Patent Office Governance and Patent System Quality

Pierre M. Picard* and Bruno van Pottelsberghe de la Potterie‡

University of Luxembourg and Université Libre de Bruxelles

24 January 2011

Abstract

The present paper discusses the role of quality in patent systems from the perspective of patent offices' behavior and organization. After documenting original stylized facts, the paper presents a model in which patent offices set patent fees and the quality level of their examination processes. Various objectives of patent offices' governors are considered. We show that the quality of the patent system is maximal for the patent offices that maximises either the social welfare or its own profit. Quality is lower for the self-funded patent office maximizing the number of patent applications and even smaller for the self-funded patent office maximizing the number of granted patents. A labor union improves examination quality and may compensate for the potentialy inappropriate objectives of patent office management.

JEL Classifications: L30, O30, O31, O34, O38

Keywords: Patent system, quality, intellectual property, public firm organization.

*CREA, University of Luxembourg, Luxembourg, and CORE, Université catholique de Louvain, Belgium. Email: pierre.picard@uni.lu.

†Université Libre de Bruxelles (ULB), SBS-EM, ECARES, CEPR and Bruegel. Email: bruno.vanpottelsberghe @ulb.ac.be.

‡The authors are grateful to Paul Belleflamme and Gaétan de Rassenfosse for their useful comments and remarks.

1 Introduction

Over the past century patent offices have evolved to very large and heavy administrations. To put some perspective, when the Venice republic passed the first-known law on intellectual rights in 1474, it organized a 'general welfare board' gathering some government officials and wise citizens to examine the usefulness of the inventions for the city. Similarly, in the US, after the Congress passed the first US patent law in 1790, the patent applications were initially reviewed by Thomas Jefferson who, at the time, was the Secretary of State and a prolific inventor. Jefferson simply passed the documents of accepted innovations to the Secretary of War for review and then gathered the signatures from the Attorney General and the President George Washington. Since then the rate of innovation and the stock of knowledge have drastically increased worldwide. As a consequence, the patent examination process requires large organizations, patent offices, with thousands of highly specialized professionals who search and examine the inventions submitted by an ever increasing number of firms engaged into industrial research and development, universities and independent inventors.[1]

For most economists, the central debate about patenting focuses on the protection of intellectual property, where a balance must be found between dynamic efficiency effect (worth to the public) and the static inefficiency effect (embarrassment) caused by the market power that patent systems grant to innovating firms.[2] However, the constant growth in patent filings and the consequent backlogs (longer pendency during the examination process) have drawn the attention of many observers on the nature and the cost of the examination process. In particular, it is questioned whether examiners should spend less time on the examination of patent files and whether the resulting lower quality and cost of the patent process is socially valuable. The question is of particular interest as two of

[1] To fix ideas, the USPTO receives more than 400,000 patent applications each year (this number has dropped with the crisis), of which a large percentage will be granted and potentially enforced. About 2 million patents are currently in force in the US.

[2] Thomas Jefferson (1794) penned perhaps one of the best-known maxims: "Patents should draw a line between the things which are worth to the public the embarrassment of an exclusive patent, and those which are not. Patents are, after all, government-enforced monopolies and so there should be some 'embarrassment' (and hesitation) in granting them".

the largest patent offices in the world, namely the US Patent and Trademark Office (USPTO) and the European Patent Office (EPO), have adopted opposite strategies. In the former the examination process is cheap and fast, with a low-to-medium relative quality of the examination process, whereas in the latter the examination is slower and more expensive, with a medium-to-high quality. The Japan Patent Office (JPO) is in an intermediate position (van Pottelsberghe, 2010). According to Lemley (2001) the USPTO performs 'rationally' a low quality examination, with too many patents per examiners. The author argues that only limited resources should be allocated to the examination process, because only a small share of patents are worth it economically. Indeed, the USPTO tackles about three times more applications per year than the EPO, with approximately the same number of examiners. However, more patents have been erroneously granted and fostered the perception of a bad quality in the US patent system, as convincingly demonstrated by Jaffe and Lerner (2004), amongst others.

The objective of this paper is to investigate the relationship between the governance of patent offices (in terms of organization and resources) and the quality of patent systems. As a point of departure one has to assume that the degree of quality in a patent system is important for patent holders. As emphasized by Ayres and Klemperer (1999), a patent is best viewed as a 'probabilistic' property right that gives the patent holder the right to sue potential infringers and a fair chance either to win the litigation in court or to reach a favorable agreement. So, it can fairly be assumed that the quality of the patent selection process reduces the uncertainty associated with the effective exploitation of granted intellectual property rights. King (2003) indeed shows that the examination hours spent on patent examination are statistically correlated with lower patent litigation activity. As a result, more examination time potentially lowers the transaction costs associated with enforcement of intellectual property rights. The present paper relies on this assumed positive relationship between the degree of quality in a patent system and the level of certainty associated with the granted patent.

The paper puts forward a model where each invention is supposed to be associated with an inherent and idiosyncratic uncertainty associated with the testing of the novelty condition with respect to the prior art, and a sufficient degree of inventiveness, called the inventive step at the EPO and non-obviousness at the USPTO. Some inventions are obvious, others are not. So, even with a comprehensive knowledge of prior art, effort and time, an examiner faces the risk of wrongly granting a patent; this risk is nevertheless smaller for "obvious" innovations. A high quality patent system can therefore be defined as the one that discriminates between inventions keeping the same inherent and idiosyncratic error risk. A medium quality patent system makes more errors and grants more than necessarily monopolistic rights to applicants. A zero quality patent system would always grant a patent and would simply consist in stamping and recording the patent application files.

Following King (2003), it can also be assumed that a better quality patent system is likely to be taken more seriously at the litigation stage by the Court. If the patent office offers a zero patent quality, the Court is unable to judge the true precedence and obviousness of a granted patent. The court will give no advantage to a patent holder and the patent will have no or little legal value for the latter. By contrast, if the patent office offers an excellent quality, the Court will more easily uphold the patent in case of a validity challenge by infringers, and will more likely rule the litigation in favor of the patent holder. In practice the link between quality of the patent system and patent value is confirmed by the fact that US patent owners frequently ask for re-examination of previously granted patents by the USPTO, in order to strengthen the certification offered by the initial patent and therefore increase the bargaining power during settlement or licensing negotiations. To sum up, the quality of a patent system contributes to the credibility of the certification process and therefore to the private value of patents and affects the demand for patent rights by firms.

Finally, the production function of patent offices, and hence examiners' behavior, also need to be formalized. In particular, it is assumed that the quality of the examination process is intrinsically subject to uncertainty in the sense that the inventiveness and breadth of some innovations remain impossible to assess with certainty. This is because the specification of a submitted patent may lie between the specification of existing patents that have no direct connection together. As a result, examiners cannot indefinitely narrow down the error risk of granting a wrong patent.

Given the properties explained above, the paper explores the behavior of patent offices that can set the fee and the quality of the examination process under budget neutrality. Patent offices can be managed under different objectives and contexts. This paper sequentially analyses offices run by benevolent social planers and compare them with the offices managed by directors who follow politician objectives such as increasing the number of patent applications or the number of granted patents.[3] The paper also considers the hypothetical case of offices with profit making objectives. The results suggest that the quality levels are too low under politician structures but may be appropriate in the monopoly setting. Finally, the paper analyzes the case of offices where politician directors negotiate examiner's working conditions with unions. In such a case the quality level can be closer to the social optimum if unions have enough negotiation power. The presence of union reduces the power of politician directors to favor quantity rather than quality of patents. Section 3 below discusses the reality of those contexts and objectives.

Related Literature This paper focuses on the role of patent offices' governance and organizational structure in the setting up of quality in patent systems. In this respect, it departs substantially from the mainstream 'patent' literature of the past 50 years. Early theoretical investigations into the role of patent systems originated with Barzel (1968), Nordhaus (1969) and Scherer (1972), who argued that stronger patent systems would induce more investment in research and development. Following these early theoretical investigations, most landmark papers have essentially focused on three major aspects of policy making: the optimal length, the optimal breadth (or the optimal combination of these two dimensions), and the optimal geographical scope of protection. For instance, Gallini (1992) analyses the optimal length of a patent as a function of imitation costs. Klemperer (1990) examines the optimal scope of protection, whereas Gilbert and Shapiro (1990) identify the optimal mix between length and breadth of patents. Scotchmer (1991) explores how patent scope may affect the speed of generation and diffusion of new knowledge in a context of cumulative innovation processes. A patent protection that is too strong could lead to socially inefficient monopoly pricing and might stifle second-stage R&D. On the other hand, a too small inventive step could lead to 'hold-up'

[3] For instance, the recently published intellectual property strategy of China has amongst its goals for 2015 a target of 2 million yearly applications of patents, utility models and design rights (cf. the document published in November 2010 by the State Intellectual Property Office of China, quoted by Steve Lohr, New York Times, January 1st, 2011).

problems, whereby a patent granted for a small increment would actually provide more power to large resourceful imitators.

