ISTITUTO DI STUDI E ANALISI ECONOMICA

Valuing environmental patents legal protection when data is not available

by

Simona Tenaglia
ISFOL, Via Morgagni, 33, 00161 - Rome - Italy
e-mail: s.tenaglia@isfol.it

and

Marco Ventura
ISAE, Piazza dell'Indipendenza, 4, 00185 - Rome - Italy
e-mail: m.ventura@isae.it

Working paper n. 103
July 2008

The Series “*Documenti di Lavoro” of the Istituto di Studi e Analisi Economica* – Institute for Studies and Economic Analyses (ISAE) hosts the preliminary results of the research projects carried out within ISAE. The diffusion of the papers is subject to the favourable opinion of an anonymous referee, whom we would like to thank. The opinions expressed are merely the Authors’ own and in no way involve the ISAE responsability.

The series is meant for experts and policy-makers with the aim of submitting proposals and raising suggestions and criticism.

La serie “Documenti di Lavoro” dell’Istituto di Studi e Analisi Economica ospita i risultati preliminari di ricerche predisposte all’interno dell’ISAE: La diffusione delle ricerche è autorizzata previo il parere favorevole di un anonimo esperto della materia che qui si ringrazia. Le opinioni espresse nei “Documenti di Lavoro” riflettono esclusivamente il pensiero degli autori e non impegnano la responsabilità dell’Ente.

La serie è destinata agli esperti e agli operatori di politica economica, al fine di formulare proposte e suscitare suggerimenti o critiche.

Stampato presso la sede dell’Istituto

ISAE - Piazza dell’Indipendenza, 4 – 00185 Roma.
Tel. +39-06444821; www.isae.it

ABSTRACT

This paper aims at estimating the value of legal patent protection of environment-related technologies, using the real options approach. In particular, we manage to overcome the problem of the lack of data for those countries that do not collect patent renewal data. Following this estimation strategy, we rank the value of legal patent protection for seventeen countries, closely reproducing other rankings based on surveys, for instance the PatVal survey by the EU Commission (2006), but relying on macro data publicly available and easy to access. The unit value of damage is found to be the most important determinant of the value of patents granted by legal protection.

Keywords: value of patents, legal protection, real options, abatement technology, environmental technologies.

JEL codes: K40; O38; Q55.

CONTENTS

1 INTRODUCTION

Following the definition given by OECD (2007) and WIPO (2008) environment-related patents pertain to two broad categories, according to their technology content: (i) patents for renewal technologies, applied to several areas such as solar, wind, geothermal, wave-tide, biomass and waste; and (ii) abatement technologies, aimed at reducing pollutants produced and released into atmosphere by any sort of engine.

Inventions related to renewable energy and abatement technology are evolving rapidly since the mid-1990s (OECD 2007). Innovation activity in both technology fields is urged by the need of alternative sources of energy in the face of rising fuel prices, as well as by more stringent environmental regulations. It follows that patents, as a measurable output of innovation activity, are urged by regulations on environmental standards. An effective patent protection is expected to bring about a higher value of patents, which in turn acts as an incentive for further R&D in all fields, especially in the field of pollution abatement and environmental target. Therefore, estimating the value of patent legal protection, namely the value of patents granted by law, is a crucial step in order to formulate effective policies to foster R&D.

All industrial patents, regardless of the technological sector they belong to, are subject to the same law. Once accounted for economic and technical characteristics, there is a common component in the value of patents that share the same law and the same degree of enforcement. Hence, estimating the legal component of the value of environment-related patents is not a different task with respect to estimating the same component for any other patent in a given country. For this reason we carry out the analysis on a sample including patents of all sectors in different countries, benefiting also from a more robust sample.

The econometric technique we propose is well grounded in economic theory, specifically in the real options literature. Following this estimation strategy, we rank the value of patent legal protection for sixteen countries, closely reproducing other rankings based on surveys, for instance PatVal survey by the EU Commission (2006), but relying on macro data publicly available and easy to access. Moreover, the main determinants of the position of the countries in the ranking are investigated. Unit loss on each infringement, borne by patent holders, is found to be the main determinant of the value of patent protection, rather than the total number of infringements. Evidence on this point is given by an estimation of the unit loss by country, proving that higher values of patent protection are correlated with lower values of the unit loss on each infringement. This result is fairly useful in terms of policy-making because it allows to concentrate policy efforts on the unit value of the damage, rather than on other factors.

As noted before, in order to formulate good public policy on intellectual property rights, policy makers need to know whether, and to what extent, patent protection is effective in providing incentives to R&D and how different government policies, such as prosecution of infringements, restrictions on patent licensing and price restriction, may affect the effectiveness and the value of patent protection. Some methodologies have been developed and, roughly speaking, they can be classified as direct and indirect ones. In the former case, data is drawn from surveys, where inventors are asked to assign a monetary value to their inventions. This technique is particularly costly and it is not always easily accessible. In the latter case, the indirect technique is based on the idea that a patent owner will pay the initial and subsequent fees only if revenues exceed costs. Put another way, inventors are considered owning an option, they are not obligated to apply for, or to renew, a patent, but they make this decision only when it is economically feasible. The original idea was first formulated by Pakes (1986), followed by the contributions of Shankerman and Pakes (1986), Pakes and Simpson (1989), Shankerman (1998), Lanjouw et al. (1998), Lanjouw (1998), among others. It is straightforward that this idea is perfectly in line with the real options paradigm[1] and it has been exploited in several empirical works by Bloom and Van Reenen (2002), Laxman and Aggarval (2003) and Schwartz (2004). In a recent contribution Wu and Tseng (2006) validate the theoretical relationships postulated by real options theory. They directly test the reliability of the theory on a panel sample of Taiwanese firms. In spite of its potentials, this promising strand of empirical literature undergoes the non negligible limit to require either micro data, as in Wu and Tseng, Bloom and Van Reenen, or renewal data such as in Pakes, Shankerman, Lanjouw et al, Shankerman and Pakes, Pakes and Simpson. Both datasets are not always available and they are not collected by every country. Therefore, the basic idea put forward in this paper is to move from a micro to a macro perspective, still remaining in the real options paradigm, and to extend the analysis from environment-related technologies to all patented inventions. The first intuition, i.e. moving from micro to macro data, is crucial to overcome lack of data on renewals, without abandoning Pake's intuition.

