) which may bias our results. In particular, they find that the number of designated countries are overstated in the OECD data. To ascertain the robustness of our earlier result, we re-estimate the Non-US source and destination country model from Table 3(A) using EPO data.

This particular dataset contains all applications to EPO countries over a period of 1978 – 2002. There are 15 EPO destination countries[38] and twenty-one source countries. These data do not contain grant numbers and so we use the data from the OECD tables, which are not subject to the same biases as the application data. From Table 5(A) we find that the variables of interest behave as before. The lagged grant rate has a positive effect of applications, although the magnitude is smaller. The time varying application elasticity is positive and significant although smaller than previously estimated. Expenditure on business R&D has a positive and increasing time varying coefficient and percentage of government financed R&D has a positive effect on applications on this model. In this specification, the technology overlap index is positive

38These countries are : AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LI, LU, MC, NL, PT, SE, FI, CY implying that when considering EPO countries inventors are more likely to apply in countries with similar technology profiles. All other coefficients in both the applications and grant equation are similar to those previously estimated.

We also conduct a sensitivity analysis for the above results. In Table 5(B), we add the aeronautics exports and substitute the law index with the stability index in the applications equation. Both are positive and significant as before. For the grant equation, the application country property right regime has no effect, although in the OECD data it was positive. In addition, the common language dummy has a positive effect on grants signifying that for EPO countries, language may be an important factor for the grant examination process.

All empirical specifications point to the importance of the endogenous application response and the effect of grants rates on applications. We find that for both the US and Non-US samples, the results are quite similar. After controlling for source and destination country characteristics, past grant rates positively influencing current applications and the time varying application elasticity is positive but declining. In addition US grant propensities have a significant positive impact on grants from large Non-US countries. These findings, we contend, provides evidence that the US patent surge was, at least partly due to an increase in world inventiveness and not a pure artifact of declining standards in the US.

Section 4: Conclusion

This paper investigates the underlying drivers of the patent explosion in the late 1990s by modeling applications and grants in different jurisdictions. We find some preliminary evidence that the US patent surge was party due to an increase in the world inventiveness and not a pure artifact of US patent law changes. We find that patent applications are strongly influenced by the patent grant rate of various destination countries. This suggests that past grant rates serve as an indicator of the 'tightness' of an IPR regime and a higher grant rate induces a higher application response. Thus any law change that influences this grant rate will in turn affect the application rate in the country. Controlling for application response to grant rates, we find that current grants are positively affected by current applications, although this elasticity is considerably smaller than one and is declining over time. The similarity of the US and Non-US response implies that the surge in patenting cannot be an artifact of US law change alone. The underlying inventiveness rate must have changed.

Another interesting finding is that the US grant propensity negatively affects non-US applications to Non-US countries. Thus there is evidence of crowding out and some part of the increase in patent applications in the US (especially if we believe that grant standards are indeed lower than other countries) may be attributed to this phenomena. Although we find no effect of US grant propensities on the Non-US grants for the full Non-US sample, the country-wise analysis points to a different direction. In the country-wise estimates, US grant propensity has a strong positive coefficient. As discussed earlier, this would rule out the US law change story. A positive coefficient implies that a country that has a high US grant propensity, also has greater number of grants in Non-US jurisdictions. If standards remain unchanged in these countries, then it signifies that increased grants in the US to these countries are not solely an artifact of the law change, because the countries getting more patents from the US are also getting more patents from other countries around the world, suggesting that they really are producing more inventions.

The current results shed light on two important things: (a) the extent to which the explosion in patenting in the U.S. can be attributed to an endogenous application response to declining examination standards and (b) the extent to which the increase in grants reflects more underlying invention. This has implications for future work. First, a more rigorous look at the US and Non-US grant propensities, disaggregated by technology class, is warranted. The grant propensities of USPTO and EPO in the various technology classes for both domestic and foreign applications in the various jurisdictions need to be estimated. These would shed light on whether grant propensities for US inventions are different by jurisdiction and technology class when compared with those of other countries. This could be used to infer underlying patent quality controlling for country characteristics. A second area is to study similar research questions based on the triadic patent family applications and grant data. This would control for quality variations across patents and investigate whether similar patents have differing grant rates in different jurisdictions, and thereby have implications for the "tightness" of IPR regimes, contributing towards our understanding of the patent surge.

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TABLE 1(A)

OECD/WIPO BILATERAL COUNTRY DATA SUMMARY STATISTICS

VARIABLE	OBS.	MEAN	STD. DEV.	MIN	MAX
ESTIMATION SAMPLE: 21 OECD COUNTRIES					
Total Applications	1460	3276.93	6544.30	8.00	45856
Total Grants	1460	873.33	2156.91	1.00	23179
Log (Real Gross R&D Expenditure)	1460	8.71	1.53	6.39	12.23
Log (Real Business R&D Expenditure)	1460	8.13	1.73	5.07	11.93
Percentage of R&D Financed by Government	1460	37.79	10.70	18.40	68.20
Log (Real GDP)	1460	12.77	1.30	10.99	15.89
Legal Quality Index (Lagged 3 Yrs.)	1460	9.66	0.73	6.67	10.00
Share of Aeronautics export in Total Exports	1460	4.97	9.73	0.02	44.56
Volume of Exports (Lagged 3 Yrs.)	1460	12.27	5.38	-16.12	18.60
Technology Overlap Index	1460	0.88	0.09	0.45	0.99
ESTIMATION SAMPLE: NON-US DESTINATION & NON-US SOURCE COUNTRIES					
Total Applications	1308	1930.03	2858.33	8.00	18480
Total Grants	1308	582.14	1428.61	1.00	12092
Log (Real Gross R&D Expenditure)	1308	8.52	1.34	6.39	11.38
Log (Real Business R&D Expenditure)	1308	7.93	1.54	5.07	11.09
Percentage of R&D Financed by Government	1308	37.94	10.92	18.40	68.20
Log (Real GDP)	1308	12.60	1.11	10.99	14.98
Legal Quality Index (Lagged 3 Yrs.)	1308	9.65	0.74	6.67	10.00
Share of Aeronautics export in Total Exports	1308	3.00	4.96	0.02	18.41
Volume of Exports (Lagged 3 Yrs.)	1308	12.32	5.13	-16.12	18.60
Technology Overlap Index	1308	0.88	0.09	0.45	0.99

