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Which Patent Systems Are Better For Inventors?

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Abstract: International comparisons of patent systems are essential to harmonization treaties and to analyze economic growth. Yet these comparisons often rely on little but conventional wisdom. This paper develops an empirical method to compare the economic strength and quality of patent systems by using renewal analysis of matched patents in different countries (same patent family). Comparing patents on the same inventions filed at the EPO for Germany and in the US, we find that the German patents generate substantially greater market power than their US equivalents, especially for small inventors. Also, the average US patent has relatively lower economic value ("quality").

JEL codes: O34, F42, K19

Keywords: patents, international treaties, technological change

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Introduction

Which national patent systems provide inventors with the strongest incentives? This question has been raised in a number of different contexts. In the economic growth literature, researchers have attempted to assess the importance of patent incentives by using indices of patent "strength" (Ginarte and Park 1997a, 1997b, Park 2008). The question also arises regarding the many patent treaties that have been negotiated in recent years. Many treaties propose to harmonize patent law around those features that maximize inventor incentives. On the one hand, treaties choose to follow the law of those nations judged to provide stronger incentives. On the other hand, opponents of harmonization often claim that certain features of national patent law favor critical groups of inventors. For example, opponents of "first-to-file" in the US claim that this will undermine incentives for the important small inventors.

However, all of these judgments are apparently based on little other than conventional wisdom about what makes a patent system "strong." Yet there are theoretical reasons to question the accuracy of this wisdom. Does a nation provide inventors with stronger incentives if it allows patents on software (a component of the Ginarte and Park index)? Perhaps not, if software patents also expose inventors to costly litigation that they cannot easily avoid (Bessen and Meurer 2008). Do stronger enforcement mechanisms mean larger incentives? Not if patent rights lack clear and predictable boundaries so that inventions are subject to overlapping claims (Bessen 2009b). Given the importance of inter-country comparisons, it might be helpful to have some empirical evidence about incentives.

This paper develops an empirical method to compare inventor incentives across countries. The notion behind the method is simple: by observing renewal behavior on equivalent patents in different countries, we infer how patent holders value their patents in these countries. We compare how much inventors are willing to spend to keep patents in force on the *same* inventions in different countries,

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relative to the size of each market. If inventors choose to spend more in one country relative to the size of that market, we infer that those patents confer greater market power and that that country provides stronger incentives. We estimate the markups realized by equivalent patents in different countries and these serve as measures of the strength of patent incentives.

Additionally, this approach provides a measure of relative economic quality across patent systems. Patent systems also differ in the economic value of inventions that they permit to be patented. Roughly speaking, patent offices that require a greater inventive step should have a population of more economically valuable patents, all else equal. These patents are more selective or of higher "quality" in this sense. We can compare the economic value of the average patent granted to our matched sample in order to compare the selectivity of patent offices in granting patents. By comparing the difference in the markup between two countries on the average patent to the difference in the markup on the group of matched equivalent patents, we can measure how much grant selectivity affects average patent markups as opposed to the economic strength of the patents granted.

The method we use is similar to the patent renewal analysis conducted first by Pakes and Schankerman (1984).[1] Several studies have used this technique to obtain estimates of patent value in different countries (Pakes 1986, Schankerman and Pakes 1986, Deng 2007). Following Putnam (1996) other studies have used international patent filings as a way of estimating patent values, including cross-country estimates.

Our approach differs from this literature in two important ways. First, our focus is on the relative market power of patents rather than their absolute value. We seek to measure the effective markup associated with a patent by estimating the patent rents divided by total market size. In theory, rents derived from a patent of given market power will increase with the size of the market, all else equal. The previous research assumes, to the contrary, that patent rents do not vary with the size of the market.

1 For overviews of this literature see Lanjouw et al. (1998) and Bessen and Meurer (2008, Chapter 5).

Our alternative assumption not only affects our model of patent holder behavior within a country, but it also allows us to compare the economic strength of different countries without having to rely on exchange rates and different deflators.

Second, we compare patent systems by using patents taken out in different countries on the same inventions, that is, patents belonging to the same patent family. Previous studies have used such matched samples of patents to study the effect of the post-grant opposition system in Europe (Graham and Harhoff 2006), differences in patent search across countries (Lei and Wright 2009), and valuation of the most valuable inventions (Harhoff et al. 2003), but, to our knowledge, patents matched to the same families have not been used in renewal analysis. This allows us to decompose patent markups into two components: an economic strength measure, based on the markups realized on matched patents in different countries, and an economic quality measure, based on the difference between the markups earned on the matched patents and the average patent in a country. This is important because the average patent markup earned in a country depends both on the economic strength of the patent system as well as on the selectivity of the patent office.

To test this method, we compare patents granted in the US from 1986 through 1996 to patents applied for at the European Patent Office (EPO) from 1984 through 1994 that were ultimately granted and designated for protection in Germany. This comparison should let us test views that the US had significantly "stronger" patent protection then and that the US patent system particularly favored small inventors. Of course, our measure of patent economic strength captures more than just the strength of patent enforcement. Patent markups also reflect other aspects of the patent system, such as litigation risk and patent notice, as well as other differences in industrial structure. For example, if one expects that the US has more competitive markets, then US patents might have higher market power, all else equal, because patents would make a bigger incremental difference in rents earned on an innovation. Or if patents are litigated more often in the US, then this, too, might reduce patent rents: net patent rents include the expected cost of litigation necessary to enforce a patent. Also, if litigation arises from poorly defined patents that generate overlapping claims, this litigation reduces the profits a patent holder can earn on an innovation.

We further explore the differences in markups between Germany and the US by conducting a multivariate analysis that identifies those characteristics of patents that contribute to the difference in markups. We find that small inventors, non-US inventors and patents in medical related technology have sharply lower markups in the US compared to Germany. Some supplementary analysis suggests that the divergent litigation environments between the two countries could explain these differences.

