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A ranking of the value of patents granted by legal protection

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Abstract

This paper aims at ranking the value of legal patent protection among countries, 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. 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 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.

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1. Introduction

On the one hand, human capital accumulation is a crucial ingredient of economic growth, but on the other hand its measurement still remains problematic. In economic literature two indictors of innovative activity have been widely used: R&D and patent counts. Nevertheless, the former is more clearly related to inputs into the innovative process rather than to the successful outputs (Lanjouw et al. 1998), while the latter are very imprecise measures of innovative output, basically because most of the granted patents are worthless, giving rise to a skewed distribution of their true value (Lanjouw 1998, Lanjouw et al. 1998, Shankerman 1998, Van Zeebroeck 2008). In spite of this difficulty, it has been shown by several authors that patents play a crucial role in providing incentives to R&D (Shankerman 1998, Arora, Ceccagnoli 2006, Arora, Ceccagnoli, Cohen 2003 among others), therefore valuing patents becomes a crucial step in valuing innovation process output.

To formulate good public policies 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. Since patent counts are not a reliable indicator, some alternative methodologies have been developed to value patents and, roughly speaking, these can be classified as direct and indirect. In the former case, data is drawn from surveys, in which 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 as having an option, they are not obliged to apply for, or to renew, a patent, but they make this decision only when it is economically feasible.

Unfortunately, both datasets, micro data and renewal data, are not always available and they are not collected by every country.

The purpose of this paper is to rank the value of patents granted by legal protection in spite of the problem of lack of data. This task is accomplished moving from a micro to a macro perspective, still remaining in the real options paradigm. Following this idea, we rank the value of patent legal 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. This result is useful in terms of policy-making because it allows policy makers to have an idea of the effectiveness of the efforts made to protect intellectual property and to foster innovation activity

The remainder of this paper is organized as follows. Section 2 briefly reviews the real option models applied to patents. Section 3 puts forward an econometric strategy to rank the effectiveness of IP protection in a panel of countries and describes the dataset. Section 4 shows the empirical results and the robustness of the results obtained. Finally, section 5 summarizes the results.

2. Review of real options literature applied to patents.

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[1] 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

$$C(S)=A_1 S^{\beta_1} \quad (1)$$

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. The next paragraph is devoted to overcome this problem using macro data, 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:

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

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

$$C_{i,t} = \alpha + \beta_1 S_{i,t} + \beta_2 \tau_{i,t} + \beta_3 r_{i,t} + \beta_4 \sigma_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \quad (6)$$

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

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[1] 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).

Equation (6) 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 (6) to macro data. This step could be very interesting for ranking 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 FE $\mu_{i,t}$ represent?

The value of a patent can be defined as the income obtained by the owner with respect to the situation without patent, namely, the income 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 by real options theory and validated by Wu and Tseng (2006). 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 FE $\mu_{i,t}$ of a macro version of equation (6).

It follows that estimating a macro version of (6) and retrieving the 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[2], not easily replicable because of the high cost of implementation. Therefore, this technique allows us to overcome the annoying problem of lack of data, without giving up this important and useful task.

As a good proxy for C(.) 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 I reports the analogy between the micro approach to patents as real options followed by Wu, Tseng and the macro approach followed in this paper

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[2] 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).

Table I. 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. Descriptive stats of the data are reported in Table AI in the appendix, while the estimate applied on seventeen countries for the time period 1977-2003 is reported in Table AII.

4. Empirical results

By retrieving the FE of the estimate it is possible to rank the legal component of patents value for those counties 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. Firstly, panel dataset generally provide an increased number of data points, generate additional degrees of freedom, and reduces the collinearity among explanatory variables. Secondly, FE 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. Of course, the analysis presented in the paper suffers from some limitations that can possibly be overcome in further research. 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.

The FE 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 II reports the index based on the FE estimate[3] in Table AII.

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

Table II. Index of patent legal protection value (*)

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

(*) 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.

In column 3 the seventeen countries have been gathered into four groups according to the results of the Wald tests on the FE. 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.