So far, however, it seems that the status-quo has prevailed in the "examination field", with little noticeable changes since the landmark contribution of Penrose (1951) and Machlup (1960): "If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it".[4] Recent studies on the effectiveness of patent systems seem to flourish, apparently in correlation with the recent boom in patent applications and criticisms to it (Jaffe and Lerner, 2004; Guellec and van Pottelsberghe, 2007; Bessen and Meurer, 2008). The present paper takes an alternative – and novel- approach to analyze the effectiveness of patent systems and the degree of quality in the examination process.

Few authors have discussed the optimal quality in patent systems. Lemley (2001) advocates for low standards of patent examination on the ground of the 'rational ignorance principle'. As the vast majority of patented inventions do not lead to successful products in the market place, it may be preferable to ignore them and wait for the small number of contentions in the product market and organize their resolution in Court. This argument is contested by King (2003), who suggests that a low quality examination would increase the uncertainty associated with the granted patents in case of litigation. One of the few authors who explicitly consider patentability requirement is O'Donoghue (1998). His theoretical model suggests that more stringent selection criteria would create longer incumbency and, thereby, would raise innovation incentives. Dewatripont and Legros (2008) show that litigation threats contribute to reducing the propensity to file low-quality applications, while they also hinder the production of strong patents. One method of reducing this negative side effect would be to sharpen the filtering process. Farrell and Shapiro (2008) also emphasize the importance of filtering, as they find that determining patent validity prior to licensing is socially beneficial.

The present paper models the trade-off between the cost of patenting and the uncertain benefit of

[4] This quotation is often attributed to Machlup [1958, p. 80]. It however appears that Machlup was in fact quoting Penrose [1951], according to Bronwyn Hall and Josh Lerner.

the patented invention after the grant date. Caillaud and Duchêne (2005) and Langinier and Marcoul (2003) consider the complexity and cost of information processing during the examination process, which creates a social cost of granting bad patents. Their main concerns relate to the efficiency of 'equal treatment' of patent applications and to the possibility of bad equilibria in which patent offices are attacked by firms that file inefficiently high numbers of bad patent applications. Gans et al. (2003) model the self-funded offices and compare their outcome to the social optimal one. None of these papers discusses the impact of the objectives of patent office's governors and examiners, or the role of governance, in the setting-up of the quality level in patent systems.

The paper is organized as follows. Section 2 presents new and original stylized facts about patent offices that motivate our analysis. Section 3 presents the model and Section 4 discusses the demand for patents. Section 4 studies the production of patents under various contexts and objectives. Section 5 discusses unionized offices. Section 6 concludes.

2 Stylized facts about patent offices

This section presents stylized facts on differences between the U.S. Patent and Trademark Office (USPTO), the European Patent Office (EPO), and the Japan Patent Office (JP0). The five following tables subsequently describe the demand for patents, the examination resources, the workload of examiners, their incentives and the governance structure of patent offices. A first stylized fact is that there is a much higher propensity to file patents at the USPTO than at the two other offices. Table 1 displays the demand for monopolistic rights in the three offices, in both absolute and relative terms. The demand can be measured either with the total number of patents filed or with the number of claims included in these patents. The latter indicator takes stock of the patent size in terms of claims, which significantly differs across patent offices. The average patent filed at the JPO includes about 9 claims, whereas a US patent includes up to 24 claims. In other words the average patent granted by the USPTO provides a larger scope of protection than the average patent granted by the JPO. With 448,000 applications in 2008 (nearly 11 million claims), the USPTO faces the largest number of filings. The demand for patents at the EPO is 51% of the demand at the USPTO (38% in terms of claims). Although the JPO and USPTO file a similar number of patents (391 and 448), the number of claims filed in Japan falls to 33% of the U.S. level because of a smaller coverage of patents in Japan. In other words, the demand for patent rights, as measured by the number of claims filed, is much higher at the USPTO than at the EPO or JPO, which both receive less than 40% of the USPTO yearly workload.

	EPO	JPO	USPTO	EU/US	JP/US
Patents filed (000s)	227	391	448	0.51	0.87
Aver. number of claims per patent	18[a]	9	24	0.75	0.38
Total claims filed (000s)	4,083	3,519	10,752	0.38	0.33
Patents filed per 1000 capita	0.4	3.1	1.5	0.27	2.10
Claims filed per 1000 capita	9	30	35	0.26	0.86
Claims in force per 1000 capita	13[b]	91	150	0.09	0.61

Table 1. Demand for monopolistic rights: patents and claims, 2008.[5]

As the EPO covers a much larger market than the USPTO or JPO, the demand per capita is probably a better measure. It is the highest in the US and the smallest in Europe, Japan being in an intermediate position (see the claims filed per capita in Table 1). The consequence of the heterogeneous propensities to rely on patent systems can also be gauged with the number of "claims

[5] Comments for Table 1: *a.* The average number of claims for patent filed at the EPO vary according to the type of patent. PCT applications include much more claims (about 23 per patent), whereas the "regional applications" (those for which the applicant wants the EPO to perform a substantive examination) include 15 claims on average. For the sake of simplicity we rely on a number of 18 claims per patent filed at the EPO.

b. The number of claims in force per 1000 capita in Europe is based on the total number of claims in force in Germany (were more than 90% of the patents granted by the EPO are validated), relative to the EU population. Source: national patent offices, trilateral statistical report and information provided by patent offices for the number of claims (cf. de Rassenfosse and van Pottelsberghe, 2008). The number of capita comes from the OECD/MSTI database. The number of patent in force is from WIPO statistical series (2009).

in force" per capita in a geographical area, where then "claims in force" are measured as the number of previously granted patents that are maintained in the country. This measure is presented in the last row of Table 1. The number of claims in force per capita is much higher in the USA (about 150 claims per 1000 capita) than in Japan and Europe, which are respectively at 60% and 10% of the US level. This very low ratio for Europe is partly explained by a stricter selection process at the EPO (van Pottelsberghe, 2010) and by the higher costs that follow the decision to grant a patent. In particular, once a patent is granted it must be enforced in each desired country, implying translation costs, validation fees and renewal fees in each desired country (van Pottelsberghe and Mejer, 2010).

A second stylized fact is that examination fees are larger in Europe. Fees and examination resources are presented in Table 2. The cumulated fees from the filing to the decision to grant a patent[6] are the most expensive in the E.U. and the cheapest in the USA and Japan. The cumulated fees for an average patent are more than four times higher at the EPO than at the USPTO. This is true whenever this charge is accrued per filed patent or per filed claim. For instance, the examination of a patent filed at the EPO would cost about USD 9,348 (more than USD 500 per claim), against USD 2,325 at the JPO (USD 258 per claim) and USD 2,426 at the USPTO (USD 101 per claim). Such differences have persisted for a significant period of time (de Rassenfosse and van Pottelsberghe, 2008). In the E.U., additional translation costs into national languages and patent renewal fees in national markets further increase the difference in the firms' cost for patent filing.

Because patent offices are "officially" non-profit organizations, the firms' cost of filing patents can also be assessed with the patent offices' revenues or budgets. Patent offices receive various payments like filing fees, examination fees, renewal fees and ancillary procedures. The offices' budgets per filed patent or claim are higher than the cumulated examination fees because the former include renewal

[6] Cumulated fees include filing fees, search fees and grant fees (any fees that must be paid up to the grant of a patent. The total budget is also composed of the renewal fees income, which explains why the budget per file is higher than the cumulated fees per file in Japan and the US. At the EPO the budget per file (claim) is lower than the cumulated fees per file (claims) because the EPO performs much more PCT searches (not all PCT applications are transferred as regional applications), at a fee which does not compensate for the costs incurred (see Danguy and van Pottelsberghe, 2010).

fees and ancillary procedures. This is however less true for the EPO, which must process many applications under the Patent Cooperation Treaty (PCT), and which receives half the renewal fees collected by national patent offices in Europe (Danguy and van Pottelsberghe, 2010). However, both the fees per claim and budget per claim yield the conclusion that the EPO and the JPO allocate two to three times more examination resources per patent or per claim than the USPTO. In other words, the USPTO seems to allocate at least twice less resources to examination than the JPO or EPO.

2008, USD	EPO	JPO	USPTO	E.U./US	JP/US
Cumulated fees per filed patent	9,348	2,325	2,426	3.9	1.0
Cumulated fees per filed claim	519	258	101	5.1	2.6
Budget per filed patent	7,527	3,042	3,627	2.1	0.8
Budget per filed claim	418	338	151	2.8	2.2

Table 2: Cumulated patent fees and office budget per patent, 2008

Source: Own calculation from annual reports of patent offices, de Rassenfosse and van Pottelsberghe (2008) and van Pottelsberghe and Mejer (2010).

