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JEL Classifications: O30, O38.

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A Policy Insight into the R&D-Patent Relationship*

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Abstract

Contrary to an accepted wisdom, this paper shows that cross-country variations in the number of patents per researcher do not only reflect differences in the propensity to patent but also signals differences in research productivity. We put forward and test an empirical model that formally accounts for the productivity and the propensity component of the R&D-patent relationship. The two components play an important role, as witnessed by the impact of several policies, including education, intellectual property and science and technology policies. Indicators based on domestic priority filings reflect research efforts and are primarily affected by varying propensities to patent. In contrast, international filings, especially triadic patents, rather capture variations in research productivity.

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1 Introduction

"*Please raise your hand if you think that patent counts reflect innovation performance*". When the 'provocateur' of the EUPACO conference held in Brussels in May 2007 asked the question, no one raised his hand.[1] Among the audience were respected scholars, senior managers from large and small innovative companies and representatives from the European Commission and national patent offices. Except for a few silent voices, there seemed to be a consensus position that patents are not an indicator of research productivity, or that the number of patents per R&D expenditure would not indicate differences in innovation performances. This silence was somewhat in line with the scholars who have for long implicitly or explicitly argued that patent counts reflect more variations in the propensity to patent than variations in innovative performance (*e.g.* Scherer (1983)). This silence further induced serious doubts on the relevance of the numerous patent-based indicators published by several institutions.[2]

Despite this wide scepticism, it could be argued that patent counts can also be taken as indicators of research productivity. Indeed, the fact remains that variation in the patent to R&D ratio may come either from different levels of research productivity or different patent practices, or both. Understanding variations in patenting performances across countries would therefore require to understand the factors that affect research productivity and those that affect the propensity to patent.

The objective of this paper is precisely to provide a better understanding of the relationship between R&D and patents at the country-level. The main contribution to the literature is threefold. First, the paper puts forward an empirical model that explicitly distinguishes the factors affecting the productivity of researchers from the factors affecting the propensity to patent. Second, the impact of three broad policies on research productivity and on patent propensity is estimated. The policy tools include education policies, science and technology (S&T) policies and intellectual property (IP) policies. Third, the paper comments and tests the relevance of several types of patent indicators, including priority filings at national patent offices, a corrected count of priority filings, EPO, USPTO and triadic filings. In this respect, this paper is one of the first to explicitly analyze the determinants of the national demand for patents.[3] The analysis is performed on 34 countries in 2003.

The empirical results suggest that the number of patents per researcher depends on a productivity component and a propensity component, which in turn are influenced by the design of several policies, namely education, IP and S&T policies. Contrary to a widely accepted wisdom, the productivity of research also matters and is affected in particular by education and research policies.

[1]EUPACO, the European Patent Conference: Towards a new European patent system, Brussels, 15 and 16 May 2007.

[2]Examples can be found in the IMD World Competitiveness Yearbook (2006), in Eurostat (2007b), p. 79. or in the Economist Intelligence Unit, The Economist (May 17th 2007).

[3]Indeed, most existing studies proxy a country's number of patent filings by looking at the number of patents that were filed in the United States Patent and Trademark Office (USPTO) or the European Patent Office (EPO).

Regarding the factors that affect the propensity to patent, the design of IP policy plays an important role. In particular, filing fees, patent coverage, and enforcement mechanisms all significantly affect patenting practices and hence the number of priority filings.

Yet, the importance of the two components greatly differs according to the patent indicator that is used. National priority filings are much more impacted by the propensity component and are highly reflective of the research input. On the contrary, international filings such as those filed at the EPO or triadic patents are strongly determined by the productivity variables.

The paper is organized as follows. Section 2 relies on the existing literature to identify the factors that may affect research productivity or patent practices. Section 3 introduces the empirical model and the variables, and sets the hypotheses that are to be tested empirically. Section 4 is devoted to the interpretation of econometric results. Section 5 draws the policy implications induced by the findings and concludes.

2 Propensity to patent vs. research productivity

Since researchers' output is generally neither tangible nor systematically codified, measuring research productivity is far from being straightforward.[4] As a matter of fact there is no widely accepted direct measure of innovative performance. A first stream of literature has rather focused on the ultimate impact of innovative activity: profitability or total factor productivity growth. This empirical methodology consists in evaluating a rate of return to business R&D (approximated with the number of researchers or total R&D expenses). Since the seminal contribution of Griliches (1979) this approach has flourished and is still extensively used. It however drastically simplifies the innovation process as one parameter, the elasticity of total factor productivity with respect to research efforts or the estimated return to business R&D, summarizes the relationship between innovative inputs on the one hand and the profitability or productivity of the firm on the other.[5] The convenience of this approach, and its implicit drawback, is that it does not rely on a direct measure of innovative output.

The need to find a more direct metric of innovative performance appears in a more recent stream of literature. Some authors have relied on innovation surveys to measure the share of output which is due to new or improved products or processes (see in particular Brouwer and Kleinknecht (1999)). Others have

[4] A technological advance performed in a firm is generally subject to a strategic mix between patenting, secrecy and publication, not to mention the commercial exploitation strategies (cf. Teece (1986)).

[5] See for instance, at the microeconomic level, the analyses performed by Cincera (1997), Griliches and Mairesse (1984), Hall and Mairesse (1995); at the industry level the papers of Griliches and Lichtenberg (1984), Odagiri (1985), Goto and Suzuki (1989), and van Pottelsberghe (1997); and at the macroeconomic level the studies of Mohnen and Nadiri (1985), Nadiri and Kim (1996) and Guellec and van Pottelsberghe (2004).

relied on patent-based metrics, which are however more frequently used as an indicator of propensity to patent than as a measure of research productivity. The fact remains that the R&D-patents relationship is potentially affected by both dimensions: research efforts lead to inventions through a productivity effect and inventions lead to patents through a propensity to patent effect. Disentangling the two components relying on research efforts as input into the invention production function and the number of patents as an output is therefore subject to some empirical complexity. The confusion is more apparent in the microeconomic literature, where the two dimensions are investigated separately, in studies implicitly relying more on one dimension or the other.

On the one hand, a large number of studies consider the number of patents as an indicator of the propensity to patent. This strategic patenting literature intensified since the mid-nineties, when the surge in patenting was observed in major patent offices worldwide. Various investigations were made in order to better understand heterogeneity in patent practices (e.g., Mansfield (1986); Arundel and Kabla (1998); Brouwer and Kleinknecht (1999); and Kortum and Lerner (1999)).[6] This literature probably originated with Scherer (1983), who explicitly assumes a constant productivity of researchers, for the sake of simplicity. While admitting a potential "*differential creativity of an organization's R&D scientists and engineers*", Scherer does not consider it important and chooses to concentrate on other "*more systematic*" factors (p. 116).

On the other hand, only a few studies emphasize that patents can be an indicator of research productivity. For instance, Cohen and Klepper (1996) observe that R&D productivity (measured with the number of patents) declines with the size of the firm. Lanjouw and Schankerman (2004) show that research productivity measures based on patent counts are inversely related to the average patent quality. Nevertheless, these articles are very cautious in justifying the use of patents as a metric for productivity. At the macroeconomic level, Furman et al. (2002), in an attempt to explain the foreign demand for patents in the US, introduce the concept of "*national innovative capacity*". They report a significant positive impact of investment in education and training on a nation's innovativeness, a dimension that might typically reflect a productivity effect.

Even if the vast majority of empirical investigations implicitly or explicitly assume that patent counts rather indicate variations in propensity to patent, there is no convincing evidence that rejects the idea that patents may also reflect research productivity. This is due to the pervasive nature of inventions and hence the lack of a reliable measure of inventiveness. The objective of the present paper is to test at the macroeconomic level the extent to which patent counts may reflect at the same time a varying propensity to patent and a varying research productivity. One way to test these apparently conflicting hypotheses is to test whether the factors that are known to affect the propensity to patent and these that are known to affect the research productivity actually correlate

[6] The terms propensity to patent and patent practices are used interchangeably throughout the paper.

with cross-country variations in the number of patents per researcher. Section 2.1 and section 2.2 summarize the existing literatures on the policies that may affect the two dimensions. These findings are used to set the hypotheses formally introduced in section 3.

2.1 The determinants of the propensity to patent

The determinants of the propensity to patent can be grouped into two categories: the design of the patent system and the type of research performed.

The microeconomic and the managerial literatures emphasize patent strategies as being one of the most important causes underlying the sharp increase in observed patenting performance. Some examples of microeconomic investigations aiming at understanding the impact of patenting strategies on patent filings are provided by Cohen et al. (2000), Arundel (2001), Peeters and van Pottelsberghe (2006), Blind et al. (2006).[7] Patenting strategies are more difficult to measure at the aggregate level (industry or country levels) but can be indirectly assessed through the institutional context that leads to the occurrence of specific strategies. Indeed, Encaoua et al. (2006) argue that "*the boom in patent applications* [is concomitant with] *a general sentiment of a relaxation of patentability requirements* [...] *in certain jurisdictions*" (p. 1430).