TABLE 1(B)

EPO PATENT STATISTICS

ESTIMATION SAMPLE: 15 EPO DESTINATION & 20 NON-US SOURCE COUNTRIES					
Total Applications	910	1063.38	1854.19	4.00	14001.00
Total Grants	910	674.28	1452.52	1.00	12055.00
Log (Real Gross R&D Expenditure)	910	8.47	1.33	6.39	11.38
Log (Real Business R&D Expenditure)	910	7.87	1.55	5.07	11.09
Percentage of R&D Financed by Government	910	38.52	11.06	18.40	68.20
Log (Real GDP)	910	12.57	1.10	10.99	14.98
Legal Quality Index (Lagged 3 Yrs.)	910	9.64	0.75	6.67	10.00
Share of Aeronautics export in Total Exports	910	2.95	4.92	0.02	18.41
Volume of Trade (Lagged 3 Yrs.)	910	14.48	1.55	9.45	17.58
Technology Overlap Index	910	0.89	0.09	0.45	0.99

TABLE 2(A)

EXPLAINING PATENT GRANTS: BASIC MODEL

Dependent Variable: Log(Applications) & Log(Grants)

	APPLICATION EQUATION	GRANT EQUATION
Log (Applications) (Instrumented)	-	0.152 (0.089) *
Log (Applications) (Predicted) * Time	-	-0.007 (0.003) **
Log(Application – Lagged 1 Year)	-	0.083 (0.072)
Log(Application – Lagged 2 Years)	-	0.115 (0.033) **
Log(Application – Lagged 3 Years)	-	0.117 (0.016) **
Lagged Patent Grant Rate	0.235 (0.057) **	-
Log (Gross Expenditure on R&D of Source Country)	-	0.675 (0.279) **
Log (Business Expenditure on R&D of Source Country)	0.570 (0.164) **	-
Log (Business Expenditure on R&D of Source Country) * Time	0.031 (0.008) **	-
Percentage of Gross R&D Expenditure Financed by Govt.	-0.009 (0.002) **	-
Legal Quality Index of Source Country	-0.072 (0.021) **	-
Log (Real GDP of Destination Country)	-0.241 (0.182)	1.108 (0.378) **
Log (Gross Expenditure on R&D of Destination Country)	-	0.417 (0.305)
Destination Country Property Rights Index	-0.004 (0.005)	-
Technology Overlap Index	-0.561 (0.150) **	1.776 (0.283) **
Log (Vol. of Exports from Source Country - Lag 3 Yrs.)	-0.0002 (0.001)	-
Time Trend	-	-0.043 (0.038)
Country Pair Fixed Effects	Yes	Yes
Destination Country Dummy	Yes	Yes
Source Country Dummy	Yes	Yes
Time Dummies	Yes	Yes
R Square	0.837	0.435
Observations	1460	1460

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 21 OECD countries and 7 years (1994-2000). '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance. The equations estimated are

TABLE 2(B)-1

SENSITIVITY ANALYSIS (I)

Dependent Variable: Log(Applications)

	APPLICATION EQUATION			
Grant Equation (Same as Basic Model)	**(i)**	**(ii)**	**(iii)**	**(iv)**
Lagged Patent Grant Rate	0.223 ** (0.057)	0.223 ** (0.057)	0.223 ** (0.057)	0.223 ** (0.057)
Log (Business Expenditure on R&D of Source Country)	0.282 * (0.165)	0.389 ** (0.148)	0.233 * (0.144)	-
Log (Business Expenditure on R&D of Source Country) * Time	0.033 ** (0.008)	0.034 ** (0.008)	0.028 ** (0.008)	-
Log (R&D Personnel of Source Country)	-	-	-	0.621 ** (0.168)
Log (R&D Personnel of Source Country) * Time	-	-	-	0.037 ** (0.008)
Percentage of Gross R&D Expenditure Financed by Govt.	-0.017 ** (0.002)	-0.014 ** (0.002)	-0.015 ** (0.002)	-0.015 ** (0.002)
Legal Quality Index of Source Country	0.088 ** (0.022)	0.094 ** (0.021)	0.081 ** (0.021)	-
Property Rights Index of Source Country	-	-	-	0.109 ** (0.021)
Technology Overlap Index	-0.558 ** (0.149)	-0.558 ** (0.149)	-0.558 ** (0.149)	-0.558 ** (0.149)
Log (Real GDP of Destination Country)	-0.242 (0.106)	-0.242 (0.180)	-0.242 (0.180)	-0.242 (0.181)
Destination Country Property Rights Index	-0.004 (0.005)	-0.004 (0.005)	-0.004 (0.005)	-0.004 (0.005)
Log (Vol. of Exports from Source Country - Lag 3 Yrs.)	-0.0004 (0.001)	-0.0004 (0.001)	-0.0004 (0.001)	-0.0004 (0.001)
Common Border Dummy	0.252 ** (0.067)	0.252 ** (0.067)	0.252 ** (0.068)	0.252 ** (0.067)
Share of Aeronautics Exports in Total Exports	-	0.008 ** (0.002)	-0.002 (0.002)	0.012 ** (0.003)
Commercial Energy Use By Source Country	-	-	0.0001 ** (0.00002)	0.0001 ** (0.00002)
R Square	0.847	0.867	0.862	0.868
Observations	1460	1460	1460	1460

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 21 OECD countries and 7 years (1994-2000). The fixed effects in this case are country-pairs. '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance. The applications equation also includes a time trend, source country, destination country, time and source country*year dummies. The grant equation specification is identical to the basic model and all estimates remain unchanged in sign and significance.