The remainder of this paper is organized as follows. Section 1 briefly reviews the real option models applied to patents. Section 2 puts forward an econometric strategy to measure the value of IP protection in a panel of countries and describes the dataset. Section 3 shows the empirical results. Section 4 checks for the robustness of the results obtained. Section 5 detects the determinants of the value of IP protection. Section 6 investigates about the

1 For a complete, though dated, review on real option theory we refer the interested reader to Dixit and Pyndick (1994).

principal determinants of the value of patent legal protection. Finally, section 7 summarizes the results and formulates useful policy recommendations.

2 REVIEW OF REAL OPTIONS LITERATURE APPLIED TO PATENTS

A financial option conveys the right, but not the obligation, to engage in a future transaction on some underlying security, or in a futures contract. For example, buying a call (put) option provides the right to buy (sell) a specified quantity of a security at a set strike price at some time on or before expiration. The original idea of comparing the patent renewal decision to a financial option was first formulated by Pakes (1986), followed by the contributions of Shankerman and Pakes (1986), Pakes and Simpson (1989), Shankerman (1998), Lanjouw et al. (1998), Lanjouw (1998), among others.

The real options theory[2] applied to patents considers patents as options the underlying of which is the expected cash flow generated by the project. The dynamic of the underlying security is supposed to follow a Geometric Brownian motion of the type:

$$\frac{dS_t}{S_t} = \alpha dt + \sigma dz_t$$

where α is the drift of the process, σ^2 the proportional variance parameter, and dz the increment of the standard Wiener process, with E(dz)=0 and Var(dz)=dt.

The patent, C(S,t), is a postive function of both, the present value of the expected cash flow, and the time to maturity, τ=T-t. As reported by empirical findings, Shankerman (1998) and all the papers dealing with renewal data, about 50% of patents drop out before they reach age ten and only a negligible part of those remaining reaches the last year of life, the twentieth. Therefore, one can reasonably assume the value of the patent to be independent of time, by simplifying the dependence C(S,t) to C(S). This step will turn out to be very useful in solving the PDE generated by applying Ito's lemma to evaluate C(S).

Very briefly, the value of the option, namely the patent, can therefore be written as

$$C(S)=A_1S^{\beta 1} \qquad (1)$$

---

[2] We do not go through the details of the theory because these are far beyond the scope of the paper, however for a complete, though dated, review on real option theory we refer the interested reader to Dixit and Pyndick (1994).

where β_1 is the positive solution to the characteristic equation:

$$r - \beta(r - \delta) - \beta(\beta - 1)\sigma^2 = 0$$

and A_1 is a constant determined by boundary conditions, (see Dixit and Pindyck (1994), p.152).

This idea has been exploited in several empirical works by Bloom and Van Reenen (2002), Laxman and Aggarval (2003) and Schwartz (2004). In a recent contribution Wu and Tseng (2006) validate the theoretical relationships postulated by the real options theory. They directly test the reliability of the theory on a panel sample of Taiwanese firms. The patent citation index is taken as the proxy for the option, under the hypothesis that a highly cited patent, namely one referred to by many subsequent issued patents, is likely to contain important technological advances (Thomas, McMillan, 2001). The underlying asset is proxied by the number of patents a firm has been granted at a given time (we will turn later to this point in more details).

In spite of its potentials, this promising strand of empirical literature undergoes the non negligible limit to require either micro data, as in Wu and Tseng, Bloom and Van Reenen, or renewal data such as in Pakes, Shankerman, Lanjouw et al, Shankerman and Pakes, Pakes and Simpson. Both datasets are not always available and they are not collected by every country. Therefore, the basic idea put forward in this paper is to move from a micro to a macro perspective, still remaining in the real options paradigm. This step is crucial to overcome lack of data on renewals, without abandoning Pake's intuition.

3 THE MODEL AND THE DATA

In the micro approach by Wu and Tseng a testable version of the theory has been obtained by partially differentiating the Black and Scholes equation in order to derive the following sensitivities:

(2) $\frac{\partial C}{\partial S} > 0$ (3) $\frac{\partial C}{\partial r} > 0$, (4) $\frac{\partial C}{\partial \sigma} > 0$ and (5) $\frac{\partial C}{\partial \tau} > 0$

which give the opportunity to write the following testable regression equation:

$$C_{i,t} = \alpha + \beta_1 S_{i,t} + \beta_2 \tau_{i,t} + \beta_3 r_{i,t} + \beta_4 \sigma_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \quad (3)$$

where the signs of the estimated betas must be in accordance with those predicted by (2)-(5).

Equation (3) has been estimated by fixed effects (FE) technique, $\mu_{i,t}$, to take into account firms' unobservable heterogeneity, using a panel of 101 firms observed over 10 years. The data reveals that β_4 is not significantly different from zero, while β_1, β_2, and β_3 take on the expected signs, making the authors argue that the theoretical framework cannot be rejected.

Following this reasoning, we can even further by thinking of extending an application of (3) to macro data. This step could be very interesting in the evaluation of patent protection systems across different countries. Let the subscript i=1…I denote a cross section of countries over a time period, t=1…T.