A recent study elaborated on behalf of the EU Commission[4] evaluates through a survey the value of patents in eight countries, seven of which are included in our estimates. Table III presents a clear comparison between the ranking stemming from the application of the two methodologies.

Table III. Comparison between I_v and a ranking based on survey data

Country	I_v	Ranking Report EU(+)
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%
(+) The report repeats the estimates over three time periods.
In this column the average rank over the three periods is reported.

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[5] 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[6] (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[7]. However, since the PR is a composite index given by the sum of other five indices, where enforcement is only one of the five, it is reasonable to expect a weaker correlation between I_v and the World Bank enforcement index.

[4] 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.

[5] 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

[6] 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.

[7] 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.

Table IV. 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$^{(+)}$	Rank-correlation between I_v and the index of enforcement$^{(++)}$
0.52**	0.38*

* significant at 10%; ** significant at 5%; *** significant at 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.
(++) 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.
Source: based on Ginarte, Park (1997) and World Bank, Doing Business in 2006.

The results reported in Table IV 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%. At this point one question is worth clarifying. It is sensible to wonder whether I_v is capturing a more general effect, namely the quality of the legal system, rather than patents only. We know that by virtue of international agreements patents share the same law throughout the world and this is particularly true for the European countries that even share the same patent office. This helps us in restricting the effect captured by the indicator[8].

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.

5. Concluding remarks

This paper moves a step ahead in the difficult task of measuring the value of innovative output. In particular, relying on 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.

In this direction, further research can take explicitly into account the different technological specialization of countries, because the technological content of patents may affect the value of patents regardless of protection granted by law.

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 economic growth through innovation activity.

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[8] A check has been carried out by correlating I_v to the World Bank rule of law index, finding no significant correlation. Proof can be given to the interested reader upon request. The authors are grateful to an anonymous referee for having raised this point.

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APPENDIX

Table AI: Descriptive stats of the data.
Mean and standard deviation in parenthesis. 1977-2003

Country	sigma	triadic	count	Interest
At	1.298 (0.602)	154.115 (70.437)	663.685 (338.351)	6.246 (1.511)
Bg	1.934 (1.021)	204.052 (112.458)	673.267 (395.644)	8.371 (2.738)
Cn	1.166 (0.610)	263.219 (141.907)	741.682 (540.716)	8.920 (2.782)
Dk	1.331 (0.905)	106.211 (64.753)	423.144 (294.393)	7.452 (2.241)
Fin	1.419 (0.697)	156.004 (134.757)	556.204 (481.825)	8.024 (3.136)
Fra	9.478 (8.493)	1425.670 (589.753)	4608.641 (1963.483)	9.044 (3.565)
Ger	0.745 (0.532)	3584.548 (1459.273)	12226.660 (5963.468)	6.736 (1.524)
Irl	1.630 (0.730)	21.135 (13.581)	88.756 (75.539)	9.934 (4.003)
It	1.028 (0.577)	449.578 (224.010)	2134.911 (1259.157)	9.222 (3.491)
Jap	1.004 (1.005)	6930.489 (3592.582	10656.960 (6294.461	3.331 (1.973)

		)	)	
Nl	0.895 (0.462)	544.511 (235.066)	1700.489 (1014.476)	7.161 (1.884)
Nor	1.873 (1.913)	47.596 (29.077)	184.426 (118.903)	8.564 (2.967)
Es	1.189 (0.882)	54.185 (34.885)	339.544 (297.486)	10.780 (4.286)
Sve	1.526 (0.603)	399.004 (217.131)	1204.744 (630.038)	8.317 (2.879)
Ch	0.527 (0.311)	603.422 (220.640)	1694.807 (641.388)	4.311 (1.023)
Uk	0.837 (0.675)	1125.496 (466.829)	3606.744 (1381.717)	9.327 (3.012)
Us	1.387 (1.017)	8686.726 (3770.919)	17104.660 (9127.529)	8.057 (2.623)
All	1.727 (2.973)	1459.366 (2810.340)	3447.607 (5766.728)	8.000 (3.318)

Source: Datastream for sigma, OECD for interest rate, triadic and count patents.

Table AII: FE estimate of equation (6) 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 (6). 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.

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