One striking example of the influence of the institutional context on patent practices is related to patentable subject matters. Not all technologies can be patented in Europe (e.g. software as such and gene related inventions are not within the patentable subject matters), whereas a large spectrum is allowed in the United States, referring to the often quoted sentence that "*anything under the sun made by man*" may be patented in the US.[8] One would therefore expect relatively more patent filings in a country with a large spectrum of subject matters. Other features of the IP system may encourage or discourage patent filings, such as filing fees or legal enforcement mechanisms. For example, de Rassenfosse and van Pottelsberghe (2007, 2008) find a negative and significant impact of patenting fees on the demand for patents for the member states of the European Patent Convention. The results of Varsakelis (2001), which show that the level of patent protection has a positive influence on R&D investments across countries, support the idea that the legal environment may affect the patenting behaviour as well. Other institutionalized incentives such as the Bayh-Dole Act regarding academic patenting in the United States or the German Employees' Inventions Act may also explain differences in patenting behaviour across countries.[9]

Besides this 'IP policy design' context, S&T policies may also play an important role through the type of institution performing the research (public

[7] An exhaustive list of the most widely used patenting strategies is provided in Guellec et al. (2007).

[8] United States Supreme Court case, Diamond vs. Chakrabarty, 447 U.S. 303 (1980).

[9] For instance, the German Employees' Inventions Act (1957) forces German employers to file a national patent application for inventions made by their researchers. If an employer does not claim the invention, the inventor can file the application in his own name. See Harhoff and Hoisl (2007).

research vs. private research) or the type of research (basic research vs. applied research). The evidence on the role played by the institutional settings, the source of funding and the type of R&D is quite scarce and rarely comprehensive. One can however logically assume that these characteristics may influence the propensity to patent. For instance, public (or basic) research aims more at publications than at the effective use of patented inventions, as opposed to business (or more applied) R&D. In this respect, Peeters and van Pottelsberghe (2006) show that the factors influencing the size of a company's patent portfolio is closely related to its innovation strategy (i.e. the extent to which the firm enters into collaborative R&D with universities, the share of basic research, and a focus on product innovations instead of process innovations).

2.2 The determinants of research productivity

The main determinants of research productivity may be related to education policies and S&T policies.

The importance of education policies for economic growth is well documented in the economic literature. Empirical evidence is provided by Barro (2001), Griliches (1997), Krueger and Lindahl (2001) and Temple (2001). For example, Griliches (1997) suggests that the changing education level in the United States has accounted for a "*significant proportion of overall productivity growth*". Engelbrecht (1997) validates this idea with an empirical analysis that covers OECD countries over a 20 years period. The author shows that human capital affects total factor productivity growth directly as a factor of production, and as a vehicle for international knowledge transfer. One may therefore logically expect that a higher level of education in a country would lead to a higher productivity of research activities, through a stronger creativity, better skills or improved absorptive capability of new knowledge.

The design of science and technology (S&T) policies may also affect the productivity of research, as suggested by the results of Guellec and van Pottelsberghe (2004). The authors show that the institutional settings (e.g. research performed by the business sector or by public research labs), the origin of funding (subsidies vs. privately funded), the absorptive capability and the type of research that is performed are four factors which strongly influence the extent to which R&D expenses contribute to productivity growth. Since the seminal contribution of Cohen and Levinthal (1989), the absorptive capabilities associated with research activities have increasingly been validated empirically (recently Griffith et al. (2004)).

At the microeconomic level, there is so far little evidence on the determinants of researchers' patent-productivity. This emerging field carries contradictory findings on the link between education and scientific productivity. For instance, while Hoisl (2007) finds no impact of education levels on scientific productivity, Mariani and Romanelli (2006) find that inventors' level of education positively affect their quantity of patents produced, using a similar dataset. This productivity effect being measured in terms of the number of patents, it is subject to a cautious interpretation induced by the very motivations of the present paper.

3 Empirical implementation

3.1 The model

The objective is to estimate the parameters of a patent production function at the macroeconomic level and differentiating between a *propensity* and a *productivity* effect.

The number of employees L_r devoted to the 'idea-production sector' is assumed to be the main driver of inventions (the number of researchers is taken as a raw measure of research efforts) as in the following patent production function:

$$\dot{P}_i = \delta L_{r_i}^{\lambda}, \tag{1}$$

where $\dot{P}_i$ is the observed number of patents, λ is the productivity of researchers and δ captures the propensity to patent.[10] Letting ln denote the natural logarithm, the 'constrained' patent production function (1) to estimate empirically can be written as follows:

$$\ln \dot{P}_i = \ln \delta + \lambda \ln L_{r_i} + \varepsilon_i, \tag{2}$$

where i (=1, ..., 34) indicates the countries. The hypothesis of fixed patent practices implies that $\ln \delta$ is a constant and the hypothesis of fixed productivity of research implies that λ is constant across countries. ε_i is the error term.

Allowing the propensity to patent to vary across countries would affect the parameter δ_i as follows:

$$\delta_i = \delta_c \prod_n X_{n_i}^{\delta_n}. \tag{3}$$

It is supposed to be a function of a fixed component (δ_c) similar for all countries (i.e. the average level of propensity to patent) and a component that varies across countries according to several factors X_n. Equation (2) becomes:

$$\ln \dot{P}_i = \ln \delta_c + \sum_n \delta_n \ln X_{n_i} + \lambda \ln L_{r_i} + \varepsilon_i. \tag{4}$$

An alternative model allows for an heterogenous productivity of research but a constant propensity to patent. The productivity of researchers λ_i is composed of a fixed component λ_c (i.e. the minimum productivity level of researchers, common across countries) and a component that varies according to a set of variable Y_m potentially affecting the productivity of researchers (such as the level of education):

[10] The model used in this paper to explain patenting performances is inspired by the knowledge production function of the technology-driven growth models developed by Romer (1990) and Jones (1995) but differs in two ways: i) the productivity of researchers λ is allowed to vary; ii) the available stock of knowledge is not supposed to have a direct impact on the knowledge produced: if it has to have an impact, it would rather be by influencing the productivity of researchers (researchers are supposed to be more productive the larger the stock of knowledge on which to build).

$$\lambda_i = \lambda_c + \sum_m \lambda_m Y_{m_i}. \tag{5}$$

The productivity variables are multiplied by the number of researchers in order to interpret the parameters in productivity terms, that is how much each variable adds to the average productivity of researchers. It is not an interaction term and should therefore not be interpreted this way. When the hypothesis of constant productivity is relaxed, equation (2) can be written as follows:

$$\ln \dot{P}_i = \ln \delta + \lambda_c \ln L_{r_i} + \sum_m \lambda_m \ln L_{r_i} Y_{m_i} + \varepsilon_i. \tag{6}$$

Equation (6) allows the productivity of researchers to vary across countries, whereas equation (4) allows the propensity to file patents to vary across countries. Allowing both components to vary yields the following equation to be estimated:

$$\ln \dot{P}_i = \ln \delta_c + \sum_n \delta_n \ln X_{n_i} + \lambda_c \ln L_{r_i} + \sum_m \lambda_m \ln L_{r_i} Y_{m_i} + \varepsilon_i. \tag{7}$$

The estimations are to be performed on a sample of 34 countries for the year 2003. The countries selected are those having at least 100 domestic priority filings in 2003 (28 OECD countries, the 5 BRICS countries and Singapore).[11] Despite the relatively small sample size, this threshold allows to capture more than 95% of the national priority patent applications filed in all national patent offices in the world in 2003. A panel data approach that would consist in adding a time dimension to the empirical analysis would not be easy to implement, as important piece of information such as the past level of patenting fees or the strength of patent rights is seldom available or is very stable over time.

3.2 The dependent variables

Most of the studies investigating the determinants of patent filings at the country level rely on the number of patents filed either at the EPO or at the USPTO (see e.g. Furman et al. (2002), Bottazzi and Peri (2003), Ulku (2004), Falk (2005), and Kang and Seo (2006)). The number of patents filed by the applicants from one country is used as a proxy for the country's innovative performance. These two types of patent counts are however subject to an important source of 'home' bias: American (European) applicants have a much higher propensity to file their patents at the USPTO (EPO) than applicants from other countries. The bias might be even stronger for European applicants who generally file at their national patent office in a first stage, and then evaluate the possibility to

[11] OECD stands for Organization for Economic Cooperation and Development and is composed of the industrialized market economy countries. BRICS is a term used to refer to Brazil, Russia, India, China and South Africa. The 34 countries in the sample are presented in Appendix Table C.

extend these applications to the EPO.[12] An alternative counting methodology, much less subject to a potential home bias, would be to count the number of priority filings in each national patent office (NPF).

Companies in small countries may however file their first applications directly in large regional patent offices. This is put forward by Grupp and Schmoch (1999), who argue that the macroeconomic assignment of patents by country of national priority filings results in biases in favor of large attractive markets. It is especially the case of small economies that share a common border and a common language with larger economies. For instance Canadian or Belgian firms have a high propensity to directly file their applications at the USPTO or the EPO, respectively. In order to avoid this source of bias, a corrected count of priority filings (PF_CORR) is computed, where the number of priority patent applications filed directly at the USPTO and at the EPO is added to priority filings at the national patent office. This improved counting methodology results in noticeable difference for countries such as Belgium, Canada, the Netherlands or Switzerland, as indicated in Appendix Table D.