Let us also assume that we have at our disposal good macro variables to proxy S, r and σ. C_i is a positive function of patent counts, S, capturing the global value of patents in a given economy. The critical point now is: what does the fixed effect $\mu_{i,t}$ represent?

The value of a patent can be defined as the profit obtained by the owner with respect to the situation without patent, namely, the profit that the patentee would not have had without the patent. Sometimes this entity is referred to as the patent premium. This premium can be broken down into two distinct components: the strictly speaking economic component and the legal one. The former component, in turn, is made up of all the technical and economic characteristics of the good that make the patent economically exploitable. It deals with the set of demand and supply characteristics related to the good the production of which is entitled by patent ownership. All these characteristics can be considered as accounted for by the economic variables postulated and validated by real options theory. The legal component, on the contrary, plays its role independently of the former and pertains legal protection granted by law. This is the object we are interested in, because it is the key to formulate valid policies concerning intellectual property. Indeed, even in the presence of the most favourable economic characteristics of the patented good, if the law does not assure even a minimum defence to the patentees, patents turn out to be worthless. Thus, for given economic characteristics, the value of patents crucially depends on legal protection. The effectiveness of legal protection may vary, and indeed it varies, among different countries, and it may be captured in the fixed effect $\mu_{i,t}$ of a macro version of equation (3).

It follows that estimating a macro version of (3) and retrieving the fixed effects, FE, provides us with the possibility of ranking the effectiveness of legal protection in a panel of countries. To our knowledge, so far this task has been pursued in economic literature only through patent renewal data, not always collected by all countries, or by relying on *ad hoc* surveys[3], not easily replicable because of the high cost of implementation. Therefore, this technique allows us

[3] For instance, see Taylor, Silberston (1973); Mansfield, Schwartz, Wagner (1981); Levin et al. (1987); Cohen, Nelson, Walsh (1996); Arora, Ceccagnoli, Cohen (2003) and Giuri et al. (2006).

to overcome the annoying problem of lack of data, without giving up this important and useful task.

As a good proxy for S(.) we take the OECD triadic patent families. A patent family is defined as a set of patents (originating from the priority filing) taken in various countries to protect the same invention. The triadic patent is a patent applied for thrice, at EPO (EU patent office), at USPTO (US patent office) and JPTO (Japan patent office) for the same patent. The underlying assumption made in using triadic patents to measure the patent quality (and therefore its value) is that triadic applications are filed only for valuable patents, and quite likely a triadic patent embodies important technological advances. It follows that the higher the patent counts in one country, the higher the probability of triadic patents, hence triadics can be regarded as a positive function of counts. The optionality of the choice consists in the fact that once has been filed an application for a patent, the patentee makes the decision of incurring the sunk cost of filing two other applications to obtain a triadic patent.

Table 1 reports the analogy between the micro approach to patents as real options followed by Wu, Tseng and the macro approach followed in this paper.

Tab. 1 Analogy between the micro and macro approaches to patents as real options

Theoretical Variable	**Micro data (Wu Tseng)**	**Macro data**
$C_{i,t}$ Call option	Average number of patents owned by firm i ($S_{i,t}$) cited by other firms' patents	Triadic patents by inventor of the i-th country
$S_{i,t}$ Underlying	Number of patents a firm i has been granted at time t	Number of patent counts by inventor at the EPO of the i-th country
$\tau_{i,t}$	Lifetime of patents	
$r_{i,t}$ risk free interest rate	Risk free interest rate	Risk free interest rate in government bonds
$\sigma_{i,t}$ volatility of the relative increment in the underlying	Standard deviation of the firm's daily stock returns at time t	Standard deviation in the Production Price Index

As a proxy for the interest rate we have taken the benchmark bond 10y and as a proxy for the volatility we have chosen the standard deviation of the increments in the Price Production Index, since patent counts are industrial patents, while $\tau_{i,t}$ is omitted for the reasons explained before. The estimate applied on seventeen countries for the time period 1977-2003 is reported in table A1 in the appendix.

4 EMPIRICAL RESULTS

By retrieving the fixed effects of the estimate it is possible to rank the legal component of patents value for those countries included in the panel, which is an index of the value granted by national legal protection, I_v. The use of panel data has various advantages. First, panel dataset generally provide an increased number of data points, generate additional degrees of freedom, and reduces the collinearity among explanatory variables. Secondly, fixed effects solve the problem of unobservable variables in conventional OLS regression estimates, and thus allow more efficient estimation of the regression parameters (Pindyck, Rubinfeld, 1998; Ernst, 2001; Greene, 2003). Moreover, the problems arising from a possible misspecification error of the omitted variable form can be significantly reduced by incorporating information relating to both cross section and time-series variables.

The fixed effects of the estimate are a "raw" index of the national value of patents granted by legal protection. They must first undergo a Wald equality test, and successively they must be normalized to take on values between 0 and 100. Table 2 reports the index based on the FE estimate[4] in Table A1.

Tab. 2 Index of patent legal protection value (1)

Country	I_v	Groups of countries
Spain	0.00	Group 1 0.00
Italy	0.24	
Ireland	1.15	
Norway	2.11	Group 2 2.79
Denmark	2.91	
Finland	2.97	
Belgium	3.18	
Canada	3.28	
Austria	3.33	
Sweden	8.28	Group 3 9.13
Netherlands	8.28	
UK	8.28	
France	8.28	
Switzerland	8.28	
Germany	8.28	
USA	79.28	Group 4 100
Japan	100.00	

Source: based on OECD data.

(1) Higher values of the index are associated to higher values of patent legal protection. The index has been normalized assigning 0 to the lowest value and 100 to the most virtuous country.

