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

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Abstract

This paper investigates whether patent counts can be taken as indicators of macroeconomic innovation performance. The empirical model explicitly accounts for the two components of patenting output: research productivity and patent propensity. The empirical analysis aims at explaining the 'correct' number of priority filings in 34 countries. It confirms that the two components play a substantial role as witnessed by the impact of the design of several policies, namely education, intellectual property and science and technology policies. A major policy implication relates to the design of patent systems, which ultimately induces, or allows for, aggressive patenting strategies.
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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 patent practices.

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 a model that explicitly distinguishes the factors affecting the productivity of researchers from the factors affecting patent practices. Second, several hypotheses are tested regarding the impact of the design of several policies on research productivity and on patent propensity. The policy tools that are used include education policies, science and technology (S&T) policies and intellectual property (IP) policies. Third, it tests the model at the macroeconomic level with a unique dataset on the national priority filings of 34 countries in 2003. In this respect, this is one of the first paper which explicitly analyzes the determinants of the national demand for patents.[3]

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

[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 it has filed in the United States Patent and Trademark Office (USPTO) or the European Patent Office (EPO).

The empirical results suggest that the number of patents per researcher depends on both the productivity of research and national patent practices, 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. Regarding the factors affecting the propensity to patent, the components of an IP policy design play an important role. In particular, filing fees, patent coverage, and enforcement mechanisms all significantly affect patenting practices and hence the number of priority filings.

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 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. As a matter of fact, 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

[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 Mairess (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) and Nadiri and Kim (1996).

invention production function and the number of patents as an output may therefore be subject to a substantial empirical complexity. This complexity probably explains why no attempt has been made so far — to the best of our knowledge — to formally address this research question. The confusion is more apparent in the microeconomic literature, where the two dimensions (i.e. productivity and propensity) 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, there are not many studies which emphasize that patents can be an indicator of research productivity. At most, it is possible to identify a few references which implicitly assume that patents reflect a productivity of research. 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 numbers 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 the factors that are known to affect the research productivity actually influence the number of patents observed in a country. Section 2.1 and section 2.2 summarize the existing literatures on the policies that may affect

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

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 three categories: i) the design of the patent system; ii) the technological specialization; and iii) 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 (i.e the design of the patent system) on patent practices is related to the subject matter. 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 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) find a negative and significant impact of filing fees on the demand for patents for the member states of the European Patent Office. 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 technological specialization and the type of R&D activities. Technological specialization must be accounted for as some industries are much more patent intensive than others. Indeed, it is well known that some industries

[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 (2006).

intensely rely on the patent system (see Hall and Ziedonis (2001) for the semi conductors industry or Bessen and Hunt (2007) for the software industry in the US). This is only partially related to the patentable subject matters effect described here above.

Finally, patent practices may be affected by the type of institution performing the research (i.e., public research vs. private research) or the type of research (i.e., basic research vs. applied research), or the source of funding. 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 i) education policies and ii) 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 (e.g., 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 — i.e., the productivity of research. Since the seminal contribution of Cohen and Levinthal (1989), the absorptive capabilities associated with research activities has increasingly been validated empirically (e.g., Griffith (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 inventor's 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, using national patent filings and differentiating between a *productivity* and a *propensity* 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]

In a first stage, the hypotheses of constant productivity (λ) and constant patent practices (δ) across countries are held; they are then subsequently relaxed. Letting ln denote the natural logarithm, the 'constrained' patent production function (1) 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 productivity of researchers to vary across countries would affect the parameter λ_i as follows:

$$\lambda_i = \lambda_c + \sum_m \lambda_m Y_{m_i}. \tag{3}$$

It 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

[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 three 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); and iii) the function explains the number of patents (instead of knowledge) produced.

(such as the level of education). Therefore, when the hypothesis of constant productivity is relaxed, equation (2) can be written as follows:

$$\ln \dot{P}_i = \ln \delta + \lambda_c \ln L_{r_i} + \sum_m \lambda_m \ln L_{r_i} Y_{m_i} + \varepsilon_i, \tag{4}$$

An alternative model allows for heterogeneous patent practices but a constant productivity of researchers. The propensity to patent δ 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:

$$\delta_i = \delta_c \prod_n X_{n_i}^{\delta_n}, \tag{5}$$

and equation (2) becomes :

$$\ln \dot{P}_i = \ln \delta_c + \sum_n \delta_n \ln X_{n_i} + \lambda \ln L_{r_i} + \varepsilon_i. \tag{6}$$

Equation (4) allows the productivity of researchers to vary across countries, whereas equation (6) allows the propensity to file patents to vary across countries. 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 is seldom available or is very stable over time.