A variety of researchers have devised indices for ranking and comparing national patent systems. As noted, Ginarte and Park (1997) developed an indicator of "patent strength" based on five dimensions: extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms, and duration of protection. This index has been widely used in studies investigating foreign direct investment, inter-firm alliances, patent protection on exporting activity, economic growth, R&D internationalization and others (for a survey see Papageorgiadis and Cross 2011). Some researchers have enhanced this index in various ways. Fraser (1999) extended the coverage in terms of number of countries, whereas Park (2008) provided an important update and increase the time series after year 2000; Papageorgiadis, and Cross (2011) added components covering search costs, servicing costs, property rights protection costs and monitoring costs.

De Saint-George and van Pottelsberghe (2011) criticize the Ginarte and Park approach as being a measure of "applicant friendliness" rather than a true measure of the economic incentives that patents provide. For example, the Ginarte-Park index reflects the extent that a country's patents cover different fields such as software or pharmaceutical compositions. While increased coverage encourages more patent applications, incentives might actually decrease if greater coverage is accompanied by greater uncertainty and litigation, reducing the returns that innovators can realize from their patents. Such considerations highlight the need to generate empirical estimates of relative incentives.

Undoubtedly, the "strength" of patents might also be related to their "quality," and a number of researchers have attempted to develop measures of quality for comparing patent systems by looking at multiple factors including grant rates (Guellec and van Pottelsberghe, 2000; Palangraya et al., 2011), speed of grant (Guellec and Van Pottelsberghe, 2000, OECD, 2010), and opposition rates (Graham and Harhoff, 2006). De Saint-George and van Pottelsberghe (2011) develop a quality index based on legal and institutional characteristics of the national patent systems. In contrast to these approaches, our method provides a quality measure based solely on observed behavior.

Model

Market power

Consider the flow of rents that patent i earns in country j at time t, r_{ijt}. If the patent holder chooses to market a product using the patent to provide a degree of exclusivity, then the rents will be equal to the additional markup of price over cost that the patent conveys times revenues. This markup reflects the market power conveyed by the patent. If, instead, the patent holder chooses to license the patent, the rents will equal the royalties received. In this case, the royalty rate on revenues reflects the market power of the patent. In either case, the rents that patent i earns in country j at year t can be written as

(1) $$r_{ijt} = m_{it} M_{jt}$$

where m is the markup/royalty associated with patent i and M is industry revenues for the market.

The magnitude of m_{it} depends on both the economic value of invention i and the degree of exclusivity conveyed by the patent, which reflects the strength of patent enforcement, the clarity of patent boundaries (the extent of overlapping rights) and the degree of exclusivity provided by other means. Thus m_{it} reflects both characteristics of the individual patent and the general economic strength of patents in a country. Differences in the economic strength of patents across countries should be captured by differences in the distributions of these values.

Renewal behavior

We can infer differences in patent markups by observing renewal behavior. Patent systems typically require the payment of periodic fees in order to keep a patent in force. Suppose that country *j* requires a payment of c_{jt} in order to keep a patent in force that is *t* years old (measured from the application date). Payment of this fee will keep the patent in force an additional *T* years. The patent holder will choose to pay the maintenance fee if the present value of the rents earned over the next *T* years exceeds the fee.[2] This decision rule provides a simple way to infer information about the distribution of patent markups by looking at when patent holders choose to allow patents to lapse.

In order to do this, however, it is necessary to make some assumptions regarding the way rents evolve over time. At the very least, rents should depreciate over time with technological obsolescence. As a starting point, suppose that the market power associated with each patent depreciates at a constant rate of obsolescence, *d*. We discuss the appropriateness of this assumption below. Then equation (1) can be written

(2) $$r_{ijt} = m_{i0} M_{jt} e^{-dt} \quad .$$

Assuming a discount rate of *s*, the present value of rents earned on patent *i* from *t* to *t*+*T* is

(3) $$w_i \equiv \int_t^{t+T} r_{ijz} e^{-s(z-t)} dz \;=\; m_i M_{jt} e^{-dt} \frac{1-e^{-(d+s)T}}{d+s} \quad ,$$

where we assume that market size remains constant during the interval and we have dropped the time subscript on *m*.[3] The decision rule then implies that the patent will not be renewed at *t* if

2 This assumes that the fee schedule is non-decreasing ($c_{jt} \mathbb{C} c_{jt+1}$), as they are in fact. This condition ensures that it will not be advantageous to take a loss in the current year in order to make a larger profit later. Because *r* depreciates, future profits will be even worse than current year profits if fees meet this condition.

3 This is a slight simplification. In some countries, e.g. the US, patent fees are due some interval (6 months) before the renewal period begins. We make an adjustment for that in the estimation, but ignore it here to simplify the exposition.

(4) $$w_i \leqslant c_{jt} \quad \text{or} \quad \ln m_i \leqslant x_{jt} \equiv \ln \frac{c_{jt}}{M_{jt}} + d\,t - \ln \frac{1-e^{-(d+s)T}}{d+s}$$

The logarithms of the initial patent markups, m_i, are distributed within each country according to some cumulative distribution, $\ln m_i \sim F$. This means that if patent holders follow decision rule (4), the share of patents in country j that have lapsed during or before year t equals $F(x_{jt})$. Moments of this distribution for each country provide an index that allows straightforward comparison of patent markups.

Estimation

In order to estimate moments, we assume a functional form for distribution F. In particular, we assume that F follows a normal distribution. We find below that a normal distribution fits the data closely. Specifically, in our basic analysis we assume that

(5) $$\ln m_{ij} = \mu_j + \epsilon_{ij}$$

where ε is a stochastic error normally distributed with zero mean and standard deviation of σ. Following Bessen (2008), we also do a multivariate analysis that takes patent characteristics into account,

(6) $$\ln m_{ij} = \beta_j \cdot Z_{ij} + \epsilon_{ij}$$

where β is a parameter vector to be estimated, Z_i is a vector of patent characteristics including a constant term. Using this more general formulation, the probability that patent i is allowed to lapse in year l but not before is (temporarily ignoring those patents never renewed or always renewed)

(7) $$P\left[\ln m_{ij} \leqslant x_{jl} \mid \ln m_{ij} > x_{jl-1}\right] = \Phi\left(\frac{x_{jl} - \beta_j Z_{ij}}{\sigma_j}\right) - \Phi\left(\frac{x_{jl-1} - \beta_j Z_{ij}}{\sigma_j}\right)$$

where Φ is the standard cumulative normal distribution function. From this it is straightforward to define a log likelihood function that can be estimated using standard maximum likelihood techniques,

(8) $$L(\beta_j, \sigma_j) = \sum_i \ln\left[\Phi\left(\frac{x_{jl} - \beta_j Z_{ij}}{\sigma_j}\right) - \Phi\left(\frac{x_{jl-1} - \beta_j Z_{ij}}{\sigma_j}\right)\right] .$$

For patents that are never renewed, we treat $x_{jl-1} = -\infty$; for patents that are always renewed, $x_{jl} = +\infty$.