4 On the basis of a Hausman test we can reject the null hypothesis of consistency of both fixed and random effect.

In column 3 the seventeen countries have been gathered into four groups according to the results of the Wald tests on the fixed effects. Within each group we have taken as a numerical reference the closest value of the FE to the next group, that is the highest value within each group is representative of all the countries in the group. For a total of J groups this operation has been repeated J-1 times, while for the J^{th} group we have taken as a reference the lowest value within the group, in order to minimize the dispersion of the indicator between groups. Clearly, this normalization procedure is arbitrary, one could have chosen any other method to assign a unique value to the countries belonging to the same group, such as the mid value, as long as the choice is invariant with respect to the final ranking, the object we are really interested in.

In the first group we find the Southern European countries (in this sense Ireland is considered as a Southern country) and in the fourth group we find the USA and Japan, as expected. The other advanced economies lie between these two bounds with some of them relatively more virtuous: Sweden, the Netherlands, the UK, France, Switzerland and Germany, and some others somewhat less virtuous: Norway Denmark, Finland, Belgium, Canada, Austria.

EU countries substantially share a common law on intellectual property, but the degree of compliance and enforcement varies greatly among countries. That explains the variability of the index among those countries.

The original procedure we have followed to rank the value that legal protection granted to patents in different countries has the twofold advantages of being theoretically grounded and overcoming the problem of lack of data. Nevertheless, the finding needs to be tested in order to assess its reliability.

5 THE RELIABILITY OF THE INDEX OF PATENT VALUE: THREE CHECKS

A recent study elaborated on behalf of the EU Commission[5] evaluates through a survey the value of patents in eight countries, seven of which are included in our estimates. Table 3 presents a clear comparison between the ranking stemming from the application of the two methodologies.

---

5 Study on "Evaluating the knowledge economy: what are patents actually worth?" Available at http://ec.europa.eu/internal_market/indprop/docs/patent/studies/final_report_lot2_en.pdf.

The authors estimate the patents value through an interval estimation based on survey data with a sample of about 8000 observations.

The two rankings differ only for one country, The Netherlands. If we remove this non serious difference the remainder of the rankings are exactly the same. The rank correlation coefficient[6] is 90% with a degree of significance at 1%. This is a startling result showing a close convergence between the two methods. It shows that the real option approach applied on macro data can closely replicate the results obtained from survey analysis. Therefore, we cannot reject the ranking made in such a way.

As a second check, one would expect higher values of patents where patent protection is stronger. To this purpose it is possible to correlate the patent value index, I_V, to the index of the strength of patent rights, PR, elaborated by Ginarte and Park[7] (1997), expecting a positive correlation. By the same token, one would also expect a positive correlation with the enforcement index elaborated by the World Bank[8]. However, since the PR is a composite index given by the sum of other five indices, where

Tab. 3 Comparison between I_v and a ranking based on survey data

Country	I_v	Ranking Report EU (1)
Spain	1	1
Italy	2	2
Denmark	3	3
Netherlands	4	6
UK	5	4
France	6	5
Germany	7	7
Rank Correlation	0.90***	

* Significant at 10%; ** significant at 5%; *** significant at 1%.

(1) The report repeats the estimates over three time periods. In this column the average rank over the three periods is reported.

Tab. 4 Rank correlation between I_v and the two indices of the strength of patent protection

Rank-correlation between I_v and the index of patent rights, PR (1)	Rank-correlation between I_v and the index of enforcement (2)
0.52**	0.38*

Source: based on Ginarte, Park (1997) and World Bank, Doing Business in 2006.

* Significant at 10%; ** significant at 5%; *** significant at 1%.

(1) The Ginarte-Park index is elaborated every 5 years, this table shows the rank correlation between I_v and the average rank over the period 1980-2005.

(2) The WB enforcement index is composed of three indices, the table shows the rank correlation between I_v and the average rank of these three indices.

6 The rank-correlation or Spearman's rank correlation indicates how the ranks of objects in one sample differ from the ranks in another sample. Its values range from -1 to 1. A value of 1 indicates that the ranks are identical, while -1 indicates that they are exactly inverted. For more details on how to work it out and how to determine its significance see: http://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient

7 The Ginarte and Park index is the sum of five other indices: (1) extent of coverage, (2) membership in international patent agreements, (4) enforcement mechanism and (5) duration of protection.

8 The World Bank enforcement index is referred to the recovery of overdue debts and is composed of three indices: (i) number of procedures, (ii) time, and (iii) cost as a % of debt. See p. 107 Doing Business in 2006.

enforcement is only one of the five, it is reasonable to expect a weaker correlation between I_v and the World Bank enforcement index.

The results reported in Table 4 perfectly fulfil our expectations. Both correlations are positive and significant, but the one referred to the GP index is stronger in the sense of both its magnitude, 52% against 38%, and its level of significance, 5% against 10%.

With this threefold validation of the index, one can be legitimated to take I_v as a good starting point to analyse the effects of policies put into effect, as well as to formulate valid policy directions.

6 THE EFFECT OF INFRINGEMENTS ON PATENT VALUE

The value of patents is closely related to the strength of protection, as shown by $E(I_v,PR)>0$. This correlation can be restated as: in a given country the value of patents decreases as the damage produced by infringements increases. That is, the value of patents decreases as economic losses suffered by patentees and caused by infringements increase. The total damage caused by infringements is given by the product of the unit value of damage times the number of infringements.

Definition 1: for a hundred percent of profit accruing to a patentee from a given patent, the unit loss, or unit value of damage, can be defined as: the share of profit subtracted to the patent holder by infringement of that given patent.

Put another way, the unit damage is the share of profit lost by the patent holder for each infringement undergone.