TABLE 2(B)-2

SENSITIVITY ANALYSIS (II)

Dependent Variable: Log(Grants)

	GRANT EQUATION			
Application Equation (Same as Basic Model)	(i)	(ii)	(iii)	(iv)
Log (Applications) (Instrumented)	0.140 * (0.089)	0.141 * (0.089)	0.136 * (0.089)	0.148 * (0.089)
Log (Applications) (Predicted) * Time	-0.007 ** (0.003)	-0.007 ** (0.003)	-0.007 ** (0.003)	-0.007 ** (0.003)
Log(Application – Lagged 1 Year)	0.086 (0.072)	0.087 (0.072)	0.090 (0.072)	0.093 (0.071)
Log(Application – Lagged 2 Years)	0.122 ** (0.033)	0.122 ** (0.033)	0.122 ** (0.033)	0.119 ** (0.033)
Log(Application – Lagged 3 Years)	0.117 ** (0.015)	0.117 ** (0.016)	0.117 ** (0.016)	0.115 ** (0.015)
Log (Real GDP of Destination Country)	1.099 ** (0.377)	1.098 ** (0.377)	1.090 ** (0.380)	1.193 ** (0.376)
Log (Gross Expenditure on R&D of Destination Country)	0.432 (0.305)	0.427 (0.305)	0.420 (0.307)	0.149 (0.316)
Log (Gross Expenditure of R&D of Source Country)	0.658 ** (0.279)	0.657 ** (0.279)	0.652 ** (0.280)	0.642 ** (0.278)
Destination Country Property Rights Index	0.026 * (0.015)	0.026 * (0.015)	0.025 * (0.015)	0.027 * (0.015)
Technology Overlap Index	1.763 ** (0.283)	1.761 ** (0.283)	1.759 ** (0.284)	1.665 ** (0.282)
Common Language Dummy	-	0.055 (0.093)	-	-
Log (Vol. of Trade - Lag 3 Yrs.)	-	-	0.016 (0.075)	-
Stability Index for Destination Country	-	-	-	0.076 ** (0.019)
R Square	0.757	0.696	0.697	0.770
Observations	1460	1460	1460	1460

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 21 OECD countries and 7 years (1994-2000). The fixed effects in this case are country-pairs. '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance. The grant equation also includes source country, destination country and year dummies. The application equation specification is identical to the basic model and all estimates remain unchanged in sign and significance

TABLE 3(A)
NON-US PATENT APPLICATIONS AND GRANTS: BASIC MODEL
Dependent Variable: Log(Applications) & Log(Grants)

	APPLICATION EQUATION	GRANT EQUATION
Log (Applications) (Instrumented)	-	0.185 (0.100) *
Log (Applications) (Predicted) * Time	-	-0.010 (0.005) **
Log(Application – Lagged 1 Year)	-	0.079 (0.075)
Log(Application – Lagged 2 Years)	-	0.122 (0.035) **
Log(Application – Lagged 3 Years)	-	0.117 (0.016) **
Lagged Patent Grant Rate	0.159 (0.059) **	-
Log (Gross Expenditure on R&D of Source Country)	-	0.554 (0.332) *
Log (Business Expenditure on R&D of Source Country)	0.989 (0.175) **	-
Log (Business Expenditure on R&D of Source Country) * Time	0.055 (0.010) **	-
Percentage of Gross R&D Expenditure Financed by Govt.	-0.006 (0.002) **	-
Legal Quality Index of Source Country	-0.061 (0.020) **	-
Log (Real GDP of Destination Country)	-0.459 (0.183) **	1.191 (0.406) **
Log (Gross Expenditure on R&D of Destination Country)	-	0.325 (0.358)
Destination Country Property Rights Index	-0.003 (0.005)	-
Technology Overlap Index	-0.481 (0.150) **	1.898 (0.304) **
Log (Vol. of Exports from Source Country - Lag 3 Yrs.)	0.001 (0.001)	-
Time Trend	-	-0.021 (0.050)
Country Pair Fixed Effects	Yes	Yes
Destination Country Dummy	Yes	Yes
Source Country Dummy	Yes	Yes
Time Dummies	Yes	Yes
R Square	0.698	0.435
Observations	1308	1308

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 21 OECD countries and 7 years (1994-2000). '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 3(B)

NON-US PATENT APPLICATIONS AND GRANTS: SENSITIVITY ANALYSIS

Dependent Variable: Log(Applications) &Log(Grants)