Comparative measures

Using equation (8), we obtain an estimate of the mean of the distribution, $\overline{\mu}$. This is the mean of the distribution of the logarithm of *m*, which implies that the *median* of the distribution of *m* itself is $e^{\overline{\mu}}$. Although there are other statistics that can be derived from our estimates, this basic one provides a simple point of comparison across nations.

Note that by using this test statistic, we avoid one criticism of renewal analysis, namely that estimates of patent value are based on an extrapolation. Because the most valuable patents are all renewed to term, renewal analysis does not directly include observations of their values. Some evidence suggests that extrapolation might not seriously bias the estimates of patent value (Bessen 2009a). Nevertheless, this has been a concern about patent value estimates.

In this paper, however, we primarily use the $\overline{\mu}$ statistic that represents the median patent, which generally is observed to lapse and so is not based on extrapolation. In other words, we are effectively comparing nations by measuring the economic strength of their median patents. If one patent system allows inventors to earn a higher markup on the median patent than they can earn on the same invention in another nation, then we can infer that, to the first order, the first nation provides inventors relatively stronger incentives. Of course, it is possible that one nation might somehow provide comparatively bigger markups on its most valuable patents than it does on its median patent. It is not clear what conditions would produce such an effect nor do the variances of the distributions appear to vary much. Moreover, in the analysis below, the differences between the US and Germany are large enough that only a very dramatic change in markups for the most valuable patents could reverse the comparison. Nevertheless, we use this statistic with the caution that while national comparisons based on these statistics apply for most patents, patent system performance might differ for the very most valuable patents.

Comparisons between national patent systems can be made along two dimensions. Let $\overline{\mu}_j$ and $\overline{\mu}_k$ designate the estimates for all patents in countries *j* and *k*, respectively. Let $\overline{\mu}_j^e$ and $\overline{\mu}_k^e$ designate the estimates only for the matched equivalent patents in countries *j* and *k*, respectively. Then the relative economic strength of patent system *j* compared to patent system *k* is P_{jk} and the relative quality of patent system *j* compared to *k* is Q_{jk}:

$$(9) \qquad \begin{aligned} P_{jk} &\equiv \overline{\mu}_j^e - \overline{\mu}_k^e \\ Q_{jk} &\equiv \overline{\mu}_j - \overline{\mu}_k - P_{jk} \end{aligned}$$

That is, P_{jk} captures the extent to which the patent system *j* provides higher markups than patent system *k* for the patents on the same inventions. Q_{jk} captures the extent to which the average patent granted in country *j* has greater economic value than the average patent granted in *k* because of differences in the selectivity of the patent grant process in the two countries.

Finally note that nations might differ in the number of patents they use to protect an invention because of differences in patent scope, different patent office policies regarding multiple patents on the same invention and different propensities to build patent thickets. When we construct the measures in equation (9), we use estimates of $\overline{\mu}$ that are adjusted by the number of patents per family for that nation (adjusted by adding the logarithm of the patents per family to the estimates of log markup).

The depreciation assumptions

The approach we have described so far relies on two assumptions: 1) rents depreciate at a constant rate, and, 2) this rate is the same across the countries being compared.[4] The first assumption—

4 The approach also requires that we choose a particular rate of depreciation, however, it is straightforward to show from equation (4) that the choice of rate does not affect the ordering of countries according to the index, just the nominal value of the index. We specify a 15% depreciation rate below; this is a common value in the literature.

a constant rate—is, in fact, the most common assumption made in the renewal literature. However, several studies have used specifications that allow varying rates as well as differences between depreciation and complete obsolescence. Two studies find that depreciation rates vary and can even increase during the first four or five years after the patent application, but appear to depreciate at a fixed rate after that (Pakes 1986, Lanjouw 1998). Since almost all of the activity observed in our data occurs after the fourth year, this suggests that a constant rate of depreciation is not a bad assumption.[5]

The second assumption—equal rates of depreciation in the two countries being compared—is consistent with the notion that technological obsolescence causes rents to decline. In a world with global trade, new technologies should be equally available in both countries, hence they should have the same effect on rents, all else equal. However, if there are trade barriers or other local market restrictions, it is possible that economic depreciation might differ between the countries. For example, a successful innovation might attract imitators in one country while trade barriers might discourage these imitators from entering the market in the second country. Then the first country might experience faster depreciation as well as lower markups. Nevertheless, estimates of depreciation rates in the literature on patent renewals do not vary much, most falling between 10% and 20%.[6]

By assuming equal and constant rates of depreciation, we simplify the construction of a reliable index. The renewal data allow us to infer patent rents at a point in time, namely, the time of the decision to allow the patent to lapse. If depreciation rates varied significantly over time or between countries, we would need to estimate an average markup over the life of the patent. By assuming constant and equal

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5 When we repeat our analysis below but exclude all observations before five years from the application date, the results do not change significantly.

6 For example, Schankerman and Pakes (1986) find rates of depreciation of 18%, 10% and 25% for UK, Germany and France, respectively, in their fixed effects regressions. Lanjouw (1998) find rates of depreciation (including obsolescence, which she measures separately) ranging from 12.1% to 17.7% for different technology groups in Germany. Schankerman (1998) finds depreciation rates (in fixed effects regressions) ranging from 5.8% to 19.2% for different technologies in France. Serrano (2005) finds depreciation of 11.6% in the US, while Bessen (2008) find depreciation of 14.0% in the US. In theory, we could directly estimate depreciation rates in our regressions, however, in practice the maximum likelihood models do not always converge when we do this. Our regressions are substantially more complex than those used in most of the renewal literature.

depreciation rates, we are able to directly convert our estimates of rents at the time a patent lapses to estimates of patent markups at the patent application date.