Formally, the total value of patents, F, in a given country at time t can be written as:

$$F_t = \sum_{j=1}^{J} V_{jt} (1 - \underbrace{\lambda_{jt}\phi_{jt}}_{unit\ loss}) \geq 0 \tag{4}$$

where V_{jt} is the value of patent j in absence of infringements at time t, λ_{jt} and φ_{jt} respectively represent the number of infringements and the unit damage on patent j, for j=1…J, at time t. Rewriting the unit damage as $d_{jt} \equiv \lambda_{jt}\phi_{jt}$, the non negativeness constraint, $F_t \geq 0$, requires $d_{jt} \leq 1$, whose sufficient condition is $\varphi_j \leq (\lambda_j)^{-1}\ \forall\, j$. Notice that $F_t \geq 0$ can still hold with $\varphi_j\lambda_j>1$ for some j, and $\varphi_i\lambda_i<1$ for at least one i≠j, but this (necessary) condition would violate the definition of unit value of damage, because it implies that infringements can subtract more than 100% from patentee's profit. Therefore, under Definition 1

$$F_t \geq 0 \text{ iff } \varphi_j \leq (\lambda_j)^{-1} \ \forall j$$

in plain English, we can claim that $\varphi_j \leq (\lambda_j)^{-1}$ for each j=1…J is a necessary and sufficient condition for inequality (4) to hold.

A given total damage in different countries can be consistent with different unit values of damage, compensated by different numbers of infringements. In principle, there is no fundamental to claim that the two components of total loss equally affect the total value of patents, but most likely the two have different weights on total patent value, and therefore different significance on the position held by a country in the ranking.

At a closer look, the total number of infringements can directly depend on the size of the gain the infringer receives, that is, the higher the gain in infringing, the higher the incentive to infringe and the higher the number of infringements, formally $\lambda = \lambda(\varphi)$ with $\lambda' > 0$. Conversely, the inverse relationship, $\varphi = \varphi(\lambda)$, does not necessarily hold. If $\varphi' < 0$ a marginal increase in λ will cause a drop in φ. This is a very extreme situation occurring when the market is "fully saturated" or crowded by infringements, implying that patent protection is completely, or almost completely, ineffective and patents are worthless. But if $F \approx 0$ there is no incentive to R&D. Ginarte, Park (1997) show that there exists a critical size of R&D sector, above which there is sufficient interest on the part of the authorities to provide effective patent rights and below which there is not. They also prove that high per-capita income countries, such as our seventeen countries, lie above this threshold, where patents are not worthless, therefore in our case F is strictly positive, $F > 0$, and φ is not a (negative) function of λ.

From another vantage point, assuming that the unit damage increases as the number of infringements increase, $\varphi' > 0$ does not make economic sense. However, in what follows, in order to derive a very general proposition we first leave φ be a (negative) function of λ and then we will restrict ourselves to the special case in which $\varphi' = 0$, representing advanced economies

Rewriting (4) as

$$F_t = \sum_{j=1}^{J} V_{jt} \left[1 - \lambda_{jt}(\phi) \phi_{jt}(\lambda_{jt}) \right] \quad (5)$$

and partially differentiating

$$\frac{dF_t}{d\phi_j} = -V_{jt}(\lambda'_j \phi_j + \lambda_j) \ , \ \frac{dF_t}{d\lambda_j} = -V_{jt}(\phi'_j \lambda_j + \phi_j)$$

for each j=1…J

recalling that $\lambda \in \mathcal{N}$, where $\mathcal{N}$ is the set of non negative integers, we obtain that $\frac{\partial F_t}{\partial \lambda_j} \geq \frac{\partial F_t}{\partial \phi_j}$, or in an easier way of looking at the effect of φ and λ on F we can claim that

$$\left|\frac{\partial F_t}{\partial \lambda_j}\right| \leq \left|\frac{\partial F_t}{\partial \phi_j}\right| \tag{6}$$

where the equality holds for φ=0, since λ(0)=0.

Proposition:

an increase in the unit value of damage, caeteris paribus, will cause a greater drop in the total value of patents, with respect to an equal increase in the total number of infringements.

Comment: notice that this interesting result is quite general in the sense that it holds both in a fully saturated market, i.e. φ=φ(λ) with φ'<0, and in the presence of effectiveness of patent rights, φ'=0. In the latter case, inequality in (6) still holds since $\frac{dF_t}{d\lambda_j} = -V_{jt}\phi_j$, with the difference with respect to the former case that now the sign of $\frac{dF_t}{d\lambda_j}$ is clearly non positive. Further, the same result applies to other forms of intellectual property such as trade marks and copy rights, since equation (4) is quite general and still holds for other forms of intellectual property.

The proposition above has straightforward implications, both normative in terms of policy, and positive, in terms of capability to understand the position taken on by countries in the international comparison. If policy makers want to simulate economic growth through innovation they ought to protect patents better, but in doing so, it is much more effective to act directly on the unit value of damage, rather than repressing infringements. For instance, Italy has recently acknowledged EU directive 2004/48 which, among other measures, establishes a new method for evaluating the damage undergone by patent holders, as well as a quicker judicial attachment to prevent infringers from harming patent holders. These two measures are devoted to affect φ and, as prescribed by the model, are more effective than increasing administrative sanctions to 10,000 euros for buying infringed products, as is also done in Italy.

From a positive point of view, once we have accounted for economic factors, φ is the most relevant determinant of the value of patents, one will expect countries with a higher value of patents to have a low value of φ.

7 SURVEY OF THE POSITION TAKEN ON BY THE COUNTRIES IN THE INTERNATIONAL COMPARISON

In the previous paragraph we have claimed that countries with higher values of I_v are expected to have lower values of φ. This statement can be verified estimating the values of φ_j, ranking the countries according to φ_j and correlating this rank to that of I_v.