In the case of Germany, there were 45,637 priority filings reported at the German patent office for the year 2003 (this is the variable NPF). If the priority patent applications that German applicants filed directly at the EPO (2,180) and the USPTO (639) are included, the corrected number of German priority filings amounts to 48,456. This is the value of the variable PF_CORR for Germany. The correction represents only 6% of the total, but can be much higher for some countries. For instance, priority filings at the Swiss patent office represent merely 47% of the corrected number of patents: Swiss applicants definitely favor the European and the American route to file their patent applications.

One drawback of using the number of priority filings is that it includes many dubious or low quality patents, which might probably explain why several authors rely on USPTO or EPO data. For example, Greenhalgh and Rogers (2006) find that "*on average,* [UK] *firms that receive only UK patents tend to have no significant market premium. In direct contrast, patenting through the European Patent Office does raise market value*". Since EPO and USPTO patents are mostly second filings (except for US firms filing patents at the USPTO) they induce higher fees and translation costs. As a result, only the most valuable patents are likely to be picked out and filed at these offices. However, these filings are subject to a home bias that affects the robustness of international comparisons. One solution put forward by the OECD is to use the triadic patent families (TRIADIC). Triadic patents include only the patents that were filed simultaneously at the USPTO, the EPO and the JPO (OECD, 2004). These patents are highly valuable (they are translated and prosecuted in three different systems) and are much less affected by any potential home-bias.

[12] See Guellec and van Pottelsberghe (2007) and Stevnsborg and van Pottelsberghe (2007) for an in-depth description of the various patenting routes that can be used for international filings. de Rassenfosse and van Pottelsberghe (2007) show that relying on filings at the EPO to explain the drivers of national demand for patents may lead to misleading results as the transfer rate of national priority filings to the EPO greatly differs across countries, according to their age of EPC membership and GDP per capita.

Figure 1 illustrates the difference between the various patent counts. The regional shares are compared with the share of researchers and of R&D expenditures. It clearly appears that the series that are the closest to the number of researchers are triadic patents, closely followed by priority filings. The ratio between TRIADIC and PF_CORR is of about 1:9, suggesting that roughly one patent out of nine is associated with a value that is high enough to justify a global protection strategy.

*** Insert Figure 1 about here ***

It is clear from Figure 1 that statistics based on EPO or USPTO data suffer from quite an important home bias. The peculiarities of each patent count methodology are displayed in Table 2. The choice between statistics based on priority filings and those based on triadic families actually depends on the purpose of the measurement. If the focus is more on the total number of patents generated, including low and high quality value patents, a corrected count of priority filings is suitable. However, the fact that some of these patents are filed at the EPO and the USPTO may reduce the relationship with national IP policies such as filing fees and the strength of the domestic patent system. If the focus is on high quality patents then TRIADIC patents could be more appropriate.

*** Insert Table 2 about here ***

It is worth mentioning that the present analysis relies on the number of patent filings instead of the number of patents granted. The rationales underlying this choice are twofold: i) countries do not have the same patentability criteria and neither do they have the same grant rate (see Guellec and van Pottelsberghe (2000)) and ii) as Griliches et al. (1989) point out, patent offices go "through [their] own budgetary and inefficiency cycle" and therefore affect the observable innovation output. To the best of our knowledge, this is the first empirical analysis that relies on the number of national priority filings. The data for NPF and PF_CORR has been extracted from PatStat (April 2007 edition), a dataset generated by the EPO that includes patent data from 73 patent offices worldwide. Data on triadic patenting activity come from the OECD/MSTI database. Finally, data on EPO and USPTO patents come from the EPO's annual report 2003 (p. 72, 80 and 81) and USPTO's annual reports 2003 and 2004 (p. 112; 124-125), respectively.

Another important issue has to be tackled regarding the count of national priority filings in Japan. The US system allows a patent to be composed of three independent claims and a large number of dependent claims, whereas Japanese patents are known to be much more restrictive in scope.[13] A US patent usually protects a larger scope than its Japanese counterpart. This can be observed

[13] See Archontopoulos et al. (2007) and van Zeebroeck et al. (2006) for a thorough analysis of the number of claims per patent, their impact and their determinants.

through the average number of claims per patent in both countries: a patent filed at the USPTO had 23 claims on average in 2003 and only 7 at the JPO. As additional evidence, Dernis et al. (2001) showed that applications at the EPO based on the merger of multiple priority applications are particularly common for patents filed by Japanese and Korean applicants. To illustrate the potential importance of the measurement bias, the number of patents per researcher (NPF) in 2003 is 0.06 on average across countries (excluding Japan and Korea), with a maximum of 0.18 for Australia (the US having a ratio of 0.14), whereas the same ratio computed for Japan and Korea is of 0.50 and 0.57, respectively. This suggests that the raw number of patents filed has to be corrected somehow to be comparable across countries, as already suggested by Tong and Frame (1994) and van Pottelsberghe and François (2009). Consequently, the number of Japanese and Korean priority patent applications is divided by 3.[14] Obviously, international filings such as triadic or EPO patent applications do not need such a correction.

3.3 Explanatory variables: hypotheses & measurement

A country's research effort, the main exogenous variable (L_r), is measured with the number of full-time equivalent scientists and engineers in 2003.[15] The estimates of the constrained model (2) consists in using only L_r as explanatory variable, implicitly assuming a constant productivity of researchers across countries and a constant propensity to patent (captured by the intercept). These constraints are subsequently relaxed in equation (6) and (4), respectively. They are simultaneously estimated in equation (7). The remainder of this section is devoted to the description of the variables used in the 'productivity' model and the 'propensity' model. All variables and data sources are presented in Appendix Table A.

Heterogenous propensity to patent

The first set of hypotheses aims at explaining the extent to which patent practices, as captured by the variables X_n in equation (4), vary across countries. Two policy tools are investigated: patent policy design and S&T policy design.

Hypotheses 2.1 - The design of patent system influences patenting performances through a propensity effect

Patent policy design is measured through several indicators, capturing the cost of filing and the strength of the IP system. In the case of national first filings, the

[14]A Japanese patent is therefore considered to have virtually 21 claims instead of 7, a number of claims much closer to European or American standards.

[15]It could be argued that it would be more appropriate to count the number of researchers prior to 2003 in order to account for a potential delay. It would however make no noticeable difference as this number is relatively stable over time. Moreover, Hall et al. (1986) showed that the lag between R&D and patent filing is very short.

administrative fees (*i.e.*, fees requested by national patent offices) consist of filing, search, examination and granting fees.[16] This structure is however far from being homogenous across countries. Not every patent office performs a search and/or an examination, some incorporate the search and examination fees into the filing fees, and others consider an examination what is merely a search. In addition, some countries ask typical 'punitive' fees, especially printing fees for pages above a certain limit, and claim-based fees above a given threshold such as 20 at the USPTO and 10 at the EPO. In the present empirical investigation, these administrative fees have been added together to compute a single fee indicator (filing, search, examination and granting fees) comparable across countries (FEES).[17] The detailed methodology adopted to estimate national filing fees is reported in Appendix B and is extensively described in de Rassenfosse and van Pottelsberghe (2007). The fees are presented in Appendix Table E.

The strength of the patent system is a second aspect of the patent policy design that may affect patent practices. As described by Guellec and van Pottelsberghe (2007), every national patent system has some specificities in terms of patentability of subject matter, restrictions on patent rights, or enforcement mechanisms. The potential impact of these characteristics on the propensity to patent is tested in the model. As they constitute the legal framework that ultimately drives — or allows for — the patent practices adopted by firms.

Ginarte and Park (1997) computed an index of patent strength ranging from 0 to 5 (IPI). The maximum value corresponds to the highest level of protection of intellectual property rights. The index is composed of 5 categories, each having a maximum score of 1: the coverage of subject matters that can be patented; the mechanisms for enforcing patents rights, indicating how strongly the country enforces the law; the restrictions on the use of patents rights, measuring protection against losses of rights; membership in international patent treaties; and the length of protection from the priority date.

An additional characteristic of institutional settings taken into account in the empirical analysis is whether a country's national patent office requires substantive search and examination of the filed patents. This is measured with a dummy variable (EXAM) that takes the value of 1 if an examination service is required and 0 otherwise. The idea is to test whether a simple 'registration'

[16] A distinction has to be made between the search and the examination of a patent: the search report provides a first indication of whether the patent has a chance to be granted; it consists in searching for the most relevant prior art related to the invention and check for its 'novelty'. The examination is the process by which examiners formally investigate whether the application meets the two other conditions for the granting of a patent: *i.e*, it must have an inventive step and be industrially applicable.

[17] Besides these administrative fees, applicants also have to bear the cost of professional representation requested by patent attorneys to prepare, file and prosecute patents. These costs are however borne by applicants to various extents, as some companies have in-house resources to directly deal with patent authorities. The largest companies, which contribute also the most to the total number of patents applied for, generally recruit their own patent attorneys. Professional representation costs are not included in the present analysis because they are difficult to evaluate in an homogenous way across countries. van Pottelsberghe and François (2009) provide a recent evaluation of the various fees and filing costs (*i.e.* professional representations and translation costs) at the EPO, the USPTO and the JPO.

mechanism, with no examination, would lead the applicants to file more patents.