	APPLICATION EQUATION *(Grt. Eqn. Same as 3(a))*		**GRANT EQUATION** *(App. Eqn. Same as 3(a))*	
	(i)	**(ii)**	**(iii)**	**(iv)**
Log (Applications) (Instrumented)	-	-	0.176 * (0.100)	0.178 * (0.100)
Log (Applications) (Predicted) * Time	-	-	-0.010 ** (0.005)	-0.010 ** (0.005)
Log(Application – Lagged 1 Year)	-	-	0.081 (0.075)	0.081 (0.075)
Log(Application – Lagged 2 Years)	-	-	0.129 * (0.035)	0.129 * (0.035)
Log(Application – Lagged 3 Years)	-	-	0.117 * (0.016)	0.117 * (0.016)
Lagged Patent Grant Rate	0.146 ** (0.058)	0.146 ** (0.058)	-	-
Log (Gross Expenditure on R&D of Source Country)	-	-	0.514 * (0.332)	0.513 * (0.332)
Log (Business Expenditure on R&D of Source Country)	0.712 ** (0.173)	0.715 ** (0.173)	-	-
Log (Business Expenditure on R&D of Source Country) * Time	0.040 ** (0.010)	0.039 ** (0.010)	-	-
Percentage of Gross R&D Expenditure Financed by Govt. (Source Country)	-0.015 ** (0.012)	-0.015 ** (0.016)	-	-
Legal Quality Index of Source Country	0.091 ** (0.021)	0.094 ** (0.021)	-	-
Log (Real GDP of Destination Country)	-0.460 ** (0.181)	-0.460 ** (0.181)	1.186 ** (0.406)	1.186 ** (0.406)
Log (Gross Expenditure on R&D of Destination Country)	-	-	0.330 (0.357)	0.325 (0.358)
Destination Country Property Rights Index	-0.003 (0.005)	-0.003 (0.005)	-	-
Technology Overlap Index	-0.478 ** (0.149)	-0.478 ** (0.149)	1.879 ** (0.304)	1.878 ** (0.304)
Log (Vol. of Exports from Source Country - Lag 3 Yrs.)	0.0004 (0.001)	0.0004 (0.001)	-	-
Common Border Dummy	0.271 ** (0.066)	0.271 ** (0.066)	-	-
Share of Aeronautics Exports in Total Exports	-	0.027 ** (0.003)	-	-
Source Country Property Rights Index	-	-	0.027 ** (0.016)	0.027 ** (0.016)
Common Language Dummy	-	-	-	0.040 (0.101)
R Square	0.710	0.693	0.613	0.688

TABLE 3(C)
COUNTRY-WISE ESTIMATION
Dependent Variable: Log(Applications) & Log(Grants)

Source	**Non-US**			
Destination	**US**	**UK**	**France**	**Germany**
APPLICATION EQUATION				
Lagged Patent Grant Rate	0.253 (0.226)	0.295 * (0.171)	0.324 * (0.193)	0.437 ** (0.189)
Log (Gross R&D Expenditure of Source Country)	0.311 * (0.180)	0.212 (0.204)	0.152 (0.208)	0.157 (0.186)
% of Gross R&D Expenditure Financed by Govt. (Source Country)	0.003 (0.004)	-0.003 (0.004)	0.002 (0.004)	0.004 (0.004)
Legal Quality Index For Source Country	0.047 ** (0.019)	0.007 (0.018)	0.013 (0.022)	0.009 (0.020)
Log (Vol. of Exports from Source Country - Lag 3 Yrs.)	0.004 (0.004)	-0.002 (0.003)	0.142 ** (0.075)	0.002 (0.004)
Technology Overlap Index	-0.524 (0.411)	-0.110 (0.370)	0.083 (0.430)	0.200 (0.373)
Share of Aeronautics Exports in Total Exports	-0.005 (0.013)	0.010 (0.016)	-0.004 (0.017)	-0.005 (0.013)
R Square	0.697	0.862	0.596	0.871
GRANT EQUATION				
Log (Applications) (Instrumented)	1.620 (1.517)	3.233 ** (1.587)	1.704 ** (0.812)	2.492 ** (0.837)
Log (Applications) (Predicted) * Time	-0.012 (0.031)	-0.033 (0.024)	-0.048 (0.037)	-0.020 (0.029)
Log(Application – Lagged 1 Year)	-0.091 (0.311)	-0.727 * (0.482)	-0.176 (0.259)	-0.475 * (0.286)
Log(Application – Lagged 2 Years)	0.205 (0.251)	0.102 (0.271)	-0.165 (0.168)	-0.074 (0.173)
Log(Application – Lagged 3 Years)	0.092 (0.221)	0.334 * (0.202)	0.334 * (0.142)	0.229 * (0.141)
Log (Gross Expenditure on R&D of Source Country)	-0.234 (0.664)	-0.156 (0.768)	0.428 (0.549)	0.002 (0.507)
Source Country Property Rights Index	-0.096 (0.087)	0.045 (0.059)	0.021 (0.053)	0.025 (0.051)
Time Trend	0.074 (0.294)	-0.125 (0.261)	0.084 (0.261)	-0.146 (0.256)
R Square	0.982	0.930	0.923	0.919

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 21 source countries and 7 years (1994-2000). No of obs = 122. Standard errors are corrected for forecast error. ‘ *’ denotes 10% level of significance and ‘**’ denotes at least a 5% level of significance. Both equations include a constant, source country and time dummy.