While the evidence from the renewal literature suggests that these assumptions are accurate to the first order in the US and Europe, these indices should be used with care, especially where there is evidence of trade barriers or other market distortions in the countries being compared. Below, we conduct a sensitivity analysis to make sure that our comparison is robust to changes in assumptions about the depreciation rates.

Data and variables

Data sources

Our analysis compares patents granted in the US from 1986 through 1996 to patents granted by the EPO, with applications filed from 1984 through 1994 and designated for protection in Germany. Patents granted by the EPO can be designated for coverage in a number of countries, including Germany, but, once granted, they remain in force only so long as maintenance fees are paid. We study invention patents in Germany and utility patents, including reissues, in the US. Our datasets include 1,021,300 US patents that are eligible for maintenance fees, 350,619 EPO patents designated for Germany as well as a supplementary sample of 167,872 patents granted by the German national patent office. The US patents were identified in the USPTO's Maintenance Fee Events database, dated December 27, 2010. The European patents were identified in the EPO Worldwide Patent Statistical Database (PATSTAT), which is available under license from OECD-EPO Task Force on Patent Statistics. We used the October 2010 version of PATSTAT.

We chose these ranges of years first because these two samples roughly correspond to patent applications filed at the same time: the mean lag from application to grant in the US sample is 1.8

years. The beginning year for the US sample was chosen so that few patents were granted that were exempt from maintenance fees (because their applications were filed before December 12, 1980 when the renewal system began coverage). The end year was chosen so that data on payment or non-payment for the third renewal fee was relatively complete.[7]

The data on patent renewals and lapses for the US also comes from the USPTO's Maintenance Fee Events database. The renewal data for European patents originate from the Patent Registry Services (PRS) database maintained by the EPO. The maintenance fee schedules change over time. For the US, these were obtained from the Federal Register and Public Laws. For Germany, we obtained the fee schedule from the controller office of the German and Trademark Patent Office.

The payment schedules differ substantially. In the US, fees are due at 3.5, 7.5 and 11.5 years after the date of patent grant and these payments extend coverage from 4 to 8 years, from 8 to 12 years and from 12 years to the end of the patent term, respectively. In Germany, fees are due annually beginning two years after the application filing date through the end of the nineteenth year. Each payment extends coverage for just one year. Both fee schedules are non-decreasing. For example, the US schedule for 2005 goes from $900 at 3.5 years, to $2300 at 7.5 years, to $3800 at 11.5 years. Patent holders designated as "small entities" in the US pay fees at half this rate. This designation includes independent inventors, firms with fewer than 500 employees, universities and non-profit organizations. The latest German schedule goes from 70 Euros at the end of the second year to 1940 Euros at the end of the nineteenth year. Given the greater frequency of payment, the German maintenance fees are substantially more expensive and, generally speaking, they will be due earlier in the life of the patent.

Our analysis uses sub-samples of patents where the underlying invention is also patented in the other country—our "matched" samples. Of course, the differences in law and institutions imply that inventors will not obtain patent protection in the same way in both countries nor will the patents cover

7 The US Patent Office allows a grace period for re-instating patent coverage where renewal payments have been missed.

exactly the same things. For example, a patent that makes software claims in the US will be worded differently at the EPO and may have narrower claims. In many cases, the number of patents filed for an invention will differ between countries. The picture is further complicated by rules allowing continuations and divisional patents in the US and rules regarding multiple patents on the same invention. The patents in the two countries are thus not exactly equivalent, however, they loosely belong to the same "patent family." The PATSTAT database helps us identify these patent families. In the October 2010 version of PATSTAT there are three kinds of patent families (see Martinez, 2010):

1. narrow equivalents, patent documents including exactly the same priorities or combination of priorities,
2. INPADOC families, patents sharing any direct or indirect priority links across them, resulting in a consolidated and self-contained group of priority links, and,
3. DOCDB families, patent documents having "similar" sets of priorities, excluding those patents that do not add new technical knowledge. These families are manually inspected and defined by the EPO examiners for the purpose of their search work.

We opted to use the INPADOC families, because we think it is more suitable for international comparisons.[8] First, it is broad enough to encompass a more effective and homogeneous unit of invention across patent offices. Second, at level of the same patent office it is robust to variation originating from continuations and divisional applications. Third, the INPADOC definition does not requires a subjective choice by experts, as is the case with DOCDB families.

Using this INPADOC family data, we constructed a sub-sample of 287,634 US patents that shared a family with at least one patent in the EPO/DE sample and a corresponding sub-sample of 250,382 EPO/DE patents that shared a family with at least one patent in the US sample.

Finally, we obtained data on patent characteristics for US patents from the NBER patent database

8 Graham and Harhoff (2006) also use INPADOC families. Palangkaraya et al. (2011) use strict equivalents for a study of patent classification at different patent offices.

(Hall et al. 2001) and we obtained supplementary data on patent litigation from the Derwent Litalert service.

Market Size

A key variable in our analysis is M, the size of the market. We decompose patent rents into a markup times the market size for the market corresponding to each patent. This means, in effect, that we normalize nominal patent fees against nominal market size in equation (4).

We cannot observe the actual market size for each patent in practice. Instead, we assume that the market size for each patent is *proportional* to an observable measures of market size and that this proportion is the same across the countries we study. The constant of proportionality is included in our estimates of $\overline{\mu}$ and is effectively subtracted out of the calculations of patent strength and quality, P and Q, in equation (9).

In this paper we use two different observable measures of market size. The first is simply national GDP. This has the advantage of being readily available for a large number of countries. However, there are several possible biases that might be introduced by using this measure. First, it does not reflect differences in the sizes of industrial sectors between nations. For example, if patenting is largely an activity of manufacturing industries, GDP might overstate the relative size of the market for a nation with a relatively small manufacturing sector. Second, if one country imports relatively more than the comparison country, GDP might understate the size of the market. Third, nations might differ in their degree of vertical integration. GDP is based on total value added, netting out the sale of intermediate goods used in manufacturing. If one nation sells an intermediate good on the market but the other nation has vertically integrated producers, the first nation has more opportunities for patents to earn markups—the so-called "double marginalization" problem. In this case, gross industry output might be a better measure of market size than value added, hence GDP might understate the size of the market in the nation with vertically dis-integrated markets.