Hypotheses 2.2 - The type of R&D influences patenting performances through a propensity effect

Patent practices may also be affected by the broad design of science and technology policies. Indeed, policy makers may drive the type and institutional settings of R&D activities; which in turn may influence the patent practices related to new inventions.

Business R&D is generally more focused on applied research and development of products and services aiming at market potentials. One may therefore expect that a higher share of business R&D (SHBRD) would lead to more patent applications per researcher. In a similar vein, the share of basic research in total R&D activities (SHBASR) and military-oriented research (DEF_GBOARD, the share of defence-oriented research in total government budget appropriation), will also be tested. A negative impact associated with the last two variables is expected because they generally lead to innovative output that are not easy to appropriate (i.e. scientific discoveries or inventions performed through defence-related contracts, for which the IP belongs to the fund-provider).

Note that countries' technological specialization may also explain differences in patenting performances. To control for this effect, variables capturing the specialization in several high-technology industries are used. The share of sectorial business R&D expenses as a percentage of total business R&D is computed for five industries: aerospace (AERO), electronic (ELEC), office machinery and computer (COMPU), pharmaceutical (PHARMA), and instrument (INSTRU).

Heterogenous productivity of researchers

Equation (6) allows the productivity of researchers to vary across countries, by introducing several indicators (Y_m) that would potentially reflect or induce differences in the productivity of research activities. Two types of hypotheses are to be tested in this respect. They are related to the 'quality' of researchers and characteristics of the research they perform.

Hypotheses 1.1 - The design of education policy influences patenting performances through a productivity effect

In order to test the hypothesis that the productivity of researchers may be improved through an appropriate education policy, the human capital index (HKI) developed by the United Nations can be used. It fluctuates between 0 and 1 according to the level of education of a country's population: the more 'educated' the country, the more productive the research efforts are expected to be.[18]

[18]The human capital index is calculated from the literacy rate, secondary enrolments and tertiary enrolments rates. It does not directly approximates the educational background of researchers, but it seems reasonable to assume that the more educated the country, the more

Hypotheses 1.2 - The design of science and technology policies influences patenting performances through a productivity effect

The other characteristics that may potentially affect the productivity of researchers are related to the institutional setting and the type of research that is performed. It may be argued that the research performed in the business sector is more productive than the research performed in public institutions, due to more stringent managerial practices for instance. This hypothesis is tested by introducing the share of researchers working in the business sector (SHBRES). To take into account the resources available to inventors (may it reflect higher wages, a better quality of the working environment, or more available resources and infrastructure), the total expenditures on R&D per researcher (GERD_RES, expressed in US PPPs) is used. Descriptive statistics of all the variables are reported in Table 3.

*** Insert Table 3 about here ***

The number of priority filings applied for is compared to the research efforts in figure 2. The graph outlines a positive relation between the number of full-time equivalent researchers and the number of priority filings. This positive relationship suggests that considering the number of researchers as a raw measure of the research input across countries is a fair assumption. It however also displays a substantial heterogeneity. The next section investigates to what extent differences in the propensity to patent and in research productivity may explain these cross-country variations.

*** Insert Figure 2 about here ***

4 Empirical results

The econometric analysis aims at testing the two broad sets of hypotheses described in the previous section: that the R&D-patent relationship is composed of a productivity component and a propensity component, which in turn are shaped by the design of several policy tools. The determinants of research productivity are grouped into the design of education and S&T policies and the determinants of the propensity to patent are grouped into the design of IP and S&T policies. Note that various samples are available for the estimates. While the full sample is composed of 34 countries, data is missing for some countries,

educated the researchers are. Unfortunately, data on the education level of researchers is not available for a large sample. This information is only available for 6 countries in the final report of the PatVal EU project (cfr. http://ec.europa.eu/invest-in-research/policy/ipr_en.htm). For those countries, the share of inventors with tertiary education and Ph.D. degrees is significantly correlated with the variable HKI (correlation coefficient of about 0.43).

leading occasionally to smaller samples. The detailed samples are described in Appendix Table C.

The empirical approach that has been adopted is first to estimate the propensity model and the productivity model independently, with the most appropriate dependent variable. For the propensity model the dependent variable is the number of priority filings (NPF) and for the productivity model it is the number of triadic patents (TRIADIC). From these two models, the most significant explanatory variables have been selected to estimate a mixed model that simultaneously account for propensity and productivity determinants. This mixed model is estimated with five alternative dependent variables: NPF, PF_CORR, TRIADIC, EPO, and USPTO counts.

Table 4 presents the estimated parameters of equation (4), which allows the propensity to patent to vary across countries. Columns (1) to (3) focus on the role of patent policy design and columns (4) to (6) on S&T policy design. In this set of regressions the dependent variable is the log of the number of national priority filings (NPF).

*** Insert Table 4 about here ***

Fees have a negative and significant impact on the number of patent filings, with an elasticity ranging from -0.3 to -0.5, which validates earlier results obtained by de Rassenfosse and van Pottelsberghe (2007) for the member states of the European Patent Convention (EPC) and de Rassenfosse and van Pottelsberghe (2008) for the JPO, the USPTO and the EPO. The price-elasticity of the demand for patents is inelastic: an increase of 10% in the cumulated administrative fees would result in a drop of about 4% in the number of first filings. Column (2) of Table 4 presents the results with a dummy variable taking the value of 1 if the patent office requires a substantive search and examination. The non significant parameter suggests that this criterion does not influence the number of priority filings in a country.[19] The role of the strength of the patent system is investigated in column (3). The aggregated index of IP protection (IPI) has a positive and significant impact on the number of filings, meaning that a stronger IP system leads to more patent filings. Every component of the IP index was also tested separately but results were not reported. The conclusion holds for each component taken individually: the coverage in terms of patentable subject matters, the enforcement mechanisms and the (lack of) restrictions on patent rights all significantly contribute to a stronger demand for patents. A cautious interpretation is nevertheless required as a reverse causality may drive the relationship between the level of IP protection and the number of filings: the higher the number of filings, the more likely a stronger system is

[19] A potential bias may arise if one considers that requesting an examination induces higher fees. When an interaction variable is introduced (FEES and FEES x EXAM in the same regression), the interaction parameter is not significant, confirming that there is no impact. It is however important to keep in mind that the average fees asked by the offices requesting an examination is of 1,300 US PPP whereas it is of 550 US PPP for those which do not request an examination.

to be put in place through business lobby and greater government awareness. This argument finds some support in Lerner (2002), who argues that wealthier nations are more likely to have stronger patent systems.

The subsequent columns present the estimates of the model related to the impact of the design of S&T policies on patent practices. The positive and significant parameter associated with SHBRD suggests that a higher share of business performed R&D induces more patents per researcher. The business sector being generally subject to intense competition, it logically displays a higher propensity to patent. The parameters presented in column (5) suggest that defense-oriented R&D has a negative though not significant impact on the propensity to patent. A negative impact would have been explained by the fact that procurement contracts — the most frequent funding mechanism in this field of research — generally allocate the related intellectual property to the fund providers, typically a federal agency. An additional explanation is that this type of R&D is not directly related to market opportunities. Finally, the share of basic research does not seem to affect the propensity to file a patent. Note that we do not report the results of a regression where all the potential drivers of the propensity to patent would be jointly estimated. It is already clear from Table 4 that the most significant drivers in the propensity model are the fees and the strength of the patent system.

Table 5 displays the estimations of the model that allows the productivity of researchers to vary across countries, as expressed by equation (6). The dependent variable is the number of triadic patents, which captures high value inventions. The first column reports the results of the 'constrained' model, where the number of researchers is the sole driver of patent filings. It exhibits increasing returns to scale, with an increase of 10% in the number of researchers (L_r) leading to a more than proportional increase in the number of patents filings of about 15%. This elasticity is an approximation of the average 'patent productivity' of researchers. In column (1), cross-country differences in the number of patent filings are exclusively explained by differences in the number of researchers.

*** Insert Table 5 about here ***

The role of education policies is presented in column (2). The estimated parameters suggest that the productivity of researchers has a fixed component (λ_c) of 0.87 and a component that varies according to the quality of the human capital. This parameter is positive and significant, meaning that a higher level of education translates into more productive researchers.[20] The role of the characteristics of R&D on the productivity of researchers is assessed in columns (3) and (4). The level of expenditures per researcher has a positive and significant impact, which suggests that more expenses per researcher leads to a higher productivity. Two explanations can be put forward: i) more R&D expenses per

[20] As an alternative measure of the quality of the education, the mean score on a standardized math test from OECD's PISA survey was also used and lead to similar results.

researcher may witness higher wages, and hence a higher potential productivity if incentive systems are at work; and ii) the additional expenses per researcher would also indicate more resources available in terms of working environment (intermediate products and equipment in a more capital intensive research environment) and hence a higher productivity. Column (4) provides an insight into the impact of the share of business researchers in total researchers. The countries in which the research activities are performed more by the business sector (as opposed to the research performed by public labs or universities) display a higher number of patents per researcher. Column (5) reports the joint impact of the various determinants and confirms the importance of the three 'productivity' variables. It is worth noting that the share of variance explained is nearly twice as high with the estimates presented in column (5) than with the estimates presented in column (1). The introduction of education and S&T indicators drastically improves the adjusted R-squared. It reflects the fact that the count of triadic filings carries more information than just the research input.