3.2 The dependent variable

Most of the existing studies investigating the determinants of patent filings at the country level actually focus on international patents flows, trying to understand what drives the foreign filing of an American or a European patent (see e.g. Furman et al. (2002), Bottazzi and Peri (2003), Eaton et al. (2004), Ulku (2004), Falk (2005), and Kang and Seo (2006)): the dependent variable is usually the number of second filings from one country to the EPO or the USPTO, and is used as a proxy for national innovative performance. These studies mainly investigate the factors influencing the propensity to patent, according no or little consideration to a potentially heterogenous productivity of research.

[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 AT, AU, BE, BR, CA, CH, CN, CZ, DE, DK, ES, FI, FR, GB, GR, HU, IE, IN, IT, JP, KR, MX, NL, NO, NZ, PL, PT, RU, SE, SG, SK, TR, US and ZA. A smaller sample of 24 countries, driven by data availability, is also used. The details are presented in Appendix Table C.

In this paper, the dependent variable is the number of priority filings at the national patent office of each country, corrected by the priority filings directly submitted to the EPO and to the USPTO by domestic applicants. Since the patent system is relatively complex to apprehend, it may be useful to briefly describe the patent filing procedure.

As far as the number of patent filings is concerned, a first critical distinction has to be made between first (or *priority*) filings and second filings: the former designates an invention that has been filed for the first time, anywhere in the world, whereas the latter encompasses the subsequent foreign filings of a priority filing.[12] For example, a German inventor may file his patent for the first time at the German patent office in order to protect the invention on the German territory. If his patent turns out to be valuable enough, the inventor can use his *priority right* to subsequently file his application at other patent offices, within a period of maximum one year from the priority date (according to the Paris Convention, 1883), therefore trying to protect his invention in other countries.

An applicant can actually choose different routes to extend his patent abroad, from the PCT (Patent Cooperation Treaty) route to direct national filings in foreign national patent offices or regional filings (*e.g.*, before the EPO). For instance, if the German inventor is willing to extend his patent protection in the French territory, several options are available. He can file his patent directly at the French patent office; he can file his patent at the EPO and validate and enforce his 'European' patent in France once it is granted by the EPO; or he can file his application through a PCT authority such as Sweden or the EPO and wait 31 months to effectively transfer his patent towards other patent offices. Each route has a different scope — and a different cost — and involves a different time constraint. For example, if a patent is first filed through the PCT route, the period for international extension is of 31 months instead of the usual 12 months.

The present model aims at explaining the domestic demand for priority filings, that is the number of first filings at each NPO plus the priority filings at the EPO and the USPTO from domestic applicants. In the case of Germany, there were 45,637 priority filings reported at the German patent office for the year 2003. 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 $\dot{P}_i$ for Germany. This correction represents only 6% of the total, but is much higher for some countries as indicated in column (3) of Appendix Table D. For instance, priority filings at the Swiss patent office represent merely 47% of the corrected number of patents: Swiss applicants seem to favor the European or the American route to file their patent applications.

All previous investigations focus on (mostly second) filings at the USPTO or at the EPO, which implicitly limits the patent indicator to the inventions subject to international competition and to the patentability criteria of foreign

[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.

patent offices. It could be argued that EPO patents are of a potentially higher quality, or value (as it is a more expensive process), and hence a more appropriate indicator of innovative performance. The number of priority filings at national patent offices is however kept for two main reasons: i) 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, ii) the number of patent filings at the EPO or at the USPTO suffers from a substantial 'home' bias: the North American countries have a higher tendency to file their patent applications at the USPTO while European applicants have a higher propensity to patent at home than abroad. Relying on national priority filings may therefore be more appropriate, as it measures all the inventions for which at least one patent has been filed.

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 national priority filings. The number of priority filings has been extracted from PatStat (April 2007 edition), a new dataset generated by the EPO which includes patent data from 73 patent offices world wide.

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 in 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 an 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 applicants. A similar observation can be made for Korean patents.

To illustrate the potential importance of the measurement bias, the number of patents per researcher 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 (2006). Consequently, the number of Japanese and Korean applications is divided by

[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.