A third stylized fact is that examiners at the USPTO process more patent applications than at the EPO or JPO. This is shown in Table 3, which provides alternative measures of the workload per examiner. The number of claims 'searched' (search for prior art) per examiner, and the number of claims 'examined' (examination for inventiveness) per examiner can be used as indicators of examiners' workload and as very rough approximation of their productivity. The figures must take into account the fact that in Japan the examiners do not perform the search report, which takes at least 50% of the time of the average examiner at the USPTO and EPO. The 'equivalent workload' indicator, which adds the claims searched and the claims examined per examiner are similar in Japan and Europe (between 1,400 and 1,700 claims per examiner each year), but is less than 50% the workload of an average US examiner. In terms of claims granted, the average EPO (JPO) examiner 'grants' each year 45% (79%) of the number of claims granted by the average USPTO examiner.[7]

[7] The JPO has a higher ratio than the EPO for granted patents partly because the grant rate of examination requests is higher in Japan than in Europe. This is due to the fact that applicants in Japan have three years to request

In a nutshell, be it in terms of incoming workload per examiner, or outgoing (granted claims per examiner), the average USPTO examiner processes at least two times more patents or claims each year than the average EPO or JPO examiner.

Workload per examiner	EPO	JPO	USPTO	E.U./US	JP/US
Claims filed (inc. PCT)	1055	2095	1776		
Claims 'searched'	1055	outsourced	1776	0,59	-
Claims examination request	642	1406	1776	0,36	0,79
Claims granted	278	857	613	0,45	1,40
Equivalent workload					
(claims searched + examined)	1698	1406	3551	0,48	0,40

Table 3. Workload per examiner, 2008

Source: Own calculation from annual reports of patent offices and de Rassenfosse and van Pottelsberghe (2008) for claim numbers.

The above measures of workload or productivity do not seem to be positively correlated with incentives. Another fact is indeed that E.U. and Japanese patent offices offer more attractive compensations to their examiners. In 2008, a typical USPTO examiner earns a civil servant GS12 (step 5) gross salary of about 87,000 USD with some 24% locality adjustments that are subject to federal and state taxation.[8] By contrast, the EPO offers one of the most comprehensive and family-friendly benefits packages in Europe. The offer comprises an internationally competitive basic salary that is exempt from national income tax. The 2009 gross salary for an A4 step 2 examiner (there are 7 grades under the President, and 13 steps per grade) is of about 120,000 EUR (or about 160,000 USD) and is not subject to state taxation. In addition, EPO employees receive excellent social security

an examination, against 18 months at the EPO. This longer period leads to more stringent self-selection process in Japan and hence to higher quality patents submitted for examination (see Yamauchi and Nagaoka, 2009). Since it takes less time to grant a patent than to refuse it, examiner in Japan turn out to grant more patent each year.

[8] See http://www.popa.org/txt/salary2008.txt.

coverage, medical insurance, and pension and saving plans and benefit from several other attractive allowances.[9] In Japan a 35 years old examiner being married and having one child would earn more than 7 million YEN (or 81,772 USD) per year, subject to taxation. He/she also receives insurance packages and support for lodging expenses (through dormitories facilities or financial allowance for apartment rental, up to 334,000 YEN each year).

The variety in compensation packages makes comparisons difficult. An alternative approach is presented in Table 4, which compares each office's compensation budget and reports it in terms of the numbers of examiners and total staff (the staff/examiners ratio lies at about 1.65 in all offices). This provides us with a higher and a lower bound for the examiners' gross compensation packages. To ease comparison, those bounds are presented in US PPPs. At the USPTO, the total compensation per staff of 106,272 US PPPs roughly corresponds to the gross salary mentioned above. Given that the tax wedge is much smaller for the EPO examiners, the figures in Table 4 confirm the fact that the EPO offers much more attractive compensation packages than the USPTO. According to this metric, it also seems to be the case for the Japan Patent Office, which devotes even more resources per examiner than the EPO.

US PPPs, 2008	EPO	JPO	USPTO	E.U./US	JP/US
Tot. Compensation/examiner	286,514	342,914	167,052	1.72	2.05
Tot. Compensation/staff	165,779	198,654	106,272	1.56	1.87

Table 4. Budget/incentive per examiner

Source: Own calculations from the annual reports of patent offices.

We may now attempt to draw some conclusions about the quality of the patent process. Combining the above information, it is more convenient to measure patent quality through the inputs in the patent office: work time and on-the-job experience. In a perfect labor market, the fact that EPO

[9] The EPO offers allowances for expatriation (16-20%), installation (a month salary), household (up to 6%), dependent children, child education (international schools fees), learning languages (fluency in English, French, German and other languages is frequent).

examiners process a smaller amount of patent applications and are better paid implies that EPO gives more time and more incentives to their examiners and that it allows for a higher quality in the patent examination process. This conclusion is corroborated by the staff turnovers and job experience in each office (van Pottelsberghe, 2010). Indeed, whereas the EPO and the JPO have a very small staff turnover, the USPTO has an annual staff turnover of about 30% in 2008. Although this difference can be partly explained by more attractive compensation packages, it also gives evidence of a much longer job experience of EPO or JPO examiners. This discussion may give ground to the idea that the patents granted by the EPO are of a higher quality in the sense that their assessment is made in a more rigorous way.

Higher compensations may arise from various reasons. Labor economics points out unionization as an important cause of high wages. An important issue therefore relates to the examiners' potential power on the decision process of their institution. The EPO is an international independent institution, whose staff includes civil servants with an international status. As said before, staff turnover is low. Examiners have two forms of representations within the institution: the staff committee that has a consultative voice in the EPO board and the SUEPO union to which 50% of staff adhere. Contrary to the staff committee, SUEPO is an independent institution that is well funded and takes independent initiatives for study, publicity and negotiation. The union has participated in negotiations on workers' compensation and has contributed to the public debate on patent quantity vs. quality. Examiners have occasionally engaged in collective actions, for instance in 2006 against a new examiner reporting system. The USPTO is an agency in the United States Department of Commerce that employs examiners as national civil servants. Examiners are represented by the POPA union (Patent Office Professional Association) that has negotiated on issues about tele-work, offices, and equitable treatment. It currently negotiates the examiner current Performance Appraisal Plan and is strongly interested in the discussion about quality so that "quality measure looks at examiner performance in a more realistic encompassing manner" (POPA news June 2010 Vol. 10 No. 3, p. 2).

It is important to shortly discuss the mission and governance of patent offices. In most cases, the patent offices' mission statements are limited to commitments to appropriate framing of intellectual property rights and to contribute to innovation, competitiveness and growth. The mission usually includes administrative functions such as the search and examination process of patent disposals as well as advisory functions to government ministries about intellectual property right. In this sense, the offices can be seen as setting and justifying their objectives by themselves.

	USPTO	EPO	JPO
Contract	Domestic civil servant	International civil servant	Domestic civil servant
Union representation		Sit on board	
Tenured contracts	Not before two years	6 month probation	6 months probation
Union organization	POPA	SUEPO	Union of METI
Severance clauses	YES	YES	YES
Unionization rate	na	50%	23% in all METI
Personnel turnover	25-33%	3-5%	0-3%

Table 5. Governance and unions in patent offices

The governance structure has also implications on the formulation of the institutions' objectives. In particular, the EPO is an international organization directed by a board (called European Patent Organization) that gathers representatives of national patent offices (or contracting States). As an intergovernmental organization, the EPO is required to balance its budget because contracting States are obliged (but reluctant) to finance any deficit. The governance structure is prone to conflict of interest on the one hand because some national patent offices are somewhat competitors for patent filing and on the other hand because national patent offices receive the proceeds of renewals of the patents granted by the EPO. The board could therefore be criticized to favor quantity over quality of patents because this strategy is expected to raise national patent offices revenues and maintain their national demand for patents. Recently, the board has attempted to reduce the backlog and has promoted productivity measurement systems, by putting more pressure on the shoulders of examiners.

The USPTO has a quite different governance structure. The USPTO is a federal agency of the U.S. Department of Commerce that is fully funded by the fees since 1991. It is led by the Director of the USPTO (who directly becomes Under Secretary of Commerce for Intellectual Property). This person is appointed by the President (heard and confirmed by the US Senate) and directly reports to the Secretary of Commerce. He/she is responsible for providing policy direction and management supervision for the USPTO and for the issuance of patents and registration of trademarks. Since 1991, USPTO directors were outsiders of the USPTO and have changed according to the changes in federal administrations. As a result, one may infer that USPTO directors are linked to current federal administrations and their political agendas. Similarly, the JPO is an agency of the Japanese Ministry of Economy, Trade and Industry and is led by a commissioner.