*** Insert Table 6 about here ***

Table 6 presents estimations of the patent production function where the most significant variables of the propensity and the productivity models are simultaneously taken into account. The estimations are performed with the five alternative dependent variables. The number of priority filings (corrected or not) in columns (1) and (2) are not influenced by the productivity components, as opposed to international filings (TRIADIC, EPO and USPTO) which are all significantly impacted by the productivity variables. None of the variables related to the propensity model has a significant impact on the number of international filings. Relative innovation performances of countries are therefore better assessed on the basis of international filings. The impact of the home bias on international filings is illustrated in columns (3) to (5). EPC is a dummy variable taking the value of 1 if the country is a member state of the European Patent Convention. It clearly appears that the variable does not play a significant role in explaining the number of triadic filings whereas it is significantly associated with a higher number of filings at the EPO. The effect is the opposite at the USPTO, where EPC Member States exhibit a lower propensity to patent. Therefore, triadic patents appear to be the best candidate if one aims at assessing countries' innovative performances,

Table 7 summarizes the results and provides a comprehensive picture on the impact of the propensity and the productivity components of the R&D-patents relationship. The table is constructed as follows. Each dependent variable has been regressed on the number of researchers and the R-square has been reported in column (1). Columns (2) and (3) report the impact of the propensity and the productivity models, respectively. Finally, the joint impact of both the propensity and the productivity variables is summarized in column (4).[21] The

[21] See Appendix Table F for the econometric results leading to columns (2) and (3). Column (4) summarizes the results presented in Table 6.

number of priority filings is highly influenced by the number of researcher (see column 1) and by the propensity components, in particular by patenting fees and by the strength of the patent system. They are also somewhat impacted by productivity components (column 3) but the effect is not robust to the inclusion of propensity variables as illustrated in column (4). The conclusions are reversed if international filings are used: the productivity component plays a remarkable role in explaining cross-country differences, while the propensity variables play a very limited role.

*** Insert Table 7 about here ***

Several robustness tests were performed to ensure the validity of the results. As discussed in section 3.2, a potential problem of using national priority filings relates to the difference of interpretation of patent counts, especially regarding Japanese and Korean applications which have on average much less claims per patent. Therefore, the regressions having NPF or PF_CORR as dependent variable were performed on a smaller sample, in which Japanese and Korean applications have been excluded, with no substantive change in the sign or the significance of the parameters presented in Tables 4 and 6.

Another important point regards technological specialization. Since not all industries exhibit the same propensity to patent, the countries' technological specialization is very likely to affect the observed number of patent filings. The results presented in the above tables do not control for technological specialization for two reasons: i) the number of available data points would drop to 26 countries and ii) including the variables of technological specialization further reduces the degrees of freedom. As a robustness test, the regressions of Table 6 were performed controlling for technological specializations (in aerospace, electronics, computers, pharmaceutical and instruments) and the above conclusions remain similar.[22] Industry effects were found for aerospace (-), electronics (+) and pharmaceutical (+).

5 Concluding remarks

The objective of this paper was to better understand the relationship between research efforts and patent filings at the country level. Using the number of researchers as the raw measure of research efforts, a model of patenting performance is put forward, which explicitly allows the productivity of researchers and the propensity to patent to vary across countries. Contrary to an accepted wisdom, we argue that variations in the number of patents per researcher would not only reflect differences in the propensity to patent but would also signal differences in the productivity of researchers.

The empirical analysis is performed with a sample of 34 countries and relies

[22]Technological specialization is defined as the share of business R&D expenses in the specific industry. The data come from the OECD MSTI database.

on 5 different dependent variables: i) the number of priority filings at national patent offices, ii) a corrected number of priority filings, including first filings at the EPO and at the USPTO, iii) the number of triadic filings, iv) the number of (priority and second) filings at the EPO and v) at the USPTO. The results suggest that both the propensity to patent and the research productivity play an important role in explaining cross-country variations in the number of patents per researcher. These dimensions are in turn heavily influenced by the design of several policy tools, including education, intellectual property (IP) and science and technologies (S&T) policies. However, the role of these policy components depend on the patent indicator that is used.

A better quality of education is a factor that substantially improves researchers' productivity in a country, and hence their observed patenting performance. The positive impact of the human capital index confirms the important role played by education policies in generating high quality researchers and improving their productivity. S&T policies also come into play: the higher the share of business R&D and the more resources are allocated to researchers, the more productive the research efforts will be.

Regarding the propensity to patent, the design of IP systems matters. Several dimensions of a patent system, including the number of patentable subject matters, restrictions, enforcement mechanisms, and especially its fees, all affect a country's patenting performance. Whereas the strength of a patent system induces a higher propensity to patent, its fees have a negative and significant impact.

Yet, these findings are greatly subject to the dependent variable that is used. Priority filings are very much in line with the research efforts and cross-country variations in the patents per researcher ratio are essentially impacted by the propensity component. On the other hand, international filings such as EPO or USPTO, but especially triadic filings are heavily determined by the productivity of researchers.

Three policy implications may be drawn from the present results. First, the simultaneous impact of several policy tools (IP, S&T and education policies) calls for a more coordinated approach, especially between the policies that directly influence the researchers' productivity and their propensity to patent. Second, the negative and highly significant impact of fees suggests that the demand for patents is partly influenced by their price. Against the current background of high numbers of applications and the resulting backlogs at the main patent offices, the results suggest that national patent offices might use fees as a policy leverage. Such a move would need to think about a potential lowering of fees for SMEs as it exists in the US and other countries. Finally, even though priority filings are appealing for obvious reasons — and the wider diffusion of the Patstat database may contribute to their popularity — they are highly influenced by the propensity component. In this respect, the triadic patent statistics produced by the OECD remain the least biased indicator of innovation performances, at least regarding international comparison. Policy makers should look more closely at this readily available source of information.

The results presented here must be taken with some caution, as they are drawn from a cross-sectional analysis on a relatively small sample. A panel data analysis would have provided some supplementary insights and a higher degree of freedom but major determinants such as the IP index, patenting fees or the human capital are too stable over time to provide a sufficient level of heterogeneity. Nevertheless, we believe that the exercise leads to a new perspective on the relationship between R&D efforts and patents, which clearly calls for further empirical validation at the microeconomic and sectorial level. Indeed, innovation strategies and patent strategies are generally firm specific and it would be interesting to confirm the role played by the design of education, S&T and IP policies in this respect. As far as a macroeconomic approach is concerned, our results suggest that patent indicators, if appropriately used and measured, 'also' reflect the research productivity of countries. This result comes particularly handy at a time when the significance of patents as indicators of inventive output is frequently challenged.

References

Archontopoulos, E., Guellec, D., Stevnsborg, N., van Pottelseberghe de la Potterie, B., van Zeebroeck, N., 2007. When small is beautiful: Measuring the evolution and consequence of the voluminosity of patent applications at EPO. Information Economics and Policy, 19(2), 103-132.

Arundel, A., 2001. The relative effectiveness of patents and secrecy for appropriation. Research Policy, 30(4), 611-624.

Arundel, A., Kabla, I., 1998. What percentage of innovations are patented? Empirical estimates for European firms. Research Policy, 27(22), 127-141.

Barro, R., 2001. Human capital and growth. The American Economic Review, 91(2), 12-17.

Blind, K., Edler, J., Frietsch, R., Schmoch, U., 2006. Motives to patent: Empirical evidence from Germany. Research Policy, 35(5), 655-672.

Bottazzi, L., Peri, G., 2003. Innovation and spillovers in regions: Evidence from European patent data. European Economic Review, 47(7), 687-710.

Brouwer, E., Kleinknecht, A., 1999. Innovative output, and a firm's propensity to patent. An exploration of CIS micro data. Research Policy, 28, 615-624.

Cincera, M., 1997. Patents, R&D, and technological spillovers at the firm level: some evidence from econometric count models for panel data. Journal of Applied Econometrics, 12(3), 265-280.

Cohen, W., Levinthal, D., 1989. Innovation and learning: The two faces of R&D. Economic Journal, 99, 569-596.

Cohen, W., Klepper, S., 1996. A reprise of size and R&D. The Economic Journal, 106(437), 925-951.

Cohen, W., Nelson, R., Walsh, J., 2000. Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not). NBER Working paper 7553, Washington D.C.

de Rassenfosse, G., van Pottelsberghe de la Potterie, B., 2007. Per un pugno di dollari: a first look at the price elasticity of patents. Oxford Review of Economic Policy, 23(4), 588-604.

de Rassenfosse, G., van Pottelsberghe de la Potterie, B., 2008. On the price elasticity of demand for patents. CEPR Discussion Paper 7029.