3.[14]

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 relaxed in equation (4) and (6), respectively. The remainder of this section is devoted to the description of the variables used in the 'productivity' model and the 'patent practices' model. All variables and data sources are presented in Appendix Table A.

Heterogenous productivity of researchers

Equation (4) 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 their scientific output, and the type of 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.[16] A second variable is the number of scientific publications per researcher (SCIR). The idea is to test whether a higher scientific production, reflecting a higher quality of research activities, would also lead to more inventions per researcher.

[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.

[16] 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 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).

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 (Guellec and van Pottelsberghe (2004)). 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). As basic research may lead more to discoveries (with publications potentials) than to inventions (with market potentials), the share of basic research in total R&D expenses (SHBASR) is tested as a variable potentially affecting the productivity of research. Finally, to take into consideration 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.

Heterogenous patent practices

The second set of hypotheses aims at explaining the extent to which patent practices vary across countries — captured by the variables X_n in equation (6). Two policy tools are investigated: patent policy design and S&T policy design (including the technological specializations and characteristics of R&D).

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 *administrative fees* (*i.e.*, fees requested by national patent offices) consist of filing, search, examination and granting fees.[17] 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 various administrative fees have been added together to compute a single

[17] 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 reasonable chances 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.

fee indicator (filing, search, examination and granting fees) comparable across countries (FEES).[18] 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 (IPCOV), the mechanisms for enforcing patents rights (IPENF, indicating how strongly the country enforces the law), the restrictions on the use of patents rights (IPRES, measuring protection against losses of rights), membership in international patent treaties, and the length of protection from the priority date. Besides the aggregate index, the impact of three of the five main components will be analyzed separately.[19]

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

Hypotheses 2.2 and 2.3 - The technological specialization and the type of R&D influence 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 technological specialization of a country (through the funding of public and business R&D in specific technologies such as ICT or biotechnologies for instance) and the type and institutional

[18] 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 (2006) 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.

[19] IPCOV, IPENF and IPRES vary substantially across countries, whereas the two remaining components are very stable.

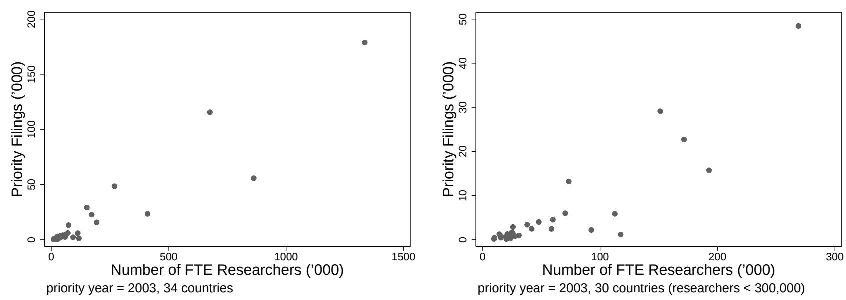
settings of R&D activities; which in turn may influence the patent practices related to new inventions.

To test the hypothesis that *technological specialization* plays a role in explaining aggregate differences in patent practices, 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 high-tech industries: aerospace (AERO), electronic (ELEC), office machinery and computer (COMPU), pharmaceutical (PHARMA), and instrument (INSTRU).

The *type and institutional settings of R&D* might also affect the propensity to patent. Indeed, 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 easily appropriable (i.e., scientific discoveries or inventions performed through defence-related contracts, for which the IP belongs to the fund-provider). Descriptive statistics of all the variables are reported in table 1.

The number of patents applied for is compared to the research efforts in figure 1. 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 priority filings $\dot{P}_i$ as a raw measure of research efforts 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.

Figure 1: 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. Cfr. Appendix Table A for the data. Source: Patstat, April 2007 edition and UNESCO Institute for Statistics.

Table 1: Descriptive statistics, 2003

Variable	Obs.	Min	Mean	Max	Std. Dev
Corrected priority filings ('000)	34	0.14	16.15	178.80	36.68
Researchers ('000)	34	9.63	149.81	1334.63	281.33
Education policy					
HKI [0,1]	34	0.25	0.78	0.98	0.20
SCIR	34	0.05	0.27	0.54	0.11
IP Policies					
FEES (US PPPs)	34	106	1,103	5,329	1,060
IPI [0,5]	34	2.18	3.81	5.00	0.64
IPCOV [0,1]	34	0.14	0.75	1.00	0.20
IPENF [0,1]	34	0.00	0.66	1.00	0.32
IPRES [0,1]	34	0.00	0.49	1.00	0.28
*R&D Type (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
Technological Specialization (base = 100)					
AERO	24	0.00	3.25	12.10	3.79
ELEC	24	0.20	14.10	49.80	13.59
COMPU	24	0.10	2.57	26.70	5.77
PHARMA	24	0.10	9.95	34.20	8.78
INSTRU	24	0.20	3.71	10.30	2.80

* Except for GERD_RES, where data are expressed in '000,000 US PPPs. See Appendix Table A for the definition of 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.