To conclude, the above stylized facts establish that the EPO processes fewer patents and claims per capita and per examiner, pays higher compensations and provides a better patent quality. The purpose of the following sections is to frame the relationships between those features. Towards this aim, we discuss a model of patent office where examiners produce patents with a quality level that affects the agents' confidence about the protection warranted by patents.

3 Model

In this model we assume a unique patent office and a set of firms or individuals that have an invention to patent and to potentially submit to the market place. Those agents enter into a five period game. In the first period, the patent office sets a (uniform) fee $f \in R^+$ and a quality standard for the patent systems $q \in [0, 1]$. The patent office receives patent applications and asks its examiners to investigate whether the inventions described in the applications are patentable (i.e., not obvious and unknown in the existing body of knowledge, or"prior art"). We assume that it costs nothing to deliver a patent with zero quality; that is, stamping, copying and archiving the application forms involves no examination cost. It however costs more in term of examiners' attention and training to check the obviousness and the inventive steps of patent applications. For the sake of simplicity, we assume that the unit cost of a patent application does not depend on the number of applications that are scrutinized by the patent office. In this sense, there are constant returns to scale in the patent examination process. This fits the fact that patent offices usually are "flat" organizations with a few hierarchy layers. We also assume constant returns to scale in quality. The patent office requires $l = q$ ($q \leq 1$) units of examiners' time to process a patent application. Hence, the unit cost to process a patent application is equal to $wl = wq$ where w is the examiner's wage.

In the second period, a unit mass of firms is endowed with an invention each. Inventions differ with respect to their specific *inventiveness probability* $b \in [0, 1]$, which captures the inherent and idiosyncratic uncertainty that technical knowledge embodied in the invention is patentable, i.e. not obvious and novel with respect to the existing knowledge (or "prior art") and that it has no close substitute in any other technological fields. In other words, an invention has a strong inventiveness probability b when it is very much likely to be recognized as patentable, or novel and inventive. In particular an invention with $b = 1$ would be granted with probability one by an examiner who has full knowledge, full expertise and infinite time to process the patent file. An invention with $b = 0$ would be granted with zero probability by the same examiner. Following Friebel, et al. (2006, p. 22) one can relate the inventiveness probability to the breadth of an invention: "if one thinks of the range of technologies and possible products in spatial terms, patent breadth refers to the "territory" in this space over which the patent-holder has exclusive control". So, the inventiveness probability is related to the ease to grasp the set of application fields for which the invention constitutes a 'prior art'. For the sake of simplicity we assume that the inventiveness b is uniformly distributed across inventions. For the sake of conciseness and with some abuse of language we will shortly call b the 'inventiveness'. Each firm is uniquely determined by its inventiveness and can simply be indexed by b.

In the third period, each firm chooses whether to apply for a patent in the patent office. If it does, the firm pays the patent application fee f plus a drafting cost c that corresponds to the cost of collating and presenting the information on its invention in a format appropriate for the patent office. The patent office then examines the novelty and inventiveness of the proposed invention and may decide whether to grant a patent or not. In practice, judging an invention is a complex process and can be subject to assessment errors. In this paper we abstract from the modelling of information processing (as is done in Caillaud and Duchêne, 2005; and in Langinier and Marcoul, 2003) and rather focus on the governance structure of patent offices. Examiners are more likely to grant patents to inventions with higher inventive step. Their search for prior art and examination are however imperfect so that some significant inventions may fail whereas some inventions with a weak degree of inventiveness can successfully pass the patent examination process. For simplicity, we assume that a firm with inventiveness b will have its patent granted with the probability $p(q, b) = (1 - q) + bq$. When the patent office offers no quality in delivering the patents ($q = 0$), all applications are patented ($p(0, b) = 1$). The patent office is just stamping and archiving the application. By contrast, when the patent office sets a higher quality level, it is more likely to grant patents to inventions with stronger inventiveness. When it sets the maximal quality ($q = 1$), the probability of granting a patent is strictly proportional to the inherent and idiosyncratic uncertainty b ($p(1, b) = b$).

In the subsequent time periods, the invention is developed, brought to the market and possibly challenged by a competitor. We describe the subsequent events according to whether the firm has applied for and/or has a patent granted. Suppose that the firm has its patent granted. In the fourth period, the firm works on the product design and marketing strategy with some uncertainty. With probability $(1 - \alpha)$, the invention gets no market value. However, with probability α, the invention has a market value $v = 1$ and the firm enters in the last period. In the last time period, the firm is able to collect the value $v = 1$ of its invention in the product market only with some probability $(1 - \beta)$. By contrast, with probability β, it faces a potential competitor who challenges the firm's ownership over its invention. There are many ways to challenge existing patents. The challenger may hold a patent that includes technical knowledge that precedes or is close to patented invention b; it may hold a patent that pertains to an application field unrelated to patent b; or it may not hold any patent and claim that the patent is simply not valid. In any case, the main reason of the contention lies in the patent office's difficulty of ascertaining the exact inventiveness of the invention.

Nevertheless, in this setup, higher quality patent systems deliver more accurate information about inventiveness. The only way to solve this challenge is to go to court (or negotiate) with a bunch of lawyers. Importantly we assume that the judge (or jury) is sensitive to the quality of the patent system q and is more likely to settle the case in favor of the firm holding the patent when the patent system is reputed to have high quality. For instance, Fisher (2010) observes that in German Courts there is a lower probability to challenge patent validity when it is delivered by the EPO, as opposed to those granted by other patent offices. Hence, patent quality translates to patent strength as in Farrell and Shapiro (2005); stronger patents are more likely to be validated in Court. Also, the judge (or jury) is sensitive to the clarity, x, of the explanations delivered by challenged firm's lawyers whose costs are given by the quadratic function $x^2/(2\gamma)$. The lawyer cost is therefore inversely proportional to the parameter γ. For the sake of analytical tractability, we assume that the judge (jury) grants a winning case to the patent holder with a probability equal to $P(q,x) = x\sqrt{(1+q)/2}$. Hence, the patented firm receives more protection when it receives a patent of higher quality. Note that the set of three parameters (α, β, γ) reflect the elements of Lemley's 'rational ignorance principle'. Patented inventions may have a high probability of being associated with a large market value (high α), a high probability to be challenged (high β) and high trial costs in case of contentions (low γ).

Suppose on the other hand that the firm has been refused a patent or has not applied for a patent. The firm faces the same events as before except that its probability to win a challenge case is smaller. In the fourth period, the firm gets a market value $v = 1$ with probability α and enters in the last period where, with probability β, it faces a potential competitor who challenges the ownership over its invention. Since it holds no patent, the judge (or jury) grants a winning case to the firm with a probability equal to $P(0,x) = x\sqrt{1/2}$. Hence, the firm receives less protection when it does not receive or apply for a patent.

In the following sections, we first determine the demand for patent examination and then discuss the production of patents by patent offices according to various governance structures. We finally study the case of a unionized patent office.

4 Demand for patents

Let the fee and the quality of a patent be denoted by f and q. We solve the above game backward.

In the last period, the firm can face a challenge over the ownership of its invention. The firm has a product market value $v = 1$ and selects the optimal effort x in lawyers that maximizes its expected profit $1 * P(q, x) - x^2/(2\gamma)$. The optimal effort is $x^* = \gamma\sqrt{1+q}/\sqrt{2}$ and yields an expected profit of $\gamma(1+q)/4$. Hence, before the possibility of a challenge over ownership, the firm has an expected profit of $(1-\beta)+\beta\gamma(1+q)/4$. When the firm holds no patent for its invention, it gets a profit equal to the latter expression where q is set to zero. In the fourth period, the firm has a probability α to develop the market value v for its invention. So, before the realization of this event the expected profit is equal to $V(q) \equiv \alpha[(1-\beta)+\beta\gamma(1+q)/4]$.

In the third period, the firm may file a patent. A firm with inventiveness b receives a patent with the probability $p(q, b)$ and has an expected profit equal to $p(q, b)V(q) + (1 - p(q, b))V(0) - (f + c)$ when it files an application, whereas it gets $V(0)$ when it does not. The firm b applies for a patent if the former profit is larger; that is, if

$$p(q, b)[V(q) - V(0)] \geq (f + c) \iff b \geq \widetilde{b} \equiv -\frac{1-q}{q} + \frac{1}{a}\frac{f+c}{q^2},$$

where

$$a \equiv \frac{1}{4}\alpha\beta\gamma.$$

The firm indifferent to apply for a patent has an inventiveness equal to $\widetilde{b}$. The parameter a measures the *net benefit of holding a patent*. It increases with larger probabilities of a successful market reach (higher α), with stronger likelihood of being challenged (higher β), and with smaller lawyers' cost (higher γ).