The relationship between λ and φ is such that for $\phi \in [0;1]$ $\lim_{\phi \to 0} \lambda = 0$ and $\lim_{\phi \to 1} \lambda = \infty$, therefore a possible functional form is

$$\frac{\lambda_{it}}{n_{it}} = \frac{\phi_{it}}{1-\phi_{it}} C \quad \text{with } \lambda' > 0 \text{ and } \lambda'' > 0 \qquad (7)$$

where n_{it}, the total number of patents in force, has been inserted in the function in order to take into account the size of the innovative activity in country i at time t. C is a strictly positive constant the role of which is to generalize (7) showing that the monotonic relationship λ(φ) is consistent with any shift of the function in (7).

As a proxy for λ we have taken the number of legal suits[9] on patents in 2004 in country i, while n_{it} has been proxied by the number of patents registered at EPO by the same country in the same year. From the functional assumption in (7) it is possible to obtain φ and to propose the following ranking for those countries whose data are available

In column 2 the countries are ranked in ascending order with respect to efficiency in protecting patents, namely in descending order with respect to φ. As in Table 2, the countries have been grouped on the basis of equality tests. In particular, since Italy is the only country whose time series data is available, we have carried out equality tests of all countries with respect to Italy, giving rise to the groups presented in column 3. Correlating the ranking in column 3 of Table

9 A more correct practice consists of using the total number of pending legal suits on patents, but this figure must be divided by the total number of live patents in the country, bringing us back to the original problem of the lack of renewal data. The total number of pending legal suits cannot be divided by the number of patents registered at EPO because the former figure is a stock and the latter is a flow, and so the ratio will give rise to a meaningless figure.

5 with the ranking of I_v in Table 2 we get a positive Spearman correlation of 0.65, significant a t 5%, with a p-value of 0.013.

Tab. 5 Ranking of countries by φ in 2004

	φ	Rank of φ	λ
Spain	0.04065	1	49
Italy	0.03302	1	1845 (1)
UK	0.02513	1	129
Germany	0.02271	1	512
Belgium	0.01568	2	22
Austria	0.01520	3	21
Denmark	0.01446	4	14
Netherlands	0.01395	5	49
Sweden	0.00994	6	21
Finland	0.00759	7	10
France	0.00632	8	51
Rank corr. with I_v		0.65**	

Source: based on OECD for n_{it}; λ Ministry of Justice for Italy, and CJA on behalf of EU Commission for all other countries.

* Significant at 10%; ** significant at 5%; *** significant at 1%

(1) The figure for Italy is comprehensive of both patents and marks, this peculiarity has been taken into account also in computing n, in order to make data comparable among countries.

The lowest value of the ranking has been attributed to the country with the highest φ

This result empirically confirms the intuition: countries with higher value of patents granted by legal protection have lower unit values of damage. This last variable is the most important determinant of the value of patents to work on, in order to spur economic growth through innovation activity, once one has accounted for economic factors.

8 CONCLUDING REMARKS

This paper moves a step ahead in the difficult task of measuring the value of innovative output. Since all industrial patents, regardless of the technological sector they belong to, are subject to the same law, estimating the legal component of the value of environment-related patents is not a different task with respect to estimating the same component for any other patent in a given country. Relying on the real option theory we have presented a new methodology to rank the value of patents granted by law in different countries, namely we rank the effectiveness of patent protection in different countries. This task has been accomplished overcoming the annoying problem of lack of renewal data or survey data.

The unit value of damage is found to be the most important determinant of the value of patents granted by legal protection. This finding may have both normative and positive relevance. From the former viewpoint, if policy makers want to simulate “green” economic growth through innovation they ought to better protect patents, but in doing so, it is much more effective to act directly on the unit value of damage, rather than repress infringements. The case of Italy has been analyzed in this light. From a positive perspective, the knowledge of φ helps in explaining the position taken by countries in the international comparison.

Of course, the analysis presented in the paper suffers from some limitations that can possibly be overcome in further research. First, a better estimate of φ can be achieved should data on pending patent processes and renewal data become available. Secondly, some explicit attention should be paid to the different technological specialization of countries, because the technological content of patents in different countries may affect the value of patents regardless of protection granted by law. In our analysis this aspect has been implicitly relegated to the unobservable heterogeneity component, accounted for by the FE estimate. Nevertheless, we consider that the analysis presented can be a good starting point to formulate sound policies in better protecting intellectual property in order to spur “green” economic growth through innovation activity.

REFERENCES

Arora A., Ceccagnoli M. (2006), "Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing", Management Science, 52(2), Feb.

Arora A., Ceccagnoli M., Cohen W.M. (2003), "R&D and the Patent Premium", NBER wp. 9431.

CJA Consultants Ltd European Policy Advisers Britain and Brussels (2006) "Patent Litigation Insurance", a study for the European Commission on the feasibility of possible insurance schemes against patent litigation risks, FINAL REPORT, June available at http://ec.europa.eu/internal_market/indprop/docs/patent/studies/pli_report_en.pdf

Cohen W. Nelson R., Walsh J. (2000), "Protecting their intellectual assets: Appropriability Condition and why US manufacturing firms patent or not" NBER wp n.7552.

Ginarte J., Park W.G. (1997), "Determinants of Patent Rights: A Cross-national Study", Research Policy, 26, 283-301.

Giuri P, Mariani M, Brusoni S, et al. (2006), "Everything you always wanted to know about inventors (but never asked): evidence from the PatVal-Eu survey" disc. paper Munich School of Management n.11.

Bloom N. and Van Reenen, J. (2002) "Patents, Real Options and Firm Performance", The Economic Journal, 112(478) March , C97–C116.