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 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.

Two samples are available for the estimates, for the year 2003. The first one is composed of 34 countries and the second one of 24 countries, the smaller sample being driven by data availability on technological specialization and characteristics of R&D (see Appendix Table C for a description of the countries included in the samples). Table 2 presents the estimated parameters of equation

(2), the restricted model, and equation (4), which allows the productivity of researchers to vary across countries.

Columns (1) and (6) of table 2 report the results of the 'constrained' model for the large and the small sample, respectively. The number of researchers is the main driver of patent filings and exhibits increasing returns to scale, with an elasticity significantly larger than one. These estimates suggest that an increase of 10% in the number of researchers L_r leads to a more than proportional increase in the number of patents filings of about 13%. This elasticity is an approximation of the average 'patent productivity' of researchers. In this model, cross-country differences in the number of patent filings are exclusively explained by differences in the number of researchers.

Table 2: Univariate Cross-sectional Regression - Heterogenous Productivity of Research

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Researchers							
ln Researchers (ln L_r)	1.29 *** (16.30)	1.18 *** (14.86)	1.35 *** (17.47)	1.04 *** (9.21)	1.17 *** (19.71)	1.26 *** (15.98)	1.26 *** (16.81)
Productivity (Y_m)							
ln L_r × HKI		0.15 *** (2.94)					
ln L_r × SCIR			0.21 ** (2.14)				
R&D Type							
ln L_r × SHBRES				0.19 ** (2.73)			
ln L_r × GERD_RES					0.51 *** (4.18)		
ln L_r × SHBASR							-0.01 (-0.08)
Constant	-6.08 ***	-6.14 ***	-7.29 ***	-4.30 ***	-5.66 ***	-5.73 ***	-5.69 ***
R-squared	0.85	0.88	0.86	0.88	0.88	0.88	0.88
Number of observations	34	34	34	34	34	22	22

The dependent variable is the corrected number of national priority filings (PF) in 2003 (i.e. PF at national patent offices plus PF at the EPO and the USPTO by domestic applicants). The econometric method is Ordinary Least Square, 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 description of the variables and Appendix Table C for a list of the countries included in the samples.

The other columns of table 2 display the results of the model that allows the productivity of researchers to vary across countries. 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 1.2 and a component that varies according to the quality of the human capital. This interaction parameter is positive and significant, meaning that a higher level of education translates into more productive researchers. In column (3), the average number of publications per researcher, another variable aiming at capturing the quality (or productivity) of researchers, is included in the model. The effect is positive and significant, suggesting that scientific productivity induces a higher productivity in terms of patents filed. Another explanation is that a higher relative number of publications denotes a better quality of scientific research, leading to more opportunities for further R&D. In other words, there seems to be a complementary relationship between publications and patents.

Columns (4), (5) and (7) assess the impact of the type of R&D on the productivity of researchers. The share of business R&D in total R&D (column 4) has a positive and significant impact on the productivity of researchers. 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) provides an interesting insight into the impact of the relative level of resources allocated to researchers. The positive and significant parameter suggests that more research expenses per researcher leads to a higher productivity. Two explanations can be put forward: i) more R&D expenses per researcher may witness higher wages, and hence 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.

Finally, the non significant parameter associated with SHBASR in column (7) suggests that the productivity of researchers does not depend on whether R&D activities are more oriented towards basic or applied research. As opposed to the type of institution performing R&D, the basic orientation of research activities do not witness more or less productive researchers.