For the sake of simplicity it is now assumed that

$$c > a/4. \tag{1}$$

This assumption implies that the drafting cost c is always above the expected value of the invention with zero degree of inventiveness ($b = 0$). Under this assumption, we get that $f + c > aq(1 - q)$

for all (f,q), that is, $\widetilde{b} > 0$ for all (f,q). This assumption allows us to avoid corner solutions in the demand function. Hence, any firm holding an invention with higher inventiveness than $\widetilde{b}$ applies for a patent. One then readily derives the following demand for patents:

$$D(f,q) = \max\left[0, \frac{1}{q}\left(1 - \frac{f+c}{aq}\right)\right].$$

This demand for patents (or the number of patent applications) increases with smaller patent fees (f). It increases in q if $q < 2(c+f)/a$. The above expression has an intuitive interpretation. The term $1/q$ in front of the parentheses relates to the screening effort performed by the patent office. A higher quality of the patent system implies a smaller probability of receiving a patent and therefore decreases the number of patent applications. By contrast, the term aq in the parenthesis relates to the expected benefit from patent protection. A higher quality in the patent system increases this protection and therefore the number of patent applications. The demand for patents therefore increases with larger *net benefit of holding a patent a*. Indeed, the demand increases with larger a, i.e., with larger success probabilities of marketing inventions and fewer challenges and smaller lawyers' costs.

The impact of the patent system's quality is also easy to understand by observing the inverse demand function F:

$$F(D,q) \equiv aq(1 - Dq) - c$$

where D is the number of patent applications. The firm with the largest inventiveness ($b = 1$) has the highest willingness to pay the fee in exchange of an examination: $F(0,q) = qa - c$. This willingness to pay increases with the quality of the patent system. Indeed, when q rises, this firm benefits from both the rise in the probability of getting a patent and the better protection against future competitors' challenges. By contrast, the firm with the lowest inventiveness ($b = 0$) has a willingness to pay equal to $F(1,q) = aq(1-q) - c < 0$. This firm never applies for a patent. Firms with intermediate inventiveness have a willingness to pay, $aq(1-q) - c$, which increases for small q and then decreases for high q. They therefore face a trade-off: when the quality of the patent system rises at small levels (small q), applying for a patent becomes more valuable because it offers more protection. However, when the quality is large and rises (large q), applying for a patent becomes less valuable because the patent office is more likely to discriminate against their inventions.

Finally, we derive the (expected) number of patents granted by the patent office:

$$B(f,q) \equiv \int_{\tilde{b}}^{1} p(q,b)db = \frac{1}{2q}\left[1 - \left(\frac{f+c}{aq}\right)^2\right].$$

The number of patents granted is then a decreasing function of the fees f. Note that $B(f,q) < D(f,q)$.

5 Production of patents

The budget of the patent office is given by its profit, i.e., its revenues minus its costs. Formally,

$$\Pi(f,q) = D(f,q)\,(f - wq)\,.$$

It is worth discussing three benchmark organizations of patent offices. The first organization is controlled by a social planner, the second by a profit maximizing manager and the third by politicians who maximize either the number of patent applications or the number of patents granted. In a final stage the impact of labor unions is investigated.

5.1 Social optimum

Suppose that the quality is chosen by a social planner who maximizes the aggregate net surplus from the patent system.[10] The planner knows each firm's inventiveness parameter b and takes the judicial system as given. Let the index function $\theta(b) \in \{1,0\}$ indicate whether the firm b is admitted to apply for a patent. The social planner chooses the index function $\theta(b)$ and quality q that maximize the following aggregate net surplus:

$$W = \int_0^1 \theta(b)\left\{p(q,b)V(q) + (1-p(q,b))V(0) - wq - c\right\} + (1-\theta(b))V(0)db$$

[10]Note that lump sum transfers (subsidy or tax) are permitted to the patent office.

where the social cost per application is equal to the sum of labor cost wq and drafting cost c. The optimal number of applications implies that $\theta(b) = 1$ if and only if

$$p(q,b)\left[V(q) - V(0)\right] \geq wq + c \iff b \geq b^o \equiv -\frac{1-q}{q} + \frac{w}{aq} + \frac{c}{aq^2}.$$

By assumption (1), $b^o > 0$. Note also that the cut-off b^o decreases in q for any $b^o \leq 1$. Using the value of $\theta(\cdot)$ and b^o and using the definition of p and V, we get

$$W = \frac{1}{2a}\left(a - w - c/q\right)^2,$$

which increases in quality q. So, the socially optimal quality is the corner solution:

$$q^o = 1.$$

The social planner chooses to implement the highest quality for the patent office and therefore does not add any noise in the examination process. This is because examination costs obliges her to screen out inventions with low inventiveness. The office then examines the inventions that have larger inventiveness and therefore higher benefits from quality. Indeed, a firm b's marginal benefit from a quality increase is equal to $\frac{\partial}{\partial q}\left\{p(q,b)\left[V(q) - V(0)\right]\right\} = 1 + 2(b-1)q$, which is larger for higher b. Because inventions with larger inventiveness bring larger welfare improvements from a same quality increase and reputation of the patent office, the planner is enticed to rise the quality to its maximal level.

The socially optimal number of patent applications is

$$D^o = 1 - b^o = \frac{a - (w+c)}{a}.$$

The socially optimal (expected) number of patents granted is given by

$$B^o \equiv \int_{b^o}^{1} p(q^o, b)db = \int_{b^o}^{1} bdb = \frac{1}{2}\left[1 - \left(\frac{w+c}{a}\right)^2\right].$$

There will be a non zero mass of firms applying for patents if $a > w + c$. For the sake of simplicity it is now assumed that the socially optimal number of patent applications is positive. That is,

$$a > w + c. \tag{2}$$

This condition guarantees that the cost of processing the application of the firm with the highest inventiveness is lower than the value of its invention.

Two additional remarks are worth it. First, the social planner has the possibility to decentralize this allocation by setting a fee such that the demand for patent examination is equal to its socially optimal level: $D(f, q^o) = D^o$. This implies that $f^o = q^o w = w$; and the patent office makes no positive profit on applications. Because the office has constant returns to scale, the social planner's decision is both an unconstrained optimum and a budget constrained optimum for quality. Second, in this model, we do not focus on the discrepancy between private value and social value of inventions frequently emphasized in the patent literature. Adding such a discrepancy in the present model would increase the planner's value of invention to $\overline{a}$ ($\overline{a} > a$) and would therefore give incentives to maintain the top quality of patent system $\overline{q}^o = 1$. It would also raise further the socially optimal number of examinations to $\left[\overline{a} - (w + c)\right] / \overline{a}$ above the demand D^o so that the examination fee should be set below its cost and the office should be subsidized. However, most patent offices seem to adopt the constraint of budget neutrality.

5.2 Profit oriented patent office

We here suppose that the patent office is delegated to a private firm (or manager) that maximizes the office's profit. Although there exists no example of such a profit oriented patent office, it is instructive to discuss the optimal quality chosen by such an organization

Let the patent office maximize

$$\Pi(f, q) = D(f, q)\,(f - wq)\,.$$

For any quality q, the optimal fee is $f^m = \frac{1}{2}(aq + qw - c)$. The demand for patent examination is then $D(f^m, q) = (aq - wq - c)/(2aq^2)$ which is positive if $a > w + c/q$. The profit then writes as $\Pi(f^m, q) = (a - w - c/q)^2 / (4a)$, which increases in q for any positive demand. The monopoly's maximizing quality is then equal to $q^m = 1$. The number of applications is equal to

$D^m = (a - w - c) / (2a)$ and the expected number of patents granted is equal to

$$B^m = \frac{1}{2}\left[1 - \left(\frac{1}{2}\frac{c + a + w}{a}\right)^2\right].$$

Like the social planner, the profit maximizing office sets the highest quality level and therefore *does not add any noise on the examination process.* The rationale is somewhat different. The office here targets firms with strong inventiveness because they are willing to pay high fees. Since the willingness to pay of these firms increases with patent quality, the office has an incentive to raise quality too. Of course the profit oriented office sets a higher fee and therefore receives a smaller number of patent applications and grants fewer patents. It is indeed readily shown that $D^m < D^o$ and $B^m < B^o$ so that the numbers of patents filed and granted are socially too small. To sum up, *the inefficiency with the profit maximizing patent office originates from its too high fees and not from its quality.*

5.3 Self-funded patent offices

Most patent offices are self-financed. An unresolved issue is what objectives patent office follow after they have balanced their budget. As discussed in Section 2, patent offices are governments agencies run by politically linked managers. One may therefore assume that patent offices could follow politician objectives. Politicians often assess and praise the effectiveness of patent systems by the numbers of patent applications or/and by the number of granted patents. First, these two numbers are obvious measurable outcomes of each patent office for which politicians are accountable to the public. Second, these two numbers are measures of the country and industrial inventiveness, which politicians often like to praise. Third, the rate of inventions has recently sharply increased in some sectors. Policy makers have therefore recommended to promote a certain form of 'quality of service' in order to fasten examination processes and thus increase the number of patents granted. Finally, in Section 2, we noted that EPO's governance structure is biased towards rewarding national patent offices. The EPO board includes representatives of the national patent offices, which collect the proceeds from renewals of patents granted by the EPO. The EPO board has thus some incentives to raise the number of granted patents. The impact of those objectives on the quality of the patent systems is illustrated in this section.