Dernis, H., Guellec, D., van Pottelsberghe de la Potterie, B., 2001. Using patent counts for cross-country comparisons of technology output. STI Review, 27, OECD, 129-146.

The Economist, May 17th 2007. Innovation, Markets and Data, Weekly Indicators.

Engelbrecht, H-J., 1997. International R&D spillovers, human capital and productivity in OECD economies: An empirical investigation. European Economic Review, 41, 1479-1488.

Eurostat, 2007b. Science, technology and innovation in Europe, Luxembourg, Office for Official Publications of the European Communities, 139 pp.

Encaoua, D., Guellec, D., Martínez, C., 2006. Patent systems for encouraging innovation: Lessons from economic analysis. Research Policy, 35(9), 1423-1440.

Falk, M., 2005. What determines patents per capita in OECD countries? Austrian Institute of Economic Research (WIFO) Working Paper.

Furman, J., Porter, M., Stern, S., 2002. The determinants of national innovative capacity. Research Policy, 31(66), 899-933.

Ginarte, J., Park, W., 1997. Determinants of Patent Rights: A cross national study. Research Policy, 26(3), 283-301.

Goto, A., Suzuki, K., 1989. R&D capital, rate of return on R&D investment and spillover of R&D in Japanese manufacturing industries. Review of Economics and Statistics, 71(4), 555-564.

Greenhalgh, C., Rogers, M., 2006. The value of innovation: The interaction of competition, R&D and IP. Research Policy, 35(4), 562-580.

Griffith, R., Redding, S., Van Reenen, J., 2004. Mapping the two faces of R&D: Productivity growth in a panel of OECD countries. Review of Economics and Statistics, 86 (4), 883-895.

Griliches, Z., 1979. Issues in assessing the contribution of research and development to productivity growth. The Bell Journal of Economics, 10(1), 92-116.

Griliches, Z., 1997. Education, human capital and growth: A personal perspective. Journal of Labor Economics, 15(1), Part 2: Essays in Honor of Yoram Ben-Porath, S330-344.

Griliches, Z., Lichtenberg, F., 1984. Interindustry technology flows and productivity growth: a re-examination. The Review of Economics and Statistics, 66(2), 653-659.

Griliches, Z., Mairesse, J., 1984. Productivity and R&D at the firm level, In: Griliches, Z., (Ed.), "R&D, Patents and Productivity", Chicago, University of Chicago Press, 339-373.

Griliches, Z., Nordhaus, W., Scherer, F., 1989. Patents: Recent trends and puzzles. Brookings Papers on Economic Activity: Microeconomics, 1989, 291-330.

Grupp, H., Schmoch, U., 1999, Patent statistics in the age of globalisation: new legal procedures, new analytical methods, new economic interpretation. Research Policy, 28(4), 377-396.

Guellec, D., van Pottelsberghe de la Potterie, B., 2000. Applications, grants and the value of patent. Economics Letters, 69(1), 109-114.

Guellec, D., van Pottelsberghe de la Potterie, B., 2004. From R&D to productivity growth: Do the institutional settings and the source of funds of R&D matter? Oxford Bulletin of Economics and Statistics, 66(3), 353-378.

Guellec, D., van Pottelsberghe de la Potterie, B., 2007. The Economics of the European Patent System. Oxford University Press, Oxford, 250p.

Guellec, D., van Pottelsberghe de la Potterie, B., van Zeebroeck, N., 2007. Patent as a market instrument (Chapter 4), In: Guellec, D., van Pottelsberghe de la Potterie, B., The Economics of the European Patent System, Oxford University Press, Oxford, pp. 85-113.

Hall, B., Griliches, Z., Hausman, J., 1986. Patents and R&D: is there a lag? International Economic Review, 27(2), 265-83.

Hall, B., Mairesse, J., 1995. Exploring the relationship between R&D and productivity in French manufacturing firms. Journal of Econometrics, 65, 263-293.

Harhoff, D., Hoisl, K., 2007. Institutionalized incentives for ingenuity - Patent value and the German Employees' Inventions Act. Research Policy, 36(8), 1143-1162.

Hoisl, K., 2007. Tracing mobile inventors: The causality between inventor mobility and inventor productivity. Research Policy, 36(5), 619-636.

Idson, T., Oi, W., 1999. Workers are more productive in large firms. The American Economic Review, 89(2), 104-108.

IMD, 2006. IMD World Competitiveness Yearbook, Lausanne.

Jones, C., 1995. R&D-based models of economic growth. The Journal of Political Economy, 103(4), 759-784.

Kang, S., Seo, H., 2006. Do stronger intellectual property rights induce more patents? (Chapter 6), In: van Pottelsberghe de la Potterie, B., Peeters, C., (Eds), Economic and Management Perspectives on Intellectual Property Rights, Palgrave Macmillan, pp. 129-150.

Kortum, S., Lerner, J., 1999. What is behind the recent surge in patenting? Research Policy, 28(11), 1-22.

Krueger, A., Lindahl, M., 2001. Education for growth: Why and for whom? Journal of Economic Literature, 39(4), 1101-1136.

Lanjouw, J., Schankerman, M., 2004. Patent quality and research productivity: measuring innovation with multiple indicators. The Economic Journal, 114(495), 441-465.

Lerner, J., 2002. 150 Years of patent protection. The American Economic Review, 92(2), 221-225.

Mansfield, E., 1986. Patents and innovation: An empirical study. Management Science, 32(2), 173-181.

Mariani, M., Romanelli, M., 2006. "Stacking" or "picking" patents? The inventors' choice between quantity and quality. Laboratory of Economics and Management, Sant'Anna School of Advanced Studies 2006/06.

Mohnen, P., Nadiri, M., 1985. Demande de facteurs et recherche-développement: estimations pour les Etats-Unis, le Japon, l'Allemagne et la France. Revue Economique, 36(5), 943-974.

Nadiri, M., Kim, S., 1996. International R&D spillovers, trade and productivity in major OECD countries. NBER Working Paper Series, No. 5801, October, 36p.

Odagiri, H., 1985. Research activity, output growth and productivity increase in Japanese manufacturing industries. Research Policy, 14, 117-130.

Organisation for Economic Co-operation and Development, 2004. Triadic Patent Families Methodology. STI Working Paper 2004/2, Paris.

Park, W., Wagh, S., 2002. Index of patent rights, In. Economic Freedom if the World: 2002 Annual Report (Chapter 2, 33-43), The Fraser Institute.

Peeters, C., van Pottelsberghe de la Potterie, B., 2006. Innovation strategy and the patenting behavior of firms. Journal of Evolutionary Economics, 16(1-2), 109-135.

Romer, P., 1990. Endogenous technological change. The Journal of Political Economy, 98(5), part 2, 71-102.

Scherer, F., 1983. The Propensity to patent. International journal of industrial organization, 1, 107-128.

Stevnsborg, N., van Pottelsberghe de la Potterie, B., 2007. Patenting procedures and filing strategies at the EPO (Chapter 6), In: Guellec, D., van Pottelsberghe de la Potterie, B., The Economics of the European Patent System. Oxford University Press, Oxford, pp. 155-183.

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy, 15, 285-305.

Temple, J., 2001. Generalizations that aren't? Evidence on education and growth. European Economic Review, 45(4-6), 905-918.

Tong, X., Frame, J., 1994. Measuring national technological performance with patent claims data. Research Policy, 23(2), 133-141.

Ulku, H., 2004. R&D, innovation, and economic growth: An empirical analysis. IMF Working Paper 04/185, Washington D.C.

van Pottelsberghe de la Potterie, B., 1997. Issues in assessing the effect of interindustry R&D spillovers. Economic Systems Research, 9(4), 331-356.

van Pottelsberghe de la Potterie, B., François, D., 2009. The cost factor in patent systems. Journal of Industry, Competition and Trade, forthcoming.

van Zeebroeck, N., van Pottelsberghe de la Potterie, B., Guellec, D., 2006. Claiming more: The increased voluminosity of patent applications and its determinants. CEPR Discussion Paper 5971.

Varsakelis, N., 2001. The impact of patent protection, economy openness and national culture on R&D investment: A cross-country empirical investigation. Research Policy, 30(7), 1059-1068.