Dixit A. and Pyndick R. (1994), Investment Under Uncertainty, Princeton University Press.

Ernst, H. (2001), Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level, Research Policy, 30, 143–57.

EU Commission (2006) Study on evaluating the knowledge economy: what are patents actually worth? http://ec.europa.eu/internal_market/indprop/docs/patent/studies/final_report_lot2_en.pdf

Greene, W. H. (2003), Econometric Analysis, 5th edn, Prentice Hall, Upper Saddle River, NJ.

Lanjouw J.O. (1998) "Patent Protection in the Shadow of Infringement: Simulation Estimations of Patent Value", Review of Economic Studies, 65(4) 671-710.

Lanjouw J.O., Pakes A., Putnam J. (1998) "How to Count Patents and Value Intellectual Property: the Uses of Patent Renewal and Application Data", The Journal of Industrial Economics, 46(4), 405-432

Levin R., Klevorick A., Nelson R., Winter S. (1987), “Appropriating the Return from Industrial R&D”, Brooking Papers on Economic Activity: Microeconomics, pp. 783-820.
Laxman P.R., Aggarwal, S. (2003) “Patent valuation using real options”, IIMB Management Review, 15(4), 44–51.
Mansfield E. Schwartz M., Wagner S. (1981), “Imitation Costs and Patents: an Empirical Study“ Economic Journal, Vol 91, pp. 907-918.
Pindyck, R. S., Rubinfeld, D. L. (1998) Econometric Models and Economic Forecasts, 4th edn, McGraw-Hill, New York.
Pakes A.S. (1986) “Patents as Options: some Estimates of the Value of Holding European Patent Stocks”, Econometrica, 54(4), 755-784.
Pakes A.S., Simpson M. (1989) “Patent Renewal Data”, Brooking Papers on Economic Activity: Microeconomics, 331-410
Schwartz E. S. (2004) “Patents and R&D as real options”, Economic Notes, 33(1), 23–54.
Shankerman M. (1998) “How Valuable is Patent Protection? Estimates by Technology Field”, Rand Journal of Economics, 29(1), 77-107
Shankerman M., Pakes A. (1986) “Estimates of the Value of Patent Rights in European Countries during the Post -1950 Period” Economic Journal, 96, Dec. 1052-76.
Taylor C.T., Silbertson Z.A. (1973) “The Economic Impact of the Patent System: a Study of the British Experience”, Cambridge: Cambridge University Press.
Thomas, P., McMillan, G. S. (2001) Using science and technology indicators to manage R&D as a business, Engineering Management Journal, 13, 9-14.
Van Zeebroeck N. (2008) “The puzzle of patent value indicators” Centre Emile Bernehim Research Institute in Management Sciences, wp 07/023.
World Bank (2007) “Doing Business 2007. How to Reform”. A publication of the World Bank and the International Finance Corporation.
Wu M.C., Tseng C.Y. (2006) “Valuation of patent - a real options perspective”, Applied Economic Letters, 13(5), 313-318

APPENDIX

Tab. A1 Fixed Effect estimate of equation (3) on macro data
Dependent variable: Triadic patents

Patent counts	0.235*** (0.057)
Sigma	1.864 (12.556)
Interest	43.703*** (16.029)
At	-300.198** (137.776)
Bg	-309.063* (161.176)
Cn	-303.399* (173.291)
Dk	-325.917** (142.788)
Fin	-321.795* (165.932)
Fra	-72.185 (357.367)
Ger	410.50 (740.295)
Irl	-432.597*** (163.860)
It	-487.573* (274.322)
Jap	5,562.225*** (992.984)
Nl	-170.446 (194.504)
Nor	-374.126** (149.403)
Es	-502.107*** (189.071)
Sve	-249.622 (203.732)
Ch	15.075 (153.709)
Uk	-132.759 (333.420)
Us	4,305.429*** (1,083.724)
Observations	380
R-squared	0.92

Robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

The table above reports the estimate of equation (3). Perfectly in line with Wu and Tseng, 2006, the coefficient β_4 is not significantly different from zero, while β_1, β_2, and β_3 take on the expected signs. The FE estimate has been carried out by a Leas Square Dummy Variable technique, instead of the more common within estimator in order to retrieve the FE for each country along with its significance. On the basis of a Hausman test we can reject the null hypothesis of consistency of both fixed and random effect.

Working Papers available:		
n. 47/05	M. MALGARINI P. MARGANI B.M. MARTELLI	Re-engineering the ISAE manufacturing survey
n. 48/05	R. BASILE A. GIUNTA	Things change. Foreign market penetration and firms' behaviour in industrial districts: an empirical analysis
n. 49/05	C. CICCONI	Building smooth indicators nearly free of end-of-sample revisions
n. 50/05	T. CESARONI M. MALGARINI G. ROCCHETTI	L'inchiesta ISAE sugli investimenti delle imprese manifatturiere ed estrattive: aspetti metodologici e risultati
n. 51/05	G. ARBIA G. PIRAS	Convergence in per-capita GDP across European regions using panel data models extended to spatial autocorrelation effects
n. 52/05	L. DE BENEDICTIS R. DE SANTIS C. VICARELLI	Hub-and-Spoke or else? Free trade agreements in the "enlarged" European Union
n. 53/05	R. BASILE M. COSTANTINI S. DESTEFANIS	Unit root and cointegration tests for cross-sectionally correlated panels. Estimating regional production functions
n. 54/05	C. DE LUCIA M. MEACCI	Does job security matter for consumption? An analysis on Italian microdata
n. 55/05	G. ARBIA R. BASILE G. PIRAS	Using Spatial Panel Data in Modelling Regional Growth and Convergence
n. 56/05	E. D'ELIA	Using the results of qualitative surveys in quantitative analysis
n. 57/05	D. ANTONUCCI A. GIRARDI	Structural changes and deviations from the PPP within the Euro Area
n. 58/05	M. MALGARINI P. MARGANI	Psychology, consumer sentiment and household expenditures: a disaggregated analysis
n. 59/05	P. MARGANI R. RICCIUTI	Equivalenza Ricardiana in economia aperta: un'analisi dinamica su dati panel