Table 3: Univariate Cross-sectional Regression - Heterogenous Patent Practices: IP Policies

	(1)	(2)	(3)	(4)	(5)	(6)
Researchers						
ln Researchers	1.42 ***	1.42 ***	1.32 ***	1.42 ***	1.29 ***	1.41 ***
	(19.60)	(19.14)	(20.96)	(19.74)	(21.76)	(19.52)
Patent Practices (X_n)						
Patent policies						
ln FEES	-0.47 ***	-0.43 **	-0.23 **	-0.37 ***	-0.32 **	-0.45 ***
	(-3.60)	(-2.72)	(-2.39)	(-3.33)	(-2.67)	(-3.76)
EXAM (d)		-0.18				
		(0.65)				
IPI			0.66 ***			
			(3.85)			
IPCOV				1.18 **		
				(2.49)		
IPENF					1.10 ***	
					(3.41)	
IPRES						0.94 **
						(2.34)
Constant	-4.35 ***	-4.53 ***	-7.37 ***	-5.94 ***	-4.64 ***	-4.85 ***
R-squared	0.88	0.89	0.93	0.90	0.91	0.90
Number of observations	34	34	34	34	34	34

The dependent variable is the corrected number of national priority filings (PF) in 2003 (i.e. PF at national patent offices plus PF at the EPO and the USPTO by domestic applicants). The econometric method is Ordinary Least Square, 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, (d) a dummy variable. See Appendix Table A for the description of the variables and Appendix Table C for a list of the countries included in the sample.

The various estimates of equation (6), allowing for a varying propensity to patent, are presented in tables 3 and 4. The former table concentrates on the role of patent policy design and the latter on S&T policy design. Fees have a negative and significant impact on the number of patent filings, with an elasticity ranging from -0.23 to -0.53, which validates earlier results obtained by de Rassenfosse and van Pottelsberghe (2007) for the member states of the European Patent Convention (EPC). The price-elasticity of the demand for patents is inelastic (*i.e.* its absolute value is lower than one), with an increase of 10% in the cumulated administrative fees resulting in a drop of about 4% in the number of first filings.

Column (2) of table 3 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.[20] In columns (3) to (6), the role of the strength of the patent system is investigated. Column (3) presents the impact of the aggregated index of IP protection (IPI). It has a positive and significant impact on the number of filings: the stronger the IP system of a country, the more patents are applied for. A cautious interpretation is 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 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 report the impact of three out of the five individual components of the IPI index, namely the patentability of subject matters (IPCOV), enforcement mechanisms (IPENF) and restrictions on patents rights (IPRES); they all significantly affect patent practices.[21] A larger coverage in terms of subject matter logically leads to a larger propensity to patent: more patentable subject matters induce more patents per researcher at the country level. The positive impact of the enforcement index suggests that better enforcement mechanisms improve the perception of the effectiveness of patent systems and hence their attractiveness. Similarly, the smaller the number of restrictions, the larger the number of patent filings.

[20] A potential bias may arise if one considers that requesting an examination induces higher fees. When an interaction variable is introduced (FEES and FEES $\times$ 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.

[21] Data on membership in international patent treaties and length of protection exhibit a very small variance across countries and were therefore not included in the econometric analysis.

Table 4: Univariate Cross-sectional Regression - Heterogenous Patent Practices: S&T Policies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Researchers								
ln Researchers	1.57 ***	1.41 ***	1.38 ***	1.40 ***	1.34 ***	1.32 ***	1.57 ***	1.30 ***
	(17.20)	(21.57)	(22.39)	(23.09)	(20.03)	(17.10)	(14.83)	(15.31)
Patent Practices (X_n)								
ln FEES	-0.53 ***	-0.37 **	-0.32 ***	-0.34 **	-0.27 *	-0.26	-0.24	-0.26
	(-3.47)	(-2.84)	(-2.34)	(-2.39)	(-2.02)	(-1.37)	(-1.55)	(-1.66)
Technological Specialization								
AERO	-0.09 ***							
	(-2.90)							
ELEC		0.01						
		(1.03)						
COMPU			0.02 **					
			(2.33)					
PHARMA				0.00				
				(0.13)				
INSTRU					0.07 *			
					(1.93)			
R&D Type								
SHBRD						2.81 **		
						(2.30)		
DEF_GBOARD							-1.78*	
							(-2.03)	
SHBASR								-1.66
								(-0.89)
Constant	-5.25 ***	-4.95 ***	-4.87 ***	-4.90 ***	-5.00 ***	-6.31 ***	-7.30 ***	-4.04 ***
R-squared	0.94	0.93	0.93	0.92	0.93	0.93	0.90	0.89
Number of observations	24	24	24	24	24	24	24	22

The dependent variable is the corrected number of national priority filings (PF) in 2003 (i.e. PF at national patent offices plus PF at the EPO and the USPTO by domestic applicants). The econometric method is Ordinary Least Square, 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 description of the variables and Appendix C for a list of the countries included in the samples.