TABLE 4(A)
EFFECT OF US GRANT PROPENSITY ON FOREIGN APPLICATIONS & GRANTS

Destination =Non-US, Source = Non-US	BASIC MODEL		SENSITIVITY ANALYSIS	
	Applications	**Grants**	**Applications**	**Grants**
Lagged Patent Grant Rate	0.150 (0.057) **	-	0.137 (0.057) **	-
US Patent Grant Propensity for Source Country	-0.538 (0.124) **	-0.020 (0.051)	-0.235 (0.112) **	-0.016 (0.051)
US Patent Grant Propensity for Destination Country		-	-	-
Log (Applications) (Instrumented)	-	0.167 (0.099) *	-	0.170 (0.098) *
Log (Applications) (Predicted) * Time	-	-0.010 (0.005) **	-	-0.010 (0.005) **
Log(Application – Lagged 1 Year)	-	0.089 (0.075)	-	0.086 (0.074)
Log(Application – Lagged 2 Years)	-	0.119 (0.035) **	-	0.127 (0.035) **
Log(Application – Lagged 3 Years)	-	0.116 (0.016) **	-	0.116 (0.017) **
Log (Gross R&D Expenditure of Source Country)	0.968 (0.210) **	0.587 (0.326) *	1.139 (0.197) **	0.531 (0.327) *
Log (Gross R&D Exp. of Source Country) * Time	0.021 (0.011) **	-	0.030 (0.009) **	-
% of Govt. Fin. Gross R&D Exp (Source Country)	-0.011 (0.003) **	-	-0.016 (0.004) **	-
Legal Quality Index of Source Country	0.095 (0.024) **	-	0.118 (0.065) *	-
Property Rights Index of Source Country	-	-	-	0.028 (0.016) *
Log (Real GDP of Destination Country)	-	1.200 (0.406) **	-	1.202 (0.406) **
Log (Gross R&D Exp. of Destination Country)	-	0.361 (0.353)	-	0.343 (0.352)
Destin. Country Property Rights Index	-0.002 (0.005)	-	-0.002 (0.005)	-
Log (Vol. of Exports Source Country - Lagged 3 Yrs.)	0.001 (0.001)	-	0.001 (0.001)	-
Technology Overlap Index	-0.465 (0.150) **	1.875 (0.304) **	-0.461 (0.149) **	1.856 (0.304) **
Common Border Dummy	-	-	0.271 (0.066) **	-
Sh. of Aeronautics Exp. in Total Exp. (Source Country)	-	-	0.033 (0.004) **	-
R Square	0.736	0.726	0.722	0.719

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 21 source countries and 7 years (1994-2000). No of obs = 1308. Standard errors are corrected for forecast error. ' *' denotes 10% level of significance and '**' denotes at least a 5% level of significance. Both equations include a constant, source country, destination country and time dummy. The application equation also includes source country*time dummy. The grant equation includes a time trend.

TABLE 4(B)
EFFECT OF US GRANT PROPENSITY ON APPLICATIONS & GRANTS TO UK, GERMANY, FRANCE

Source	Non-US		
Destination	**UK**	**Germany**	**France**
APPLICATIONS EQUATION			
Lagged Patent Grant Rate	0.270 **	0.363 **	0.150
	(0.138)	(0.162)	(0.198)
US Patent Grant Propensity for Source Country	-0.163 **	-0.211 **	-0.158 **
	(0.033)	(0.034)	(0.044)
Log (Gross R&D Expenditure of Source Country)	0.211	0.244 *	0.259
	(0.169)	(0.156)	(0.200)
Log (Gross R&D Expenditure of Source Country) * Time	0.004	-0.005	0.008
	(0.004)	(0.005)	(0.009)
% of Gross R&D Expenditure Financed by Govt. (Source Country)	-0.003	0.003	0.0001
	(0.003)	(0.003)	(0.004)
Legal Quality Index For Source Country	-0.006	-0.016	0.021
	(0.017)	(0.019)	(0.021)
Share of Aeronautics Exports in Total Exports	0.015	0.008	0.012
	(0.013)	(0.011)	(0.018)
Log (Vol. of Trade - Lagged 3 Yrs.)	0.089	0.117	0.269 **
	(0.073)	(0.084)	(0.135)
Technology Overlap Index	-0.086	0.505	0.338
	(0.319)	(0.326)	(0.409)
R Square	0.055	0.741	0.500
GRANT EQUATION			
Log (Applications) (Instrumented)	2.959 **	2.014 **	2.158 **
	(0.781)	(0.433)	(0.631)
Log (Applications) (Predicted) * Time	-0.054 **	-0.065 **	-0.017
	(0.027)	(0.018)	(0.027)
Log(Application – Lagged 1 Year)	-0.416	-0.288	0.124
	(0.335)	(0.217)	(0.284)
Log(Application – Lagged 2 Years)	0.208	0.030	-0.129
	(0.222)	(0.128)	(0.169)
Log(Application – Lagged 3 Years)	0.321 **	0.080	0.323 **
	(0.142)	(0.095)	(0.131)
US Patent Grant Propensity for Source Country	0.470 **	0.334 **	0.373 **
	(0.159)	(0.137)	(0.150)
Log (GDP of Source Country)	2.172 **	0.286	-0.598
	(1.076)	(0.592)	(0.765)
Technology Overlap Index	0.388	-0.256	1.663
	(0.907)	(0.708)	(1.081)
R Square	0.909	0.939	0.945

Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. There are 20 source countries and 7 years (1994-2000). The application and grant equations also include a constant, source country and time dummy. The grant equation includes a time trend as well. The US grant propensity is the residual from Table 3(C) where Source=Non-US countries and Destination = US. Standard errors are corrected for forecast error. ‘ *’ denotes 10% level of significance and ‘**’ denotes at least a 5% level of significance.