Working Papers available:		
n. 60/05	M. BOSCHI A. GIRARDI	Euro Area inflation: long-run determinants and short-run dynamics
n. 61/05	M. BOVI	Book-Tax Gap. An Income Horse Race
n. 62/06	M. BOVI	The Cyclical Behavior of Shadow and Regular Employment
n. 63/06	G. BRUNO C. LUPI C. PAPPALARDO G. PIRAS	The cross-country effects of EU holidays on domestic GDP's
n. 64/06	M. COZZOLINO F. DI NICOLA M. RAITANO	Il futuro dei fondi pensione: opportunità e scelte sulla destinazione del TFR
n. 65/06	S. LEPROUX M. MALGARINI	Clima di fiducia e spesa delle famiglie in Italia: un'analisi disaggregata secondo il reddito degli intervistati
n. 66/06	M. BOVI	Consumers Sentiment and Cognitive Macroeconometrics Paradoxes and Explanations
n. 67/06	G. ROCCHETTI	Modelli di business nel mercato del software e partecipazione delle imprese italiane al fenomeno open source
n. 68/06	L. CROSILLA	La stagionalità delle inchieste ISAE su imprese e consumatori: aspetti metodologici ed evidenza empirica
n. 69/06	C. OLDANI	Money demand & futures
n. 70/06	R. BASILE S. DE NARDIS A. GIRARDI	Pricing to market of italian exporting firms
n. 71/06	B.M. MARTELLI G. ROCCHETTII	The ISAE Market Services Survey: Methodological Upgrading, Survey Reliability
n. 72/06	M. FIORAMANTI	Predicting sovereign debt crises using artificial neural networks: a comparative approach
n. 73/06	S. ZECCHINI M. VENTURA	Public Credit Guarantees and SME Finance

Working Papers available:		
n. 74/06	G. FERRI M. VENTURA	Macchinari del *made in Italy* e dinamiche dei distretti industriali
n. 75/07	R. BASILE	Intra-distribution dynamics of regional per-capita income in Europe: evidence from alternative conditional density estimators
n. 76/07	M. BOVI	National Accounts, Fiscal Rules and Fiscal Policy Mind the Hidden Gaps
n. 77/07	L. CROSILLA S. LEPROUX	Leading indicators on construction and retail trade sectors based on ISAE survey data
n. 78/07	R. CERQUETI M. COSTANTINI	Non parametric Fractional Cointegration Analysis
n. 79/07	R. DE SANTIS C. VICARELLI	The “deeper” and the “wider” EU strategies of trade integration
n. 80/07	S. de NARDIS R. DE SANTIS C. VICARELLI	The Euro’s Effects on Trade in a Dynamic Setting
n. 81/07	M. BOVI R. DELL’ANNO	The Changing Nature of the OECD Shadow Economy
n. 82/07	C. DE LUCIA	Did the FED Inflate a Housing Price Bubble? A Cointegration Analysis between the 1980s and the 1990s
n. 83/07	T. CESARONI	Inspecting the cyclical properties of the Italian Manufacturing Business survey data
n. 84/07	M. MALGARINI	Inventories and business cycle volatility: an analysis based on ISAE survey data
n. 85/07	D. MARCHESI	The Rule Incentives that Rule Civil Justice
n. 86/07	M. COSTANTINI S. de NARDIS	Estimates of Structural Changes in the Wage Equation: Some Evidence for Italy
n. 87/07	R. BASILE M. MANTUANO	La concentrazione geografica dell’industria in Italia: 1971-2001
n. 88/07	S. de NARDIS R. DE SANTIS C. VICARELLI	The single currency’s effects on Eurozone sectoral trade: winners and losers?
n. 89/07	B.M. MARTELLI G. ROCCHETTII	Cyclical features of the ISAE business services series

Working Papers available:		
n. 90/08	M. MALGARINI	Quantitative inflation perceptions and expectations of Italian Consumers
n. 91/08	P. L. SCANDIZZO M. VENTURA	Contingent valuation of natural resources: a case study for Sicily
n. 92/08	F. FULLONE B.M. MARTELLI	Re-thinking the ISAE Consumer Survey Processing Procedure
n. 93/08	M. BOVI P. CLAEYS	Treasury v dodgers. A tale of fiscal consolidation and tax evasion
n. 94/08	R. DI BIASE	Aliquote di imposta sul lavoro dipendente: analisi per figure tipo e con dati campionari
n. 95/08	M. BOVI	The "Psycho-analysis" of Common People's Forecast Errors. Evidence from European Consumer Surveys
n. 96/08	F. BUSATO A. GIRARDI A. ARGENTIERO	Technology and non-technology shocks in a two-sector economy
n. 97/08	A. GIRARDI	The Informational Content of Trades on the EuroMTS Platform
n. 98/08	G. BRUNO	Forecasting Using Functional Coefficients Autoregressive Models
n. 99/08	A. MAJOCCHI A. ZATTI	Land Use, Congestion and Urban Management
n. 100/08	A. MAJOCCHI	Theories of Fiscal Federalism and the European Experience
n. 101/08	S. de NARDIS C. PAPPALARDO C. VICARELLI	The Euro adoption's impact on extensive and intensive margins of trade: the Italian case
n. 102/08	A. GIRARDI P.PAESANI	Structural Reforms and Fiscal Discipline in Europe