To correct for these possible biases, we also use a market size measure based on gross industry output, we add net imports[9], and we apportion patents to 48 different industries. To calculate these industry measure for each patent, we began with consistent cross-country data on gross output, imports and exports for a standardized set of 48 industries from the STAN database of the OECD (2005). We then created a concordance apportioning each patent to one or more industries in STAN.

To create this concordance, we relied on the consolidated patent portfolios of US, EU and Japanese publicly listed companies. These patent portfolios provide consolidated counts for patent applications made by these firms at the USPTO, EPO and PCT (Thoma et al. 2010). The idea is to calculate the share of patents in an IPC class going to firms in a given industry by looking at the share of patents in each IPC class assigned to publicly listed firms in that industry. In particular, in these three offices during the period 1978-2007 we could identify 3.4 million patent application filed in 626 IPC 4 digits classes for 10,750 listed companies. Where a patent was listed in more than one IPC class, we apportioned that patent across those classes, coming up with a fractional patent count.[10] Then, we linked these technology classes to industry SIC codes for those firms using industry data from Compustat Global Vantage and translating the 4 digit US SIC codes for each firm's primary line of business into codes corresponding to the 48 STAN industries.[11] Using these data, we calculated the share of patents in each 4 digit IPC class that went to firms in each of the STAN industries.[12] The

9 This assumes, to the first order, that patent rents are earned in the markets where products are sold, ignoring rents that might be earned on goods produced within a nation but sold abroad.

10 In the overall PATSTAT September 2010 dataset we could identify 635 distinct IPC 4 digits patent classes. We opted not to take into the account the family links across patent applications because we are interested only on the patent classes in which these patents are classified. Indeed, it could happen that a patent filling is classified differently in two distinct patent offices even in the case the patent does not constitute a first filing to the receiving office. For example at the EPO a PCT filing from an International Search Authority could be republished with a supplementary search report by an EPO examiner.

11 For more details on how to execute an industry grouping compatible with STAN database starting from the US SIC codes see Thoma et al. (2010).

12 Dropping out industries that accounted for less than 5% of the total weight for each IPC and pro-rating the remaining industries.

market size for each patent in an IPC class is then calculated by multiplying the industry share for that IPC code times the industry market size (gross output plus net imports) for each year.

Finally, one might wonder whether patent holders sometimes view rents relative to the size of a regional market rather than the size of a national market. For example, perhaps a German patent is valuable not only because it brings rents in Germany but also because by protecting Europe's largest market, it blocks competitors from entering other European nations. In this case, a German patent might earn rents outside of Germany and one would expect a Germany to receive a disproportionate share of European patents. While such considerations might influence some patent holders, it does not appear to be the dominant behavior, however. In Europe, while over 90% of EPO patents are designated for Germany, more than 80% are designated for Great Britain and for France. More generally, each nation's share of EPO patent designations is roughly proportional to that nation's GDP (van Pottelsberghe and van Zeebroeck 2008) with no disproportionate share going to Germany.

Empirical Findings

Data characteristics

Table 1 reports summary statistics on the different samples. Note first that a much higher percentage of the EPO/DE patents are matched to patents granted in the US.

We use the six NBER technology categories to classify the patents (by the first technology class listed). We apply the classification for US patents to the matching EPO/DE patents, pro-rating if patent counts differ between the matched samples (fractional counts). Chemicals, drugs and other medical patents are more heavily represented in the matched samples.

We also classify the inventor region based on the first inventor listed on the US patent. Not surprisingly, the matched sample is more likely to include European inventors. Similarly, the matched sample is much less likely to include patents owned by small entities. This is not surprising if one assumes that large multinationals are more likely to enter overseas markets.

The matched patents tend receive more citations and have more claims than unmatched patents in the US. This corresponds with the notion that patents taken out in two countries are more valuable patents, all else equal. Also, the matched sample of US patents tends to have slightly more patents per family than does the matched sample of EPO/DE patents.

Finally, the last two lines show summary statistics that are highly suggestive of the results to follow. For the matched sample, the last fee that the median patent holder pays in Germany is nearly twice as large as the last fee paid on the median patent in the US, both calculated in constant dollars. This is despite the fact that the US GDP is over four times larger than the German GDP. The last line of the table lists the nominal GDP of the two countries in 1999, near the midpoint of our samples. This suggests that patent holders are willing to spend substantially more to keep their patents in force in Germany than in the US, especially relative to the relative sizes of the two markets.

Of course, it is also true that German renewal fees are much higher, as noted above. A skeptic might wonder whether patent holders naïvely continue paying both fees until they decide it is no longer worthwhile and then stop paying both of them at the same time. That is, perhaps patent holders have bounded rationality and do not bother to make the optimal decision indicated by the model above. Then the higher fees paid in Germany might simply reflect the higher fee schedule there. However, the data suggest that while some patent holders might behave this way, this is not the dominant behavior. If one looks at all of the US:EPO pairs in the matched sample where at least one patent in the pair expires (the median patents fall into this group), the dates on which the last fees were paid fall within a year of each other only in 11% of the cases. In 17% of the cases, a US fee is paid after the German patent lapses and in 22% of the cases, a German fee is paid after the US patent lapses (over four years from when the last US fee was paid). These numbers suggest that patent holders by and large are making different decisions in the two countries, however noisy the decisions to renew patents might be. This is supported by research showing that differences in patent renewal fees across European nations consistently affect renewal behavior (Danguy and van Pottelsberghe 2011). However, the simple comparison of the magnitudes of last fees paid does not take into account the timing of when the fees were paid in each country. For this we need the model.

Scatterplots

By observing the share of patents lapsed at different times over different values of x_{jt}, one can construct a scatterplot of distribution F for each country. This is shown in Figure 1 for the matched datasets. Each dataset was broken into a number of cohorts. For the EPO/DE matched sample the cohorts were by application year; for the US sample the cohorts were by grant year and small entity status. Each cohort was then broken into sub-groups according to the year in which the patent lapsed. For each sub-group we calculated x_{jt} and the cumulative share of the total cohort that had lapsed as of that year.[13] These are then plotted in the figure with the horizontal axis representing different values of x_{jt} and the vertical axis representing the cumulative share of patents that were allowed to lapse at or before that year. For each dataset, a dashed line shows the best fit for a normal distribution. As can be seen, the normal distribution fits the data fairly well.