On the one hand, suppose that the offices follow a politician objective to increase the number of patent applications. The budget balance condition implies that the fees should be set to cover the examination cost so that $f = wq$. The politicians' optimal quality and fee are computed as follows. The offices maximize

$$D(wq, q) = \max \left[0, \frac{1}{q} \left(1 - \frac{w}{a} - \frac{c}{aq} \right) \right].$$

The second term in the bracket reaches a maximum at $q = 2c/(a-w)$. So, the optimal quality is

$$q^D = \begin{cases} \frac{2c}{a-w} & \text{if} \quad \frac{2c}{a-w} \leq 1 \\ 1 & \text{if} \quad 1 < \frac{2c}{a-w} \leq 2 \end{cases} \tag{3}$$

and the number of patent applications is

$$D^D = \begin{cases} \frac{1}{4} \frac{(a-w)^2}{ac} & \text{if} \quad \frac{2c}{a-w} \leq 1 \\ 1 - \frac{w}{a} - \frac{c}{a} & \text{if} \quad 1 < \frac{2c}{a-w} \leq 2 \end{cases}$$

whereas if $\frac{2c}{a-w} > 2$, the number of applications is nil and the quality undefined. The (expected) number of patents granted by the patent office:

$$B^D = B(wq^D, q^D) = \begin{cases} \frac{a-w}{4c} \left[1 - \left(\frac{(a-w)(f+c)}{2ac} \right)^2 \right] & \text{if} \quad \frac{2c}{a-w} \leq 1 \\ \frac{1}{2} \left[1 - \left(\frac{f+c}{a} \right)^2 \right] & \text{if} \quad 1 < \frac{2c}{a-w} \leq 2 \end{cases}.$$

The above expressions allow us to draw three conclusions. First, *even though a politician oriented management does not formally value the quality of the patent system, it implements a positive quality.* This is because a better quality increases the firms' value of a patent examination through a lower uncertainty associated with their intellectual rights protection. The office indeed needs to set a low enough quality to help applicants to pass through the examination procedure but at the same time it needs to set a high enough quality to insure a good reputation for the patent office and a better patent judicial protection. Second, the office raises its quality for higher personnel costs w. Higher costs induce the office to raise its fees and to lose some demand; to compensate this loss, the office raises its quality. This is an important result: *higher personnel costs is correlated with the quality* *of patent system even though the office's management puts no formal weight on quality.* Finally, the patent office raises its quality if the external drafting cost c rises. Additional drafting costs diminish the firms' demand for patent examination and entices the office to raise its quality to compensate for this loss.

On the other hand, suppose that the patent offices follow an objective measured by the number of granted patents. This setup might correspond to the incentives structure of the EPO board. Under this objective, the office maximizes

$$B(wq,q) \equiv \frac{1}{2q}\left(1-\left(\frac{w}{a}+\frac{c}{aq}\right)^2\right)$$

so that an increase in quality would lead to more patents being granted if and only if

$$\frac{d}{dq}B(wq,q) \geq 0 \iff -\left(a^2-w^2\right)q^2+4cwq+3c^2 \geq 0.$$

The last polynomial is concave and has a unique positive root. This condition yields the following optimal quality

$$q^B = \min\left\{\frac{c}{a^2-w^2}\left(2w+\sqrt{3a^2+w^2}\right),1\right\}. \tag{4}$$

Interestingly, this expression allows us to draw the same conclusions as before: $q^B > 0$, $dq^B/dw > 0$ and $dq^B/dc > 0$. Under this objective, the office has an incentive to reduce its quality to zero and to grant patents to any invention application. Yet, a zero quality strategy is not optimal because it eliminates any value for patents by exacerbating the uncertainty in the intellectual rights protection. To attract firms, the office must implement some positive quality. Similarly, higher examiners' costs entice the office to raise its fees and to compensate for the demand loss by a higher quality. Finally, the quality reached under this objective is nevertheless lower. Indeed, it is easy to check that $q^B \leq q^D$. The office prefers to lower the quality in order to supply more patents even though the latter are less attractive to firms. Also, since $D^D = \max_q D(wq,q)$ and $B^B = \max_q B(wq,q)$, we naturally have that $D^D \geq D^B$ and $B^D \leq B^B$.

The quality and the numbers of patent applications and granted patents can readily be compared for the above benchmark organizations:

$$q^B \le q^D \le q^o = q^m = 1,$$

$$D^m < D^o \le D^D \quad \text{and} \quad D^B \le D^D,$$

$$B^m < B^o \le B^B \quad \text{and} \quad B^D \le B^B.$$

We can similarly rank the patent fees. Because $f^B = wq^B \le f^D = wq^D \le f^o = w$ and $f^m = (a + w - c)/2 > w$ by (2), we get the following inequalities:

$$f^B \le f^D \le f^o < f^m.$$

So, the fees are obviously the highest in the office that freely maximizes profits and the smallest in the office with a governor that maximizes the number of granted patents. It must be noted that fees can be equal to its social optimal value $f^o = w$ when the office governor has incentives to raise the quality to its highest level $q^B = q^D = 1$.

These results can be summarized in the following proposition.

Proposition 1 *The quality of a patent system is maximal for the social planner and monopoly patent office, is smaller for the self-funded patent office maximizing the number of patent applications and even smaller for the self-funded patent office maximizing the number of granted patents. The number of applications is smaller in the monopoly patent office than in the social planner's office and larger in the self-funded patent office maximizing the number of patent applications.*

We now turn to a perhaps more realistic organization of patent office.

5.4 Unionized Patent Offices

In this section we assume that the patent office is run by a governor that follows a politician objective. However, examiners in the patent office are organized in a (single) union that makes claims on wages. Unionization can easily be understood in the context of a patent office because it is usually the sole employer of highly trained professionals. In particular, when an office like the EPO is set up as an international institution, employees are put away from national labor contract laws and customs and are likely to ask for more protection and exert more pressure on the institution. Hence, the power of insiders is likely to be increased and their wages pushed up. In Section 2, we presented some factual evidence of the existence and the power of the union of patent offices in Europe, Japan and the USA. In this section we argue that insiders' power is an important element determining the quality of a patent system, in particular, in the E.U. We show that a larger power of insiders raises not only wages but also the quality of the patent office. The objectives of offices' management are not clearly defined in practice. We therefore focus on the hypothetical but relevant objectives of increasing the number of patent applications and increasing the number of patents granted.

5.4.1 Governor maximizing the number of patent applications

We assume Nash bargaining between the union and the politician oriented governor. The governor maximizes the number of patent applications, $D(f,q)$, while he/she maintains the patent office at a break even situation. As before, the production of patents is subject to constant returns to quality so that the number of examiners per patent application is equal to $l = q$ and the unit cost per application is equal to wq where w is the examiners' wage. So, the number of examiners is clearly linked to the quality of the patent system. We further assume that the union seeks to increase the examiners' income w over an outside (fallback) wage $\underline{w}$ (e.g. their wage in the industry). For the sake of simplicity, we assume that the value of a patent is larger than examining cost for the highest quality standard. That is, we impose that $a > \underline{w} + c$.