Table 4 presents the estimates of the model related to the impact of the design of S&T policies on patent practices, namely the technological specialization (columns (1) to (5)) and the type of R&D activities (columns (6) to (8)). The specialization in three high technology industries appears to have a significant impact on the propensity to patent. The more a country's research efforts are directed towards the aerospace industry, the smaller the number of patents applied for. This result confirms the common view that the aerospace industry has a relatively low propensity to protect its inventions with patents, preferring secrecy, first mover advantage or natural barriers to entry for instance. To the contrary, the instrument and computer industries account for a larger-than-average propensity to patent.

Column (4) provides an interesting insight into the patent practices of the pharmaceutical industry. One would indeed expect to find a positive and significant impact of a specialization in the pharmaceutical industry, but the estimated parameter is not significantly different from zero. Though it is widely accepted that the pharmaceutical industry heavily relies on patents to protect its inventions, the non significance of the parameter suggests that the effect at the country level is not observable. One explanation is related to the amount of resources needed to produce one patent in this industry: more inventions are patented, but more resources are needed to make one invention, leading to a mixed effect at the aggregate level. Another interpretation is that inventions in the pharmaceutical industry are frequently patented, but with a smaller number of patents.

Columns (6) to (8) are related to the type of R&D activities and their potential effect on patenting 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 (7) of table 4 suggest that defense-oriented R&D has a negative and significant impact on the propensity to patent, possibly due to 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 (e.g. a federal agency). An additional explanation is that this type of R&D is not directly related to market opportunities (cfr. Guellec and van Pottelsberghe (2004)). The share of basic research does not seem to affect the propensity to file a patent.

Several robustness tests were performed in order to validate these results.[22] First, an important specificity — and contribution to the literature — of the present paper is to use a corrected number of priority filings in each national patent office as the dependant variable. The parameters presented in the three previous tables were also estimated using the raw number of priority filings, which does not take into account the priority patent applications filed at the EPO and at the USPTO by foreign applicants (see column (1) Appendix Table D). The empirical results remained similar to the ones presented in table

[22]Results are available upon request.

2 to 4. It is however worth noticing that the impact of the productivity variables are more significant when the corrected number of priority filings is used as the endogenous variable. This result points out the importance of using a patent indicator as accurate as possible if one aims at assessing the innovative performance of countries.

Second, the parameters were also estimated on a smaller sample from which countries whose applicants use to file a significant part of their patents in foreign patent offices were excluded (Belgium, Canada, Switzerland, India, the Netherlands and Singapore). The results remained consistent.

Third, as discussed in section 3.2, a potential problem of using national priority filings relates to the differences of interpretation of patent counts, especially regarding Japanese and Korean applications which have on average much less claims per patent. Therefore, the regressions 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 table 2 to 4.[23]

5 Concluding remarks

The objective of this paper is 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 propensity to patent but would also signal differences in the productivity of researchers.

The empirical analysis is performed on a sample of 34 countries and relies on a unique dataset of national priority filings. The results suggest that both dimensions play an important role in explaining variation in countries' patenting performance. These dimensions, in turn, are heavily influenced by the design of several policy tools, including education, intellectual property (IP) and science and technologies (S&T) policies.

A higher level of education and a larger number of scientific publications per researcher are two factors which substantially contribute to improve researchers' productivity in a country, and hence their observed patenting performance. The positive impact of the two variables confirm 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.

[23] Since Japanese and Korean patents are virtually composed of three times more claims, it could be argued that patenting fees should be computed accordingly. Therefore, the econometric regressions were performed with Japanese and Korean fees multiplied by three and results remained broadly similar.

Regarding the propensity to patent, the design of IP systems matters. Several dimensions of a patent system, including the number of patentable subject matters, the restrictions, the 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. S&T policies, and in particular a country's specialization in some specific high technology industries, also explain differences in the apparent patent productivity of researchers through varying patent practices.

Three important policy implications may be drawn from these results. First, 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 backlog at the main patent offices, the present results suggest that national patent offices might use fees as a policy leverage.

Second, the other dimensions of the design of an IP system (*i.e.*, subject matter, enforcement mechanisms and restrictions to patent use) all substantially influence patent practices and hence the observed patenting performance of countries. These dimensions ultimately set up the framework that allows for, or even induces, the patenting strategies adopted by firms.