A Variables description and data sources

Variable	Description	Source
Dependent variables $\dot{P}$		
NPF	Priority filings at national patent offices (utility models are excluded).	PatStat (April 2007 edition), database maintained by the European Patent Office.
PF_CORR	Priority filings at national patent offices, corrected by the number of first filings at the EPO and the USPTO by domestic applicants (utility models are excluded).	Patstat
TRIADIC	Patents filed simultaneously at the EPO, the USPTO and the JPO	OECD Main Science and Technology Indicators (MSTI)
EPO	European patent applications filed and Euro-PCT entering the regional phase in 2003	EPO's annual report 2003, p. 72, 80 and 81.
USPTO	US patent applications filed by nationality of residents	USPTO's annual reports 2203 and 2004, p. 112 and p. 124-125
Research efforts (L_r)		
Researchers	Number of full-time equivalent scientists and engineers	UNESCO Institute For Statistics (UIS)
Education policy		
HKI	Human Capital Index, calculated from the literacy rate, secondary enrolments and tertiary enrolments	United Nations World Investment Report 2005, p.291
S&T Policies		
SHBRES	Researchers in the business sector as a percentage of total researchers	UIS
SHBRD	Percentage of total gross domestic expenditures on R&D performed by the Business Enterprise sector	OECD MSTI
DEF_GBOARD	Share of defence-oriented research in total government budget appropriation for R&D	OECD MSTI
GERD_RES	Gross expenditures on R&D (in million US PPP) per researcher	OECD MSTI (UIS for BR and IN)

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Variable	Description	Source
SHBASR	Basic research expenditures as a percentage of total research expenditures	OECD MSTI
IP Policies		
FEES	Cumulated administrative patenting fees up to the grant in 2003, for the "average" patent, including filing, search, examination and granting fees. Cf. Appendix B	Data collected from the website of national patent offices. For a few countries, when the information was incomplete or unclear, we relied on Global IP, an online database that generates estimates of patenting fees, as a complementing source of information.
EXAM	Dummy variable taking the value of 1 if the patent office requires a substantive search and examination, 0 otherwise.	Data collected from the WIPO Website (Resources > WIPO Index of Patent Systems) and completed by website of national patent offices.
IPI	Ginarte and Park's IP Index of patent rights. The index ranges from 0 to 5, the highest level of protection of IP rights. The index is composed of five categories, each having a maximum score of 1. These categories include the number of subject matters that can be patented (coverage), the length of protection, the mechanisms for enforcing patents rights, memberships in international patent treaties, and restrictions on the use of patents rights.	Ginarte and Park (1997) and Park and Wagh (2002). Estimates for the year 2000 are used for the year 2003.

B Methodology adopted to measure fees

As patenting fees may vary according to the number of claims and pages included in the filed document, the fee is computed for the *average* patent in 2003, for which the average numbers of claims and pages per patent were approximated using EPO data. For the patents filed at the EPO by all the applicants from a given country, the average number of claims per patent is divided by the average number of national priority filings included in the EPO filings; which gives an approximation of the average number of claims per priority filing. The average number of pages is calculated on the assumption of a linear relation with the average number of claims. Archontopoulos et al. (2007) provide evidence that such a methodology makes sense. Fees were converted into US PPPs to allow for a proper international comparison. Other working assumptions were adopted: the applicant is a large firm (no SME reduction), application is in paper (no electronic application) and payments are done in time (no surcharge for late payments). A detailed methodology is available in de Rassenfosse and van Pottelsberghe (2007).

C Countries included in the samples

	Name	OECD	EPC	BRICS	A	B	C	D
AT	Austria	x	x	-	x	x	x	x
AU	Australia	x	-	-	x	x	x	x
BE	Belgium	x	x	-	x	x	x	-
BR	Brazil	-	-	x	x	-	-	-
CA	Canada	x	-	-	x	x	x	-
CH	Switzerland	x	x	-	x	x	x	x
CN	China	-	-	x	x	x	-	x
CZ	Czech Republic	x	x	-	x	x	x	x
DE	Germany	x	x	-	x	x	x	-
DK	Denmark	x	x	-	x	x	x	x
ES	Spain	x	x	-	x	x	x	x
FI	Finland	x	x	-	x	x	x	-
FR	France	x	x	-	x	x	x	x
GB	United Kingdom	x	x	-	x	x	x	-
GR	Greece	x	x	-	x	x	x	-
HU	Hungary	x	x	-	x	x	-	x
IE	Ireland	x	x	-	x	x	x	x
IN	India	-	-	x	x	-	-	-
IT	Italy	x	x	-	x	x	-	-
JP	Japan	x	-	-	x	x	x	x
KR	Korea	x	-	-	x	x	x	x
MX	Mexico	x	-	-	x	x	x	x
NL	Netherlands	x	x	-	x	x	x	-
NO	Norway	x	-	-	x	x	x	x
NZ	New-Zealand	x	-	-	x	x	-	x
PL	Poland	x	x	-	x	x	-	x
PT	Portugal	x	x	-	x	x	x	x
RU	Russia	-	-	x	x	x	x	x
SE	Sweden	x	x	-	x	x	x	-
SG	Singapore	-	-	-	x	x	-	x
SK	Slovakia	x	x	-	x	x	x	x
TR	Turkey	x	x	-	x	x	-	-
US	United States	x	-	-	x	x	x	x
ZA	South Africa	-	-	x	x	x	-	x
Total		28	20	5	34	32	24	22

OECD stands for Organization for Economic Cooperation and Development; EPC designates member states of the European Patent Convention and BRICS stands for Brazil, Russia, India, China and South Africa. Countries with more than 100 priority filings in 2003 were selected for the full sample. The smaller samples were then driven by data availability. '-' indicates countries for which information on SHBRD is missing in (B); information on both SHBRD and DEF_GBOARD is missing in (C); and information on SHBASR is missing in (D).

D Patent indicators, 2003

Country	(1) NPF	(2) PF_CORR	(3) [(1)/(2)]	(4) TRIADIC	(5) EPO	(6) USPTO
AT	1,361	1,488	0.91	281	1,010	1,009
AU	12,985	13,192	0.98	409	870	2,498
BE	523	924	0.57	340	1,374	1,420
BR	4,472	4,531	0.99	55	107	333
CA	4,486	5,865	0.76	712	1,609	8,138
CH	1346	2,856	0.47	794	4,180	2,362
CN	55,495	55,744	0.99	253	334	1,230
CZ	581	588	0.99	15	58	52
DE	45,637	48,456	0.94	6,176	22,701	19,646
DK	1,271	1,558	0.82	233	867	1,145
ES	1,965	2,196	0.89	167	695	633
FI	2,031	2,454	0.83	259	1,480	1,866
FR	14,576	15,718	0.93	2,407	7,431	6,887
GB	22,234	22,711	0.98	1,637	4,843	8,215
GR	444	453	0.98	12	66	44
HU	776	783	0.99	37	58	128
IE	362	410	0.88	48	270	382
IN	851	1,165	0.73	128	156	1,105
IT	4,869	5,990	0.82	703	3,676	3,325
JP*	112,679	115,584	0.97	14,428	18,534	61,177
KR*	28,793	29,125	0.99	2,018	2,075	9,614
MX	797	829	0.96	17	23	213
NL	2,298	3,387	0.68	1,203	6,459	2,382
NO	1,221	1,259	0.97	102	358	470
NZ	816	840	0.97	73	145	473
PL	2,432	2,435	0.99	10	40	48
PT	124	137	0.90	9	39	22
RU	23,396	23,431	0.99	50	122	345
SE	3,452	4,007	0.86	596	2,562	2,311
SG	365	611	0.60	83	128	817
SK	157	160	0.98	3	14	6
TR	314	339	0.93	12	46	41
US	178,804	178,804	1.00	16,037	31,863	197,948
ZA	1,222	1,232	0.99	32	133	263

* The number of priority filings for Japan and Korea was divided by 3. See Appendix Table A for the data sources.

E Other key data

Country	Researchers	HKI	FEES	IPI
	(1)	(2)	(3)	(4)
AT	24,124	0.875	612	4.71
AU	73,344	0.971	576	4.19
BE	30,901	0.924	1,069	4.05
BR	59,838	0.579	639	3.05
CA	112,624	0.914	1,226	3.90
CH	25,808	0.799	1,062	4.05
CN	862,108	0.298	2,343	2.48
CZ	15,809	0.701	407	3.52
DE	268,943	0.810	444	4.52
DK	25,546	0.934	1,072	4.19
ES	92,523	0.895	762	4.05
FI	41,724	0.982	831	4.19
FR	192,790	0.877	542	4.05
GB	171,523	0.951	298	4.19
GR	15,390	0.794	564	3.19
HU	15,180	0.758	911	3.71
IE	10,039	0.848	575	4.00
IN	117,528	0.247	5,329	2.18
IT	70,332	0.789	200	4.33
JP	675,330	0.835	1,315	4.19
KR	151,254	0.866	1,513	4.19
MX	27,626	0.477	1,990	2.86
NL	37,928	0.904	421	4.38
NO	20,989	0.957	810	3.90
NZ	15,568	0.955	165	4.00
PL	58,595	0.867	309	3.24
PT	20,242	0.814	637	2.98
RU	409,775	0.817	3,554	3.52
SE	47,836	0.982	878	4.38
SG	20,024	0.621	1,450	4.05
SK	9,626	0.664	436	3.52
TR	23,995	0.355	2,097	2.86
US	1,334,628	0.905	2,373	5.00
ZA	14,182	0.475	106	4.05

(2) The human capital index ranges from 0 to 1, the maximum. (3) Patenting fees are expressed in 2003 US PPPs. (4) The IP index ranges from 0 to 5, the maximum. See Appendix Table A for the data sources.