TABLE 5(A)

EPO APPLICATIONS AND GRANTS: BASIC MODEL

	APPLICATION EQUATION	GRANT EQUATION
Log (Applications) (Instrumented)	-	0.215 (0.092) **
Log (Applications) (Predicted) * Time	-	-0.045 (0.006) **
Log(Application – Lagged 1 Year)	-	0.275 (0.078) **
Log(Application – Lagged 2 Years)	-	0.025 (0.051)
Log(Application – Lagged 3 Years)	-	0.040 (0.004) **
Lagged Patent Grant Rate	0.072 (0.040) *	-
Log (Gross Expenditure on R&D of Source Country)	-	0.122 (0.281)
Log (Business Expenditure on R&D of Source Country)	0.667 (0.145) **	-
Log (Business Expenditure on R&D of Source Country) * Time	0.046 (0.012) **	-
Percentage of Gross R&D Expenditure Financed by Govt.	0.003 (0.001) **	-
Legal Quality Index of Source Country	-0.064 (0.018) **	-
Log (Real GDP of Destination Country)	-0.135 (0.140)	1.379 (0.341) **
Destination Country Property Rights Index	-0.001 (0.003)	-
Technology Overlap Index	0.488 (0.106) **	0.680 (0.264) **
Log (Volume of Bilateral Trade - Lagged 3 Yrs.)	-0.002 (0.026)	-
Time Trend	-	0.250 (0.047) **
Country Pair Fixed Effects	Yes	Yes
Destination Country Dummy	Yes	Yes
Source Country Dummy	Yes	Yes
Time Dummies	Yes	Yes
R Square	0.929	0.427
Observations	910	910

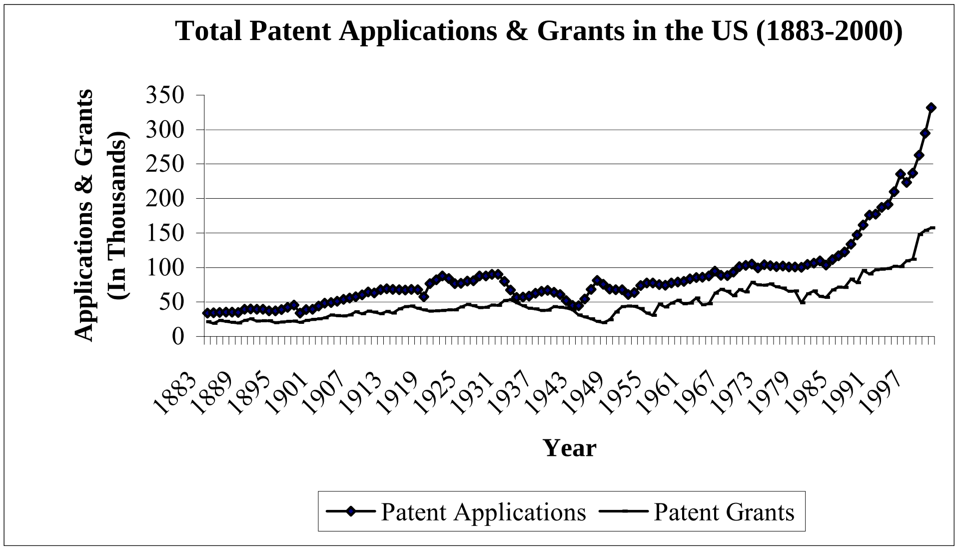
Note: A fixed effects instrumental variable regression model has been used to estimate the two equations. This specification is identical to the one in Table 3(A). The only difference is the estimation sample. This sample consists of 20 source countries (same as out original sample (without US) and 15 destination countries 7 years (1994-2000). Number of obs. = 910. '*' denotes 10% level of significance and '**' denotes at least a 5% level of significance.

TABLE 5(B)