Third, the simultaneous impact of several other policies (*e.g.*, S&T and education policies) suggests that they interact not only with each other but also with IP policies. Such interactions call for a more coordinated approach, especially between the policies that directly influence the researchers' productivity and their propensity to patent.

The results presented here must be taken with some caution, as they are drawn from a macroeconomic, highly aggregated, approach. A panel data analysis would have provided some supplementary insights and a higher degree of freedom but major determinants such as the IP index or patenting fees 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. As far as a macroeconomic approach is concerned, our results suggest that patents 'also' reflect the research productivity of countries.

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A Variables description and data sources

Variable	Description	Source
Dependent variable		
$\dot{P}$	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). Cfr section 3.2 in main text for the methodology	PatStat (April 2007 edition), database maintained by the European Patent Office.
Research efforts (L_r)		
Researchers	Number of full-time equivalent scientists and engineers	UNESCO Institute For Statistics
Productivity (Y_m)		
HKI	Human Capital Index, calculated from the literacy rate, secondary enrolments and tertiary enrolments	United Nations World Investment Report 2005, p.291
SCIR	Number of scientific publications per researcher	ISI Web of Knowledge, Science Citations Index Expanded Database
S&T policies		
SHBRES	Researchers in the business sector as a percentage of total researchers	Unesco Institute for Statistics (UIS)
SHBRD	Percentage of total gross domestic expenditures on R&D performed by the Business Enterprise sector	OECD Main Science and Technology Indicators (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)
SHBASR	Basic research expenditures as a percentage of total research expenditures	OECD MSTI
Patent Practices (X_n)		
IP Policies		

Continued on next page

Table 5 - continued from previous page

Variable	Description	Source
FEES	Cumulated administrative patenting fees up to the grant in 2003, for the “average” patent, including filing, search, examination and granting fees. Cfr. 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 subsequent updates. Estimates for the year 2000 are used for the year 2003.
IPCOV	One category of the IP Index, taking the value of 1 if utility models, pharmaceutical products and chemical products can be patented.	Park and Wagh (2002)
IPENF	One category of the IP Index, taking the value of 1 if the country strongly enforces the law (availability of preliminary injunctions, contributory infringement pleadings, burden-of-proof reversals)	Park and Wagh (2002)

Continued on next page

Table 5 - continued from previous page

Variable	Description	Source
IPRES	One category of the IP Index, measuring protection against losses arising from three sources: working requirements, compulsory licensing and revocation of patents. A value of 1 indicates that the country protects against all losses.	Park and Wagh (2002)
Technological Specialization		
AERO	Technological specialization in the aerospace industry: share of business R&D expenses in aerospace as a percentage of total business R&D expenses	OECD MSTI
ELEC	Technological specialization in the electronic industry: share of business R&D expenses in electronic as a percentage of total business R&D expenses	OECD MSTI
COMPU	Technological specialization in the office machinery and computer industry: share of business R&D expenses in computer and office machinery as a percentage of total business R&D expenses	OECD MSTI
PHARMA	Technological specialization in the pharmaceutical industry: share of business R&D expenses in pharmaceutical as a percentage of total business R&D expenses	OECD MSTI
INSTRU	Technological specialization in the instrument industry: share of business R&D expenses in instrument as a percentage of total business R&D expenses	OECD MSTI

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	L.S.	T.S.	C. R&D
AT	Austria	x	x	-	x	-	x
AU	Australia	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
CN	China	-	-	x	x	-	-
CZ	Czech Republic	x	x	-	x	x	x
DE	Germany	x	x	-	x	x	x
DK	Denmark	x	x	-	x	x	x
ES	Spain	x	x	-	x	x	x
FI	Finland	x	x	-	x	x	x
FR	France	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	-
IE	Ireland	x	x	-	x	x	x
IN	India	-	-	x	x	-	-
IT	Italy	x	x	-	x	x	-
JP	Japan	x	-	-	x	x	x
KR	Korea	x	-	-	x	x	x
MX	Mexico	x	-	-	x	x	x
NL	Netherlands	x	x	-	x	x	x
NO	Norway	x	-	-	x	x	x
NZ	New-Zealand	x	-	-	x	-	-
PL	Poland	x	x	-	x	x	-
PT	Portugal	x	x	-	x	-	x
RU	Russia	-	-	x	x	x	x
SE	Sweden	x	x	-	x	x	x
SG	Singapore	-	-	-	x	-	-
SK	Slovakia	x	x	-	x	-	x
TR	Turkey	x	x	-	x	x	-
US	United States	x	-	-	x	x	x
ZA	South Africa	-	-	x	x	-	-
Total		28	20	5	34	24	24

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 large sample (L.S.). The smaller samples were then driven by data availability. "T.S." stands for the sample where information on technological specialization was available and "C. R&D" for the sample where data on characteristics of R&D was available.