As can be seen, small entities in the US have a distinctly different distribution than large entities. Furthermore, the distribution for the German EPO patents stochastically dominates the distribution for large US entities which stochastically dominates the distribution for small US entities in the observed range of the matched samples. Surprisingly, this figure indicates that the German patent system delivers substantially higher markups on the same group of inventions.

13 We calculated the values of x assuming a 15% rate of depreciation and applying the mean lag between application date and patent grant for each cohort of US patents.

Basic regressions and comparative measures

This notion can be formally tested using the economic strength and quality measures described above. The top panel of Table 2 shows basic estimates of the logarithm of the patent markup regressed against a constant for both nation's datasets, for both the total dataset and the matched sub-samples. This table reports results normalizing maintenance fees with GDP. Because US renewal fees are different for small entities and these firms apparently behave differently, we also include a dummy variable that is 1 for a small entity and zero otherwise in the US regressions.

The bottom panel does the comparison calculations. First, to account for differences arising from the small entities, the row titled "Mean μ" shows the predicted mean for the sample. These figures are adjusted for the differences in patents per family between the two samples so that we measure the mean per invention instead of the mean per patent. Using these means, we can compare the US and EPO/DE samples. The logarithm of the markup for the US matched sample is lower than the log markup for the German matched sample by 1.26 and this difference is highly significant. This is an economically large difference as well, implying that the median invention in the matched sample earns a markup in Germany that is over three times higher than the markup it earns in the US.

We performed this analysis assuming that the depreciation rate for patents, d, is 15% per annum. To make sure that our results are robust to variation in the depreciation rate, we repeated the estimates assuming a rate of 10% and a rate of 20%. The results were broadly similar and the difference in the mean between the matched samples, P, varied from -1.38 with a 10% depreciation rate to -1.13 with a 20% depreciation rate. Hence our estimate is not particularly sensitive to this choice.

Additionally, we can test how sensitive our estimates are to the assumption of equal depreciation rates. Suppose that US patents depreciated at 20% per annum while German patents depreciated at only 10% per annum. Then we can calculate the average of the logarithm of the the markup over, say, a thirteen year patent life (see Table 1). Comparing these averages, the difference in the log markup between the countries is now -0.54. This doubling of the relative depreciation rate reduces the index of relative patent strength, however, even such a large difference does not affect the judgment about which country has patents with greater market power. Thus our index appears robust to various assumptions about depreciation rates in this example.

The bottom panel also includes a comparison of the average patent granted in the US to the average patent granted by the EPO and designated for Germany. The log markup for the US patent is 0.50 less than the log markup for the average EPO/DE patent after taking differences in economic strength into account as measured in the matched sample. This implies that the US patent office grants patents that have, on average, 39% less market power than patents granted by the EPO, after accounting for differences in national patent strength.

However, an inventor seeking to obtain a patent in Germany does not necessarily need to file at the EPO; an inventor can also file for a German patent at the German national patent office. It is possible that the average EPO patent is more valuable than the average of all patents filed in Germany because inventors might find it economical to file their more valuable inventions at the EPO. This might mean that part of the difference between the USPTO and the EPO in the above comparison might reflect this special role of the EPO rather than differences in the quality of the grant process. To check this possibility, we also estimated the markup for patents granted at the German patent office (DEPO). These are shown in column 5 of Table 2. Clearly, the markups on these patents are not less than those granted through the EPO, implying that the comparison between the USPTO and the EPO is not biased by selection issues.

Table 3 repeats these basic regressions normalizing maintenance fees against industry-specific measures of market size (gross output plus net imports).[14] The estimates of the constant term are larger

14 Sample sizes are slightly smaller because not all industries are included in the STAN database for all countries.

(less negative) than those in Table 2 because the market size measures for individual industries are substantially smaller than GDP. However, the measures of patent strength and quality are fairly close. The difference in patent strength, P, is now -1.05 instead of -1.26, and the difference in patent quality, Q, is now -.53 instead of -.50. Because these differences are not large, it suggests that biases associated with the distribution across industries in these countries, the relative size of net imports and the degree of vertical integration are not large.

The finding of higher quality (selectivity) in the European patent system is supported by some previous research. Graham and Harhoff (2006) find that the post-grant opposition system at the EPO serves to eliminate some low quality patents that lead to litigation. Lei and Wright (2009) find that the USPTO fails to find substantial prior art that is found at the EPO. Both of these factors could contribute to higher economic value of the patents granted at the EPO.

For a comparison with the previous literature, we also obtained estimates of patent value for the US and German samples using standard renewal analysis.[15] For the samples of all patents, the mean value of US patents was $67,900 while the mean value of the EPO German patents was $175,800, both in 2005 dollars (medians were $13,400 and $18,200, respectively). For the matched samples, the mean US value was $92,600 while the mean EPO German value was $190,600 in 2005 dollars (median values of $33,200 and $19,500, respectively). For small entity patents in the matched sample, the means were $38,200 and $128,300 for the US and Germany respectively (respective medians of $8,600 and $12,800). Although these estimates are made under slightly different assumptions, they generally confirm the impression of the greater value of German patents especially relative to the size of the

15 We used a non-linear least squares regression similar to Schankerman (1998) and then used a Monte Carlo analysis as in Bessen (2008) to compute mean and median values, details available from the authors. We converted these estimates to 2005 dollars as follows. US values are calculated at time of patent grant; EPO/DE values are calculated at the end of the second year after filing (US patent pendency average 1.8 years in this sample). US values were deflated using the implicit GDP deflator. The EPO/DE values were deflated using a combined Euro/Deutsche Mark deflator. These values were converted to current Euros for the second year after application, then converted to US dollars at the current exchange rate and deflated to 2005 dollars using the GDP deflator.

German economy.