Under right to manage, the office has the right to hire the examiners after wages are negotiated and set. After the wage negotiation, the self-financed office must set a fee that reimburses the cost of an examination: $f = wq$. Because of constant returns to scale to quality, the total number of examiners is equal to $l\,D(f,q) = q\,D(wq,q)$. The office then sets the quality q that maximizes the number of applications $D(wq,q)$. At the wage bargaining stage, the office seeks to maximize the same objective whereas the union seeks to maximize the wage bill $q^D D(wq^D, q^D)$ given the examiners' outside wage $\underline{w}$. Let ϕ be the bargaining power of the examiners' union. Then, the outcome of the negotiation process is given by the Nash bargaining solution

$$\max_w \mathcal{N} = \max_w \left[(w - \underline{w})\, q^D D(wq^D, q^D)\right]^{\phi} \left[D(wq^D, q^D)\right]^{1-\phi} \qquad \text{s.t.} \qquad q^D = \max_q D(wq, q).$$

Two regimes occur according to whether the quality is maximal or not after the negotiation. Suppose first that $2c/(a-w) < 1$ so that the quality chosen by the office is $q^D = 2c/(a-w)$. The demand for examination is $D(wq^D, q^D) = (a-w)^2/(4ac)$. Then, after some algebra and using the envelop theorem, the first order condition of the above program simplifies to

$$\begin{aligned} \frac{d\ln \mathcal{N}}{dw} &= \frac{d}{dw}\left\{\phi \ln\left[(w-\underline{w})\, q^D\right] + \ln D(wq^D, q^D)\right\} \\ &= \phi \frac{d\ln(w-\underline{w})}{dw} + \phi \frac{d\ln q^D}{dw} + q^D \frac{\partial \ln D}{\partial f}. \end{aligned} \tag{5}$$

The last expression shows the trade-off between wage and quality. The first two terms represent the positive effect of wage negotiation on earnings and on the number of examiners. The last term reflects the negative effect of a wage increase on the demand for patent rights. This does not only reduce the objective of the office but also that of the union since budget neutrality imposes to reduce the number of examiners if demand falls. In some sense, the office and union agree on the principle of increasing demand for patents.

After some lines of computations, the above expression simplifies further to

$$\frac{d\ln \mathcal{N}}{dw} = \frac{\phi}{w-\underline{w}} - \frac{2-\phi}{a-w},$$

which decreases in w and has a zero at the bargained wage

$$w^* = \underline{w} + \frac{1}{2}\phi\,(a-\underline{w})$$

so that the optimal quality is given by

$$q^* = \frac{2c}{a-w^*} = \frac{4c}{(2-\phi)(a-\underline{w})}.$$

As a result, *the wage and the quality increases with the bargaining power of union.* The quality is equal to the one obtained in the case of a self-funded office for $\phi = 0$ or for wage $w^* = \underline{w}$ (see (3)). Quality increases above this level as the union power increases. We know from the previous section that even though a politician oriented management does not formally value the quality of the patent system, it implements a positive quality to maintain the firms' value of a patent examination and it raises quality for higher personnel costs. *By putting an upward pressure on personnel costs, the union contributes to a further rise in quality.* Finally note that the condition $2c < a - w$ becomes

$$c < (2 - \phi)(a - \underline{w})/4.$$

This condition and condition (1) form a non empty set if $a/\underline{w} > (2 - \phi)/(1 - \phi)$.

Suppose that $2c \geq a - w$ so that $q^D = 1$ and $D(w, 1) = 1 - w/a - c/a$. Then, the first order condition of this program is

$$\frac{d \ln \mathcal{N}}{dw} = \frac{d}{dw}\{\phi \ln[(w - \underline{w})] + \ln D(w, 1)\} = \phi \frac{d \ln (w - \underline{w})}{dw} + \frac{\partial \ln D}{\partial f}. \tag{6}$$

This equation shows the same effects of a wage increase on the union's objective and the patent office as discussed for condition (5). Ceteris paribus, higher wages benefit the union but increase the office's operating costs and fees, and hence reduce the number of patent applications. Simple computations yield

$$\frac{d \ln \mathcal{N}}{dw} = \frac{\phi}{w - \underline{w}} - \frac{1}{a - w - c},$$

which decreases in w and has a zero at

$$w^* = \frac{\underline{w} + \phi (a - c)}{1 + \phi} \quad \text{and} \quad q^* = 1.$$

So, the wage increases with the bargaining power of union for all cases with positive demand for patents $D^D > 0$. The condition $2c \geq a - w$ becomes

$$\phi \geq (a - \underline{w} - 2c)/c.$$

Proposition 2 *Consider a unionized patent office managed by governors who maximize the number of patent applications under the right to manage. Then, the quality and the wage (weakly) increase with the bargaining power of the union. The quality is maximal if and only if the union bargaining power is sufficiently large:* $\phi \geq (a - \underline{w} - 2c)/c$.

As for the monopoly patent office, this office may implement the socially optimal quality. This situation occurs if the union bargaining power is sufficiently large. In this case, the patent office obeys to the union's objective to maximize its rent by setting higher fees so that to attract firms with the strongest inventiveness. To augment the number of such firms, the union has an incentive to set the highest possible quality.

5.4.2 Governor maximizing the number of patents granted

We now study the case of a patent office run by a politician oriented governor who maximizes the expected number of granted patents and who negotiates with the examiners' union. Let again the governor run the patent office under the right to manage. Given that the break even constraint imposes that the fee f equals the application processing cost wq, the bargaining outcome is the solution of

$$\max_w \mathcal{N} = \left[(w - \underline{w})\, q^B D(wq^B, q^B)\right]^{\phi} \left[B(wq^B, q^B)\right]^{1-\phi} \quad \text{where } q^B = \max_q B(wq, q).$$

The quality level q^B is given by condition (4) where $dq^B/dw > 0$. Suppose that $q^B < 1$. Then the first order condition can be written as

$$\begin{aligned} \frac{d\ln \mathcal{N}}{dw} &= \phi \frac{d\ln (w - \underline{w})}{dw} + \phi \frac{d\ln q^B}{dw} + \phi q^B \frac{\partial \ln D}{\partial f} \\ &\quad + (1-\phi)\left[\frac{\partial \ln B}{\partial f} - \frac{\partial \ln D}{\partial f}\right] + \phi \frac{d}{dq} \ln D(wq^B, q^B) \frac{dq^B}{dw} = 0. \end{aligned} \tag{7}$$

It is not possible to obtain a close form solution for this problem. However, we can infer the direction of the bargained wage from this expression. The first line of expression (7) is the same as the expression in the wage setting equation (5). The two terms of the second line of expression (7) introduces two new effects. The first term embeds a correction for the objective of this politician oriented governor. One can check that

$$\frac{\partial \ln B}{\partial f} - \frac{\partial \ln D}{\partial f} = \frac{1}{aq + c + f} \geq 0.$$

Because of the break-even constraint, a wage increase raises the patent fee and therefore decreases the expected number of granted patents; but it decreases the latter less than the number of applications.

So, this governor is more inclined to keep fees and wages high. The second term embeds the impact of wages on the number of patent applications and thus demand for examiners' labor. Higher wages entice this governor to increase both quality and fees, which have opposite effects on labor demand. From the previous analysis we know that, at a given wage, the governor sets a lower quality if he/she maximizes the expected number of granted patents rather than the number of patent applications. Also, when the quality is low enough, the number of patent applications increases with higher quality because patents offer better legal protections. It turns out that, under this governor's objective, the number of patent applications raises more with increased quality than it falls with increased fees. Indeed, since, at a given w, $q^B \leq q^D = \arg\max_q D(wq, q)$, we have that $\frac{d}{dq} \ln D(wq^B, q^B) \geq 0$. Hence, the two terms in the second line of expression (7) are positive. The wage bargained with this governor, w^{**}, is therefore larger than the wage, w^*, bargained with a governor that maximizes the number of patent applications.

Finally, suppose that $q^B = 1$. Then, the first order condition becomes

$$\frac{d \ln \mathcal{N}}{dw} = \phi \frac{d \ln (w - \underline{w})}{dw} + \phi \frac{\partial \ln D}{\partial f} + (1 - \phi) \left[\frac{\partial \ln B}{\partial f} - \frac{\partial \ln D}{\partial f} \right].$$

This expression is larger than condition (6) because the last term is positive. Again, the bargained wage w must be larger in the office run by a governor that maximizes the expected number of granted patents than by the one that maximizes the number of patent applications.

Proposition 3 *Consider a unionized patent office managed by governors under the right to manage. Then, the examiners' wage is larger in the office that is run by a governor who maximizes the number of granted patents compared to the one who maximizes the number of patent applications.*

So, this governor permits higher wages $w^{**} > w^*$. Numerical examples suggests that it still sets lower quality $q^B(w^{**}) < q^D(w^*)$.

6 Conclusions

The objective of this paper is to study the relationship between the quality of patent systems and the governance of patent offices. The paper firstly establishes some stylized facts about the major patent offices in the U.S., E.U. and Japan. As a case in point, the E.U. patent office processes fewer patents and claims - in per capita and per examiner -, pays higher compensations to examiners and devotes more resources per staff that potentially contribute to a better patent quality. The stylized facts suggest that compensation packages and union power are discriminating elements of patent office behaviors. Also, while patent offices can influence their own targets, they are managed by politically driven governors who must fund the offices with their resources and must interact with examiners' organizations (unions). Although patent offices are managed under different contexts and constraints, their objectives -be they explicit or implicit - most probably include the maximization of a combination of the numbers of patent applications or the number of granted patents.