D Patent filings and researchers, 2003

Country	PF (1)	PF Corrected (2)	[(1)/(2)] (3)	Researchers (4)	[(2)/(4)] (5)
AT	1,361	1,488	0.91	24	61.68
AU	12,985	13,192	0.98	73	179.86
BE	523	924	0.57	31	29.90
BR	4,472	4,531	0.99	60	75.72
CA	4,486	5,865	0.76	113	52.08
CH	1,346	2,856	0.47	26	110.66
CN	55,495	55,744	0.99	862	64.66
CZ	581	588	0.99	16	37.19
DE	45,637	48,456	0.94	269	180.17
DK	1,271	1,558	0.82	26	60.99
ES	1,965	2,196	0.89	93	23.73
FI	2,031	2,454	0.83	42	58.81
FR	14,576	15,718	0.93	193	81.53
GB	22,234	22,711	0.98	172	132.41
GR	444	453	0.98	15	29.43
HU	776	783	0.99	15	51.58
IE	362	410	0.88	10	40.84
IN	851	1,165	0.73	118	9.91
IT	4,869	5,990	0.81	70	85.17
JP*	112,679	115,584	0.97	675	171.15
KR*	28,793	29,125	0.99	151	192.56
MX	797	829	0.96	28	30.01
NL	2,298	3,387	0.68	38	89.30
NO	1,221	1,259	0.97	21	59.98
NZ	816	840	0.97	16	53.96
PL	2,432	2,435	0.99	59	41.56
PT	124	137	0.91	20	6.77
RU	23,396	23,431	0.99	410	57.18
SE	3,452	4,007	0.86	48	83.77
SG	365	611	0.60	20	30.51
SK	157	160	0.98	10	16.62
TR	314	339	0.93	24	14.13
US	190,538	178,804	1.07	1.335	133.97
ZA	1,222	1,232	0.99	14	86.87

(1) PF stands for (domestic) priority filings in 2003. * The patents counts for Japan and Korea were divided by 3. (2) PF corrected indicates the number of priority filings for each country (in column (1)), augmented with the number of priority filings at EPO and USPTO filed by domestic applicants. The data is extracted from the Patsat April 2007 edition, utility models are excluded; (4) Thousands of researchers reported.

E Other key data

Country	HKI (1)	SCIR (2)	FEES (3)	IPI (4)
AT	0.875	0.32	612	4.71
AU	0.971	0.28	576	4.19
BE	0.924	0.34	1,069	4.05
BR	0.579	0.22	639	3.05
CA	0.914	0.29	1,226	3.90
CH	0.799	0.54	1,062	4.05
CN	0.298	0.05	2,343	2.48
CZ	0.701	0.31	407	3.52
DE	0.810	0.24	444	4.52
DK	0.934	0.30	1,072	4.19
ES	0.895	0.27	762	4.05
FI	0.982	0.18	831	4.19
FR	0.877	0.24	542	4.05
GB	0.951	0.31	298	4.19
GR	0.794	0.38	564	3.19
HU	0.758	0.29	911	3.71
IE	0.848	0.40	575	4.00
IN	0.247	0.17	5,329	2.18
IT	0.789	0.49	200	4.33
JP	0.835	0.11	1,315	4.19
KR	0.866	0.13	1,513	4.19
MX	0.477	0.21	1,990	2.86
NL	0.904	0.49	421	4.38
NO	0.957	0.23	810	3.90
NZ	0.955	0.25	165	4.00
PL	0.867	0.21	309	3.24
PT	0.814	0.21	637	2.98
RU	0.817	0.06	3,554	3.52
SE	0.982	0.30	878	4.38
SG	0.621	0.23	1,450	4.05
SK	0.664	0.19	436	3.52
TR	0.355	0.42	2,097	2.86
US	0.905	0.17	2,373	5.00
ZA	0.475	0.25	106	4.05

(1) The human capital index ranges from 0 to 1, the maximum. (2) SCIR is the number of publications per researcher. (3) Patenting fees are expressed in 2003 US PPPs. (4) The IP index ranges from 0 to 5, the maximum.