Multivariate analysis

Although the findings about patent office selectivity are consistent with prior research, the large difference in markups between the US and Germany for the matched sample stands at odds with conventional wisdom. While a full analysis for the causes of this difference is beyond the scope of this paper, some clues can be gleaned by looking at which groups of patents display particularly large differences. Table 4 shows results from multivariate regressions where log *m* is regressed on a variety of dummy variables as well as the constant term. The first column shows the results for the US matched sample, the second column shows the estimates for the EPO/DE matched sample and the third column shows the US coefficients minus the EPO/DE coefficients, all for estimates where maintenance fees are normalized by GDP. The three columns in the right-hand panel are for estimates with fees normalized by industry-specific output.

Three large differences stand out in both groups: small entity patents have much smaller markups than large entity patents, patents from US inventors have much larger markups than patents from foreign inventors, and drug and medical patents have smaller markups in the US.[16] What do these three groups of patents have in common? At least the first two are notable for the difficulty of enforcement and possibly the third group is as well. Small firms have a higher risk of litigation than large firms in the US (Lanjouw and Schankerman 2004) while this difference is not true in Germany (Cremers 2004). Also, the relatively high cost of litigation in the US might be especially burdensome for small firms and individual inventors. Second, patents from foreign inventors are harder to enforce in US courts than are patents from US inventors because juries tend to be biased against foreigners (Moore 2003). In contrast, Germany does not have jury trials in patent lawsuits. Finally, the role of the FDA in the US

16 In addition, the industry-specific estimates show lower markups in chemical and computer and communication technologies.

might make patents less significant for obtaining rents on patents on drugs and medical devices – if FDA exclusions provide substantial markups themselves, the markups from patents per se might be reduced. In addition, non-drug health patents appear to be the most highly litigated technology group in the US (Lanjouw and Schankerman 2004) and Hatch-Waxman in the US encourages a special category of litigation over drugs.

To explore this notion of the role of litigation further, we conduct an analysis on litigation hazards for these same groups in the US matched sample in Table 5. The first column shows a probit regression of the probability that each patent will be the main patent listed in the Derwent Litalert database for one or more patent lawsuits. The second column shows a Poisson regression where the dependent variable is the number of such lawsuits for which the patent is listed. As can be seen, each of the three groups stands out: small entity patents and medical patents are much more likely to be litigated multiple times while foreign inventions are much less likely to be litigated relative to US inventions.

The differences in enforcement for these three groups contribute to the differences in patent markups on the matched sample. However, they do not fully explain it: the constant terms in Table 4 still differ by roughly the same amount. Nevertheless, these “worst cases” might point to a possible source of the more general problem. The probability that a patent will be litigated is about four times higher in the US than in Germany.[17] Greater enforcement costs reduce the net rents a patent holder can expect to receive. Also, if patent rights overlap because of “fuzzy boundaries,” then the risk of litigation reduces the expected rents on an invention (Bessen and Meurer 2008). Fully exploring this hypothesis is beyond the scope of this paper, however.

17 Lanjouw and Schankerman (2004, Table 1) report an aggregate litigation hazard of 2.1% over the life of a patent for the 1990s in the US while Cremers (2004, p. 21) reports a litigation hazard of 0.5% for Germany for 1993-5. This difference might arise from legal, institutional and cultural differences and the larger size of the US market might also contribute to this difference.

Conclusion

Using a simple model, this paper develops an empirical method for comparing the patent systems of two countries along dimensions of patent economic strength and the economic quality of the patent grant. We apply this method to a comparison between US patents and patents granted by the EPO and designated for coverage in Germany.

Our findings are at odds with some of the conventional wisdom about these patent systems. For example, Ginarte and Park (1997a,b, 2008) construct an index of patent "strength" using conventional considerations of patent enforcement. Their index for 1990 for the US is substantially "stronger" than their index for Germany (4.52 to 3.71). We find, to the contrary, that patents in Germany earn markups that are about four times larger than the markups that patents on those same inventions earn in the US. Also, it is widely argued that the US patent system favors small firms and independent inventors. Our estimates suggest, to the contrary, that small inventors earn relatively more on their patents in Germany, than they earn on patents on the same inventions in the US. Although it may well be true that the US innovation system particularly encourages small inventors, this appears to be *despite* the US patent system, not because of it.

Our analysis suggests that these findings might be driven, at least partly, by differences in the litigation environment between the two countries. If so, this result highlights the bias implicit in constructing an index of patent "strength" based on enforcement measures that does not also consider the ways in which patent litigation might reduce the economic incentives for inventors.

Nevertheless, our exercise makes clear that the real economic behavior of national patent systems differs substantially from the conventional wisdom. An understanding of this behavior based on empirical evidence seems particularly urgent given the extent to which such conventional wisdom is used to negotiate patent harmonization as part of trade treaties.

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Table 1. Summary statistics

	US		EPO/DE	
	All	Matched	All	Matched
Number of patents	1,021,300	287,692	350,619	250,382
Percent matched		28%		71%
Technology				
Chemical	19%	27%		26%
Computers & Communications	12%	12%		13%
Drugs & Medical	9%	12%		11%
Electrical & Electronic	18%	16%		18%
Mechanical	22%	19%		21%
Others	21%	14%		15%
Inventor region				
EPO (original 18)	20%	38%		41%
US	54%	35%		30%
Other	27%	27%		29%
Small entity status				
Small entity	27%	12%		12%
Large	73%	88%		89%
Patent characteristics				
Mean application to grant lag (years)	1.8	1.8	4.7	4.8
Mean life (years from application)	13.8	15.7	12.9	13.1
Citations received	5.3	6.0		
Claims	12.6	13.3		
Patents / family		1.2		1.1
Median last fee paid (annualized, 2005 $)	$ 307	$ 488	$ 899	$ 914
Nominal GDP, 1999 (trillion $)	9.3		2.1	

Note: EPO/DE sample are patent applied for at the EPO from 1984 through 1994 and designated for coverage in Germany when granted. The US sample are patents granted from 1986 through 1996 and subject to renewal fees. The matched samples are patents that are members of an INPADOC family that also contains at least one patent in the other country sample. GDP from the World Bank.