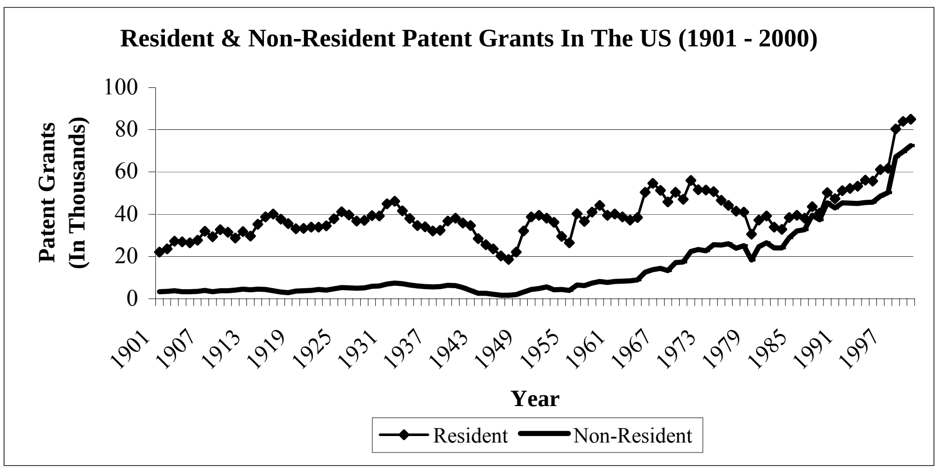
EPO APPLICATIONS AND GRANTS: SENSITIVITY ANALYSIS

Source= Non-US	**APPLICATION EQUATION**		**GRANT EQUATION**	
	(Grt. Eqn. Same as 3(a))		*(App. Eqn. Same as 3(a))*	
Destination = EPO Countries	**(i)**	**(ii)**	**(iii)**	**(iv)**
Log (Applications) (Instrumented)	-	-	0.208 ** (0.092)	0.202 ** (0.092)
Log (Applications) (Predicted) * Time	-	-	-0.045 ** (0.006)	-0.046 ** (0.006)
Log(Application – Lagged 1 Year)	-	-	0.264 ** (0.078)	0.272 ** (0.078)
Log(Application – Lagged 2 Years)	-	-	0.023 (0.051)	0.016 (0.051)
Log(Application – Lagged 3 Years)	-	-	0.040 ** (0.004)	0.040 ** (0.004)
Lagged Patent Grant Rate	0.072 * (0.040)	0.072 * (0.040)	-	-
Log (Gross Expenditure on R&D of Source Country)	-	-	0.132 (0.281)	0.138 (0.281)
Log (Business Expenditure on R&D of Source Country)	0.232 ** (0.071)	-	-	-
Log (Business Expenditure on R&D of Source Country) * Time	-0.009 (0.007)	-	-	-
Percentage of Gross R&D Expenditure Financed by Govt. (Source Country)	-0.011 ** (0.004)	-0.027 ** (0.005)	-	-
Log (R&D Personnel of Source Country)	-	0.495 ** (0.164)	-	-
Log (R&D Personnel of Source Country) * Time	-	0.066 ** (0.011)	-	-
Stability Index of Source Country	0.211 ** (0.027)	0.286 ** (0.039)	-	-
Log (Real GDP of Destination Country)	-0.135 (0.140)	-0.135 (0.140)	1.372 ** (0.340)	1.377 ** (0.340)
Destination Country Property Rights Index	-0.001 (0.003)	-0.001 (0.003)	-	-
Technology Overlap Index	0.488 ** (0.106)	0.488 ** (0.106)	0.663 ** (0.264)	0.671 ** (0.264)
Log (Volume of Bilateral Trade- Lagged 3 Yrs.)	-0.002 (0.026)	-0.002 (0.026)	-	-
Share of Aeronautics Exports in Total Exports	0.028 ** (0.010)	-0.009 (0.009)	-	-
Common Language Dummy			0.248 * (0.134)	0.248 * (0.134)
Source Country Property Rights Index	-	-	-	-0.016 (0.014)
R Square	0.954	0.890	0.334	0.656

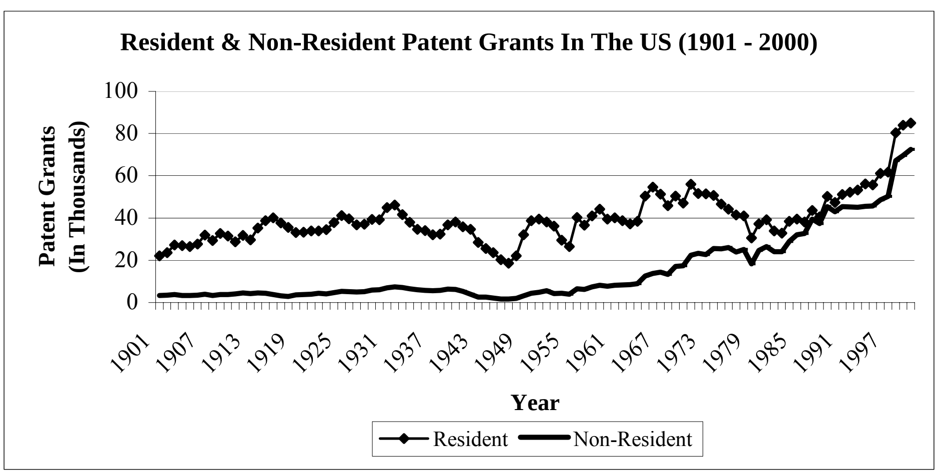
APPENDIX GRAPHS



GRAPH 1(A)

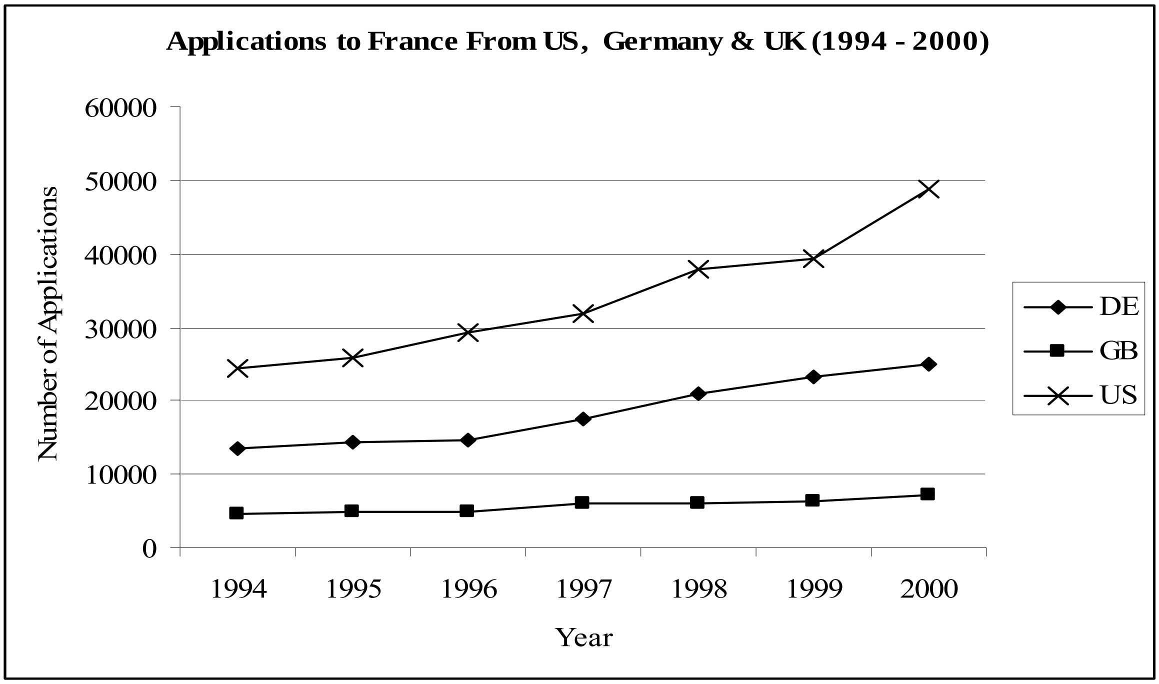


GRAPH 1(B)