F Propensity and productivity component, for all the dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Propensity Model					Productivity Model				
Dep. variable	NPF	PF_CORR	TRIADIC	EPO	USPTO	NPF	PF_CORR	TRIADIC	EPO	USPTO
ln Researchers (ln L_r)	1.36***	1.29***	0.93***	0.78***	0.97***	1.11***	1.03***	0.33**	0.10	0.41***
	(22.74)	(21.86)	(6.21)	(5.29)	(6.69)	(10.42)	(10.62)	(2.56)	(0.83)	(2.95)
ln FEES	-0.31**	-0.24**	0.02	-0.20	0.21					
	(2.76)	(2.44)	(0.07)	(0.72)	(0.85)					
IPI	0.41**	0.47**	2.07***	2.06***	2.34***					
	(2.15)	(2.34)	(4.88)	(5.28)	(5.50)					
SHBRD	0.79	1.17	1.66	2.28	0.74					
	(0.92)	(1.38)	(1.04)	(1.39)	(0.44)					
ln $L_r\times$ HKI						0.13*	0.12*	0.22***	0.31***	0.18***
						(1.71)	(1.72)	(4.32)	(6.61)	(2.49)
ln $L_r\times$ GERD_RES						0.32*	0.39**	1.37***	1.54***	1.33***
						(1.96)	(2.76)	(5.27)	(6.12)	(5.07)
ln $L_r\times$ SHBRES						0.03	0.06	0.25***	0.21**	0.28***
						(0.39)	(0.83)	(2.99)	(2.55)	(2.78)
Constant	-6.90***	-6.92***	-14.00***	-10.19***	-14.73***	-6.01***	-5.22***	-3.94***	-1.15	-2.94*
R-squared	0.93	0.94	0.85	0.82	0.85	0.89	0.91	0.91	0.91	0.88
Observations	32	32	32	32	32	34	34	34	34	34

The econometric method is Ordinary Least Square with robust estimates; t-stat are in parentheses; *, ** and *** denote significance at the 10%, 5% and 1%-probability threshold, respectively. ln denotes the natural logarithm of the variable. See Appendix Table A for the definition of all variables and Appendix Table C for a description of the samples.

G Tables and figures [to be included into the text]

Figure 1: Research efforts and patenting activity

Notes: for EU15 data for Luxembourg is missing but amount to a very small difference. Cf. Appendix Table A for the data sources.

Table 2: Particularities of various patent count methodologies

Indicator	Particularities
USPTO	Unique standard of quality of the examination
	More valuable patents (except for US applicants)
	Home bias
EPO	Unique standard of quality of the examination
	More valuable patents
	Home bias
NPF	Priority filings abroad are missing
	Difference in the quality of examination
	Low quality patents included
PF_CORR	Include all the inventive output
	No or small home bias
	Difference in the quality of examination
	Low quality patents included
TRIADIC	Unique standard of quality of the examination
	Only high value patents
	No home bias

Table 3: Descriptive statistics, 2003

Variable	Obs.	Min	Mean	Max	Std. Dev
NPF	34	124	15,680	178,804	36,444
PF_CORR	34	137	16,155	178,804	36,682
TRIADIC	34	3	1,451	16,037	3,687
EPO	34	14	3,363	31,863	7,096
USPTO	34	6	9,898	197,948	34,946
Researchers ('000)	34	10	150	1335	281
Education policy					
HKI [0,1]	34	0.25	0.78	0.98	0.20
IP Policies					
FEES	34	106	1,103	5,329	1,060
IPI [0,5]	34	2.18	3.81	5.00	0.64
EXAM (d)	34	0	0.73	1	-
*S&T Policies (base = 1)**					
SHBRES	34	0.12	0.45	0.80	0.19
GERD_RES	34	0.04	0.15	0.25	0.06
SHBRD	24	0.30	0.61	0.76	0.13
DEF_GBOARD	24	0.00	0.11	0.54	0.15
SHBASR	22	0.05	0.22	0.34	0.08

* Except for GERD_RES, where data are expressed in '000,000 US PPPs. (d) indicates a dummy variable. See Appendix Table A for the definition of all variables and Appendix Table C for a list of the countries included in the samples. Appendix Tables D and E show the values of the most important variables.

Figure 2: Priority filings vs. research effort

The number of priority filings (excluding utility models) encompasses filings at national patent office as well as filings at the EPO and the USPTO from domestic applicants. See Appendix Table A for the data sources.

Table 4: Univariate cross-sectional regression - Heterogenous propensity to patent

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable	ln NPF					
Researchers						
ln Researchers (ln L_r)	1.46***	1.46***	1.38***	1.39***	1.58***	1.36***
	(20.80)	(20.23)	(21.70)	(17.86)	(16.27)	(14.93)
Propensity to patent (X_n)						
ln FEES	-0.54***	-0.54***	-0.34***	-0.32*	-0.31**	-0.36**
	(3.94)	(3.40)	(3.06)	(1.74)	(2.15)	(2.60)
EXAM (d)		0.02				
		(0.08)				
IPI			0.56***			
			(3.25)			
SHBRD				2.24*		
				(1.74)		
DEF_GBOARD					-1.33	
					(1.59)	
SHBASR						-1.71
						(1.00)
Constant	-4.54***	-4.52***	-7.11***	-6.47***	-7.17***	-4.14***
R-squared	0.89	0.89	0.92	0.92	0.91	0.90
Observations	34	34	34	24	24	22

The dependent variable is the number of national priority filings (NPF) in 2003. The econometric method is Ordinary Least Square with robust estimates; t-stat are in parentheses; *, ** and *** denote significance at the 10%, 5% and 1%-probability threshold, respectively. ln denotes the natural logarithm of the variable. See Appendix Table A for the definition of all variables and Appendix Table C for a description of the samples.

Table 5: Univariate cross-sectional regression - Heterogenous productivity of research efforts

	(1)	(2)	(3)	(4)	(5)
Dep. Variable	ln TRIADIC				
Researchers					
ln Researchers (ln L_r)	1.15***	0.87***	0.74***	0.37	0.33**
	(4.72)	(4.82)	(5.00)	(1.45)	(2.56)
Productivity (Y_m)					
ln $L_r \times$ HKI		0.37***			0.22***
		(5.99)			(4.32)
ln $L_r \times$ GERD_RES			1.75***		1.37***
			(6.55)		(5.27)
ln $L_r \times$ SHBRES				0.59***	0.25***
				(7.55)	(2.99)
Constant	-7.34***	-7.48***	-5.90***	-1.76	-3.94***
R-squared	0.48	0.63	0.78	0.73	0.91
Observations	34	34	34	34	34

The dependent variable is the number of triadic filings (TRIADIC) in 2003. The econometric method is Ordinary Least Square with robust estimates; t-stat are in parentheses; *, ** and *** denote significance at the 10%, 5% and 1%-probability threshold, respectively. ln denotes the natural logarithm of the variable. See Appendix Table A for the definition of all variables and Appendix Table C for a description of the samples.

Table 6: Univariate cross-sectional regression - Heterogenous productivity and propensity

	(1)	(2)	(3)	(4)	(5)
Dep. variable	ln NPF	ln PF_CORR	ln TRIADIC	ln EPO	ln USPTO
Researchers					
ln Researchers (ln L_r)	1.32***	1.22***	0.45**	0.34**	0.41**
	(9.45)	(8.84)	(2.76)	(2.29)	(2.60)
Propensity to patent (X_n)					
ln FEES	-0.44***	-0.34**	0.08	-0.04	0.21
	(2.78)	(2.38)	(0.37)	(0.21)	(0.97)
IPI	0.41	0.41	0.62	0.58	0.76
	(0.88)	(0.95)	(1.29)	(1.28)	(1.49)
Productivity (Y_m)					
ln $L_r\times$ HKI	-0.03	-0.02	0.14*	0.17**	0.15
	(0.36)	(0.29)	(1.74)	(2.34)	(1.56)
ln $L_r\times$ GERD_RES	-0.01	0.11	1.24***	1.29***	1.30***
	(0.03)	(0.67)	(3.76)	(4.43)	(3.50)
ln $L_r\times$ SHBRES	0.09	0.10	0.17**	0.18**	0.15*
	(0.79)	(0.92)	(2.10)	(2.09)	(1.97)
EPC (d)			-0.14	0.47*	-0.81**
			(0.45)	(1.74)	(2.53)
Constant	-5.34*	-5.08*	-6.76*	-4.27	-5.74*
R-squared	0.92	0.93	0.91	0.93	0.92
Observations	34	34	34	34	34

The econometric method is Ordinary Least Square with robust estimates; t-stat are in parentheses; *, ** and *** denote significance at the 10%, 5% and 1%-probability threshold, respectively. ln denotes the natural logarithm of the variable. See Appendix Table A for the definition of all variables and Appendix Table C for a description of the samples.

Table 7: Univariate cross-sectional regression - Heterogenous productivity and propensity

	(1)	(2)	(3)	(4) Multivariate	
	R^2	Propensity	Productivity	Prop.	Prod.
PF	0.84	+	(+)	+	0
PF_CORR	0.85	+	(+)	+	0
TRIADIC	0.48	(+)	+	0	+
EPO	0.36	(+)	+	0	+
USPTO	0.51	(+)	+	0	+

Notes: '+' denotes a strong impact, (+) a mitigate impact and 0 no impact. The econometric results leading to columns (2) and (3) are reported in Appendix Table F. Column (4) summarizes the results presented in Table 6.