Table 2. Basic estimates, Market size = GDP

	US		EPO/DE		DEPO
	All	Matched	All	Matched	
Parameter	(1)	(2)	(3)	(4)	(5)
μ	-21.09 (0.00)	-20.87 (0.00)	-19.67 (0.00)	-19.59 (0.00)	-19.47 (0.00)
Small entity	-1.69 (0.00)	-0.97 (0.01)			
–	1.61 (0.00)	1.31 (0.00)	1.86 (0.00)	1.85 (0.00)	1.71 (0.00)
Ln L	-1312279	-330300	-878973	-630944	-418008
Percent small	27%	12%			
Observations	1,021,300	287,634	350,619	250,382	167,872

Comparison of US to EPO/DE patents

	(1)	(2)	(3)	(4)
Mean μ per family	-21.36 (0.00)	-20.79 (0.00)	-19.61 (0.00)	-19.53 (0.00)

Economic strength, P = (2) – (4)	-1.26 (0.01)
Economic quality, Q = (1) – (3) – P	-0.50 (0.01)

Note: Maximum likelihood estimation. Asymptotic errors in parentheses. Because small entities are charged different renewal fees in the US, a dummy variable is estimated for them. The "Mean μ" is then the weighted mean of the distribution for small and large entities adjusted for the number of patents per family. The economic strength of the US system is the difference between the mean μ for the US and EPO/DE matched patents. The quality index is the difference for all patents, less P. This table uses the nation's GDP to normalize patent fees.

Table 3. Basic estimates, Market size = industry gross output + net imports

	US		EPO/DE	
	All	Matched	All	Matched
Parameter	(1)	(2)	(3)	(4)
μ	-17.47 (0.00)	-17.18 (0.00)	-16.22 (0.00)	-16.11 (0.00)
Small entity	-1.71 (0.00)	-1.01 (0.01)		
–	1.74 (0.00)	1.50 (0.00)	1.95 (0.00)	1.94 (0.00)
Ln L	-1253325	-328277	-838360	-603092
Percent small	27%	12%		
Observations	926,618	264,776	350,393	250,217
Comparison of US to EPO/DE patents				
	(1)	(2)	(3)	(4)
Mean μ per family	-17.74 (0.00)	-17.10 (0.00)	-16.16 (0.00)	-16.05 (0.00)
Economic strength, P = (2) – (4)		-1.05 (0.01)		
Economic quality, Q = (1) – (3) – P		-0.53 (0.01)		

Note: Maximum likelihood estimation. Asymptotic errors in parentheses. Because small entities are charged different renewal fees in the US, a dummy variable is estimated for them. The “Mean μ” is then the weighted mean of the distribution for small and large entities adjusted for the number of patents per family. The economic strength of the US system is the difference between the mean μ for the US and EPO/DE matched patents. The quality index is the difference for all patents, less P. This table uses industry gross output plus net imports to normalize maintenance fees. Each patent is assigned a pro-rated set of industry market sizes using the primary IPC patent class and a concordance of IPC classes distributed across industry shares.

Table 4. Multivariate analysis

	Normalized to GDP			Normalized to industry output		
	US	EPO/DE	Δ	US	EPO/DE	Δ
	(1)	(2)	(1) - (2)	(3)	(4)	(3) - (4)
Constant	-20.89 (0.01)	-19.48 (0.01)	-1.41	-17.29 (0.01)	-16.18 (0.01)	-1.11
←	1.25 (0.00)	1.83 (0.00)		1.38 (0.00)	1.86 (0.00)	
Technology						
Chemical	-0.01 (0.01)	0.03 (0.01)	-0.04	-0.01 (0.01)	0.21 (0.01)	-0.21
Computers & Communications	0.37 (0.01)	0.39 (0.01)	-0.02	0.77 (0.01)	1.01 (0.02)	-0.24
Drugs & Medical	0.16 (0.01)	0.44 (0.02)	-0.27	0.48 (0.01)	1.05 (0.02)	-0.57
Electrical & Electronic	0.17 (0.01)	0.11 (0.01)	0.06	0.35 (0.01)	0.41 (0.01)	-0.07
Mechanical	0.01 (0.01)	0.04 (0.01)	-0.03	0.00 (0.01)	0.01 (0.01)	-0.01
Inventor region						
EPO (original 18)	-0.52 (0.01)	-0.40 (0.01)	-0.12	-0.63 (0.01)	-0.53 (0.01)	-0.10
US	0.33 (0.01)	-0.15 (0.01)	0.47	0.32 (0.01)	-0.19 (0.01)	0.52
Small entity	-0.89 (0.01)	-0.32 (0.01)	-0.57	-0.88 (0.01)	-0.35 (0.01)	-0.53
N	287,689	250,378		264,774	250,213	
ln L	-319681.8	-628323.2		-314908.5	-595351.5	

Note: Maximum likelihood regressions, asymptotic standard errors in parentheses. The excluded categories are Other technologies, Other inventor regions, and large entities. We use the technology classification of Hall et al. (2001). The left panel is for estimates with maintenance fees normalized by national GDP. In the right panel, maintenance fees are normalized by gross industry output plus net imports.

Table 5. Litigation hazards for US matched sample

Estimation procedure	Probit	Poisson
Dependent variable	Patent is main patent in one or more suits (yes=1, no=0)	Number of lawsuits in which patent is main patent
Technology		
Chemical	-0.33 (0.03)	-1.06 (0.06)
Computers & Communications	-0.06 (0.03)	0.13 (0.06)
Drugs & Medical	0.08 (0.03)	0.39 (0.05)
Electrical & Electronic	-0.19 (0.03)	-0.44 (0.06)
Mechanical	-0.17 (0.03)	-0.35 (0.06)
Inventor region		
EPO (original 18)	-0.03 (0.03)	-0.01 (0.06)
US	0.55 (0.02)	1.60 (0.05)
Small entity	0.27 (0.02)	0.51 (0.04)
Constant	-2.63 (0.03)	-5.03 (0.06)
N	287,689	287,689
Pseudo Rsq	0.071	0.078

Note: Regressions for the US matched sample on the probability that a patent is the main patent (as listed by Derwent) in litigation through 2009. Asymptotic standard errors in parentheses.

Figure 1. Cumulative distribution of patent markups