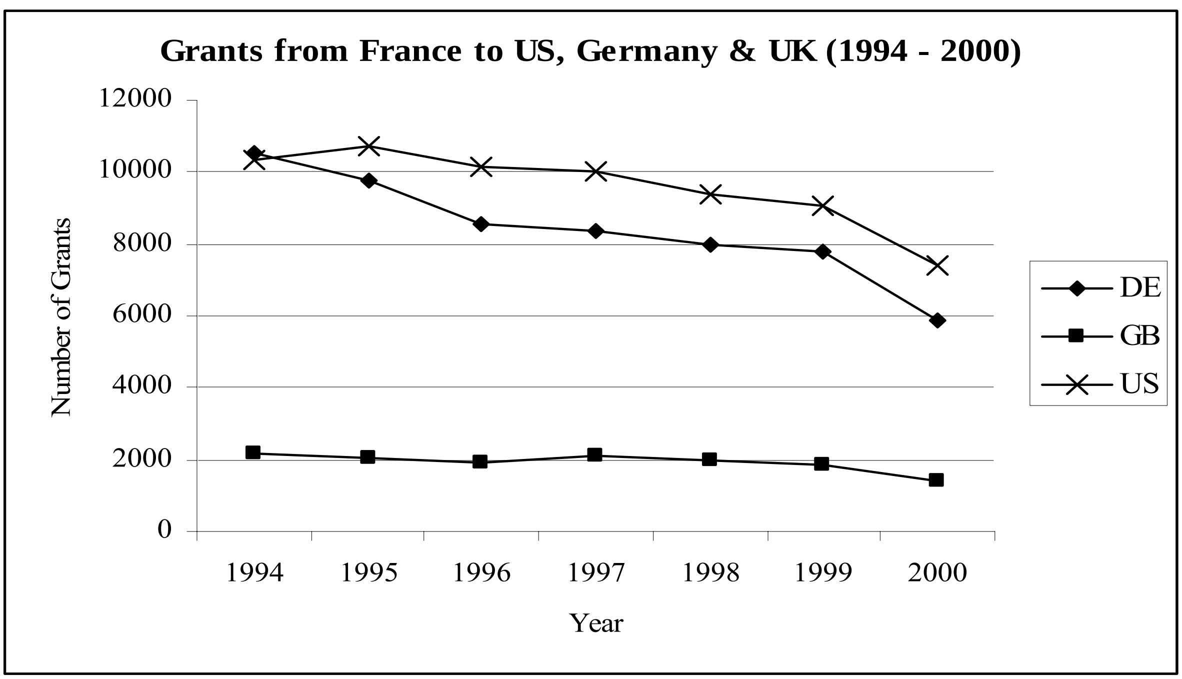


GRAPH 1(C)

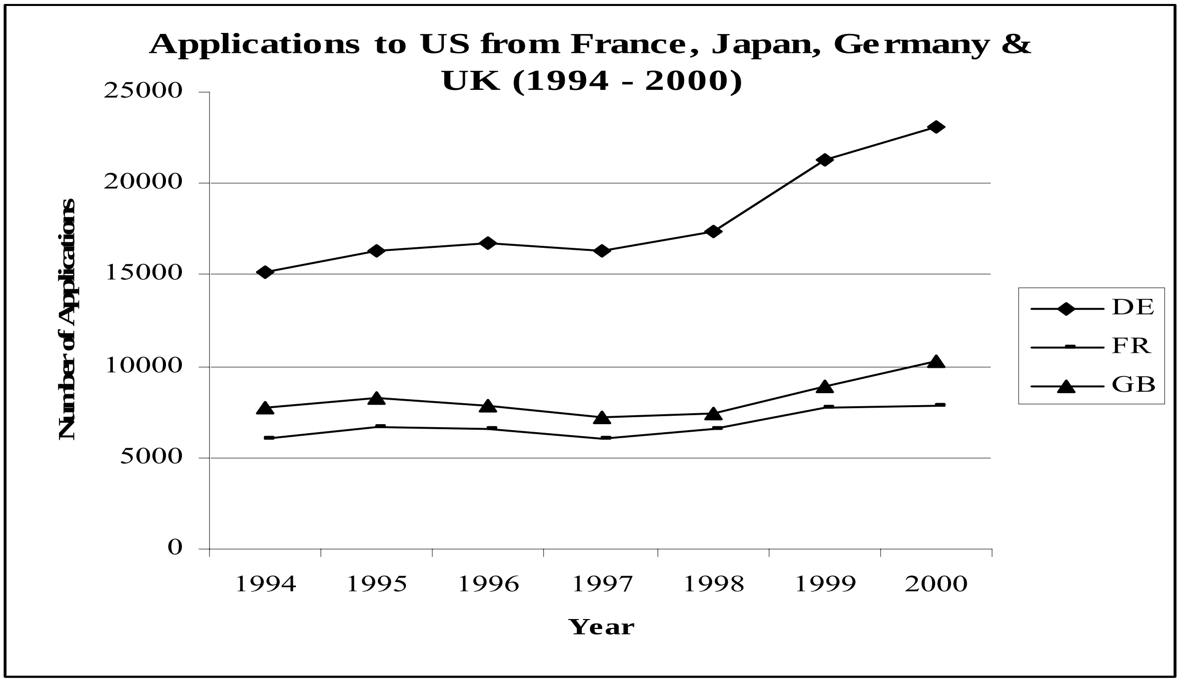
GRAPH 2(A)



GRAPH 2(B)



GRAPH 2(C)



GRAPH 2(D)