The paper then presents a model that describes the potential behaviors of patent offices with respect to the setting of their fees and the quality of their examination processes. These fee/quality settings depend on the four alternative objectives that patent offices' governors may target, namely, welfare, patent office's profit, number of patent applications and number of patents granted. The paper also analyzes the behavior of governors who follow the last two objectives but negotiate the wage conditions with examiners' unions. As a point of departure, we assume that the patent system quality is important for patent holders. A patent is viewed as a 'probabilistic' property right that gives the patent holder the right to sue potential infringers and a fair chance either to win the litigation in court or to reach a favorable agreement. Therefore, a higher quality in patent examination lowers the transaction costs associated with enforcement of intellectual property rights and increases the demand for patents. The quality of the patent system contributes to the credibility of the patent certification process and hence to the private value of and the demand for patents by firms. Finally, the model includes elements of Lemley's 'rational ignorance principle'. We indeed model the aftermath of patent examinations, where patents have uncertain market opportunities and a probability to be challenged by a competitor and to win in Court with some cost.

The results of the theoretical model firstly show that the demand for patent examination increases with smaller patent fees but is a non-monotone function of the patent system quality. Indeed, a higher quality patent system implies a more rigorous selection of the inventions submitted by firms and a better enforcement of granted patents in the judicial system. Whereas the latter effect is good for all innovators, the former effect is bad for the innovators with 'small' inventions and reduces their incentives to apply for a patent. Hence, whatever its objective, a self-funded patent office faces a trade-off between softer examination and better credibility of the granted patents. The question is whether the governors and examiners have incentives to soften the examination process and add noise on the quality of the patent system.

We review four types of governors' objective. First, we study the hypothetical but interesting cases of an office maximizing either the social welfare or its profits. We show that this office chooses a high quality level and therefore does not add any noise on the examination process. The office targets firms with strong inventiveness because those firms are willing to pay high fees. Since the willingness to pay of those firms increases with patent quality, the office has incentives raise the quality too. The profit oriented office sets a higher fee and therefore receives a smaller number of patent applications and grants fewer patents. Second, we study the case of a self-funded office where the governor maximizes the number of patent applications. Policy makers sometimes praise themselves for this number as a measure of either patent office attractiveness or global level of economic activity. We show that, even though this governor does not formally value the quality of the patent system, it implements a positive quality level because a more rigorous patent examination process reduces the degree of uncertainty associated with the effective enforcement of the intellectual property rights. The office indeed decides to set a low enough quality to help applicants to pass through the examination procedure but at the same time needs to set a high enough quality to insure a good reputation for the patent office and a better patent judicial protection. We also show that higher examiners' wages (or resources devoted to the examination process) increase with the quality of patent systems; even though the office's management puts no formal weight on quality. Finally, we study the situation in which the governor maximizes the number of patents granted, supposedly an indicator of good functioning of the patent office and the economy. Under this objective, the office has an incentive to reduce its quality to zero and to grant patents to any patent application. Yet, for the reason stated before, a zero quality strategy is not optimal because it eliminates any value for patents by exacerbating the uncertainty in the intellectual rights protection. Comparing those four cases we show that the quality of the patent system is maximal for the first best patent office (i.e., maximizing social welfare) and in monopoly patent office, is smaller for the self-funded patent office maximizing the number of patent applications and even smaller for the self-funded patent office maximizing the number of granted patents. By contrast, the number of applications is smaller in the monopoly patent office than in the social optimum office and larger in the self-funded patent office maximizing the number of patent applications.

We finally study the impact of the examiners' union power in patent offices' decision making processes. Unions have many times lobbied and exerted power not only about compensation issues but also about quality issues. As a higher examination quality necessitates a larger workforce, it is not surprising that unions promote better patent quality. We show that when the governor seeks to maximize the number of patent applications, both examiners' wage and patent quality increases as unions get more power. Even though a politician oriented management does not formally value the quality of the patent system, it implements a positive quality to maintain the firms' value of a patent examination and raises quality to compensate for higher personnel costs. The union puts an upward pressure on personnel costs and, as a consequence, contributes further to the increase in patent quality. Unions therefore balance the politically oriented governors' incentives to cut on the quality of patent systems. As in the case of the profit maximizing office, this nevertheless occurs at the cost of too high fees. Finally, the model suggests that incentives to raise examiner's wage are even stronger for a governor who maximizes the number of granted patents.

The present paper addresses the issue of patent quality from the perspective of the patent offices' behaviors and organizations. It deliberately abstracts from the other - no less relevant - issues covered in the past and recent patent literature such as optimal length, scope and breadth. However, to the best of our knowledge, the literature has not properly covered the relationship between the offices' organization and the effective quality of the patent systems. Our main result is that offices offering high compensation packages like the EPO are likely to keep a high patent system quality whereas offices offering lower compensation packages like the USPTO have incentives to soften examination process and introduce noise in the patent system, with the consequence of having more patent filed and granted. The presence of organized labor (union) fosters the patent system quality and compensates for the potential inappropriate objectives of patent office management.

The discussion and results presented in this paper have their own limitations as many additional features of patent systems have not been taken into account. The reality is indeed somewhat different and much more complex than suggested in our stylized model. Compensation packages, fee settings, budget components and even quality are composed of many facets that cannot be tackled in one model.[11] However, examiners must be managed, their wage must be set, and they have some right to be heard. Last but not least, patent offices' governors must set priorities that implicitly or explicitly relate to the number of patent filings or patents granted. In the light of the stylized facts presented in this paper, it seems that the EPO gets closer to the model where the governor maximizes the number of patent filings and bargain examiners' labor conditions with a strong union (its strength being implicitly linked to the status of international civil servants, who have secured positions). The USPTO seems closer to the model of a patent office that maximizes the number of patent granted. This paper does not only offer a grid of analysis for existing patent offices but it also provides evidence about the relationship between, on the one hand, the governance of patent offices (including their strategic objectives and the role of examiners' unions) and, on the other hand, the quality of patent systems, its cost and the demand for patents.

References

Ayres I. and P. Klemperer, 1999. Limiting Patentees' Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies, 97, Michigan Law Review 985.

[11] For instance the renewal fees paid for previously granted patents may be an important component of a patent office's budget. At the EPO the renewal fees correspond to approximately 25% of the total budget. An interesting extension would be to assess the extent to which the maintenance rate of patents depend on the quality of the examination process.

Barzel, Y., 1968. Optimal timing of innovation. Review of Economics and Statistics, 50, 348-355.

Bessen J. and M. J. Meurer, 2008, Patent Failure: How Judges, Lawyers and Bureaucrats Put Innovators at Risk, Princeton, NJ: Princeton University Press.

Caillaud B. and A. Duchêne, 2009. Patent Office in innovation policy: Nobody's perfect,PSE Working Papers 2009-39, PSE (Ecole normale supérieure).

Danguy J., G. de Rassenfosse and B. van Pottelsberghe de la Potterie, 2010. The R&D-patent relationship: An industry perspective. ECARES Working Paper.

de Rassenfosse G. and B. van Pottelsberghe de la Potterie, 2009. On the price elasticity of demand for patents, CEPR Discussion Papers 7029.

de Rassenfosse G. and B. van Pottelsberghe de la Potterie, 2010. The role of fees in patent systems: theory and evidence, ECARES Working Paper, 2010-023.

Dewatripont M. and P. Legros, 2008. "Essential" patents, FRAND royalties and technology standards, ECARES Working Paper 2008_010.

Farrell, Joseph, and Carl Shapiro, 2008. How Strong Are Weak Patents? American Economic Review, 98(4): 1347–69.

Fisher T., 2010. Defending patents' validity - An empirical analysis of German patent invalidation proceedings. Technische Universität München.

Friebel G. , A. Koch , D. Prady and P. Seabright, 2006. Objectives and Incentives at the European Patent Office. Centre: IDEI - Institut d'Economie Industrielle (Université Toulouse 1)

Gans G., S. King S. and R. Lampe, 2004. Patent Renewal Fees and Self-Funding Patent Offices, The B.E. Journal of Theoretical Economics, Berkeley Electronic Press, vol. 0(1).

Gallini, N., 1992. Patent policy and costly imitation. The RAND Journal of Economics, 23(1), 52-63.

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

Gilbert, R. and C. Shapiro, 1990. Optimal patent length and breadth. The RAND Journal of Economics, 21(1), 106-112.

Jaffe, A., and J. Lerner, 2004. Innovation and its discontents: How our broken patent system is endangering innovation and progress, and what to do about it. Princeton University Press, New Jersey, 236 p.

King J.L., 2003. Patent examination procedures and patent quality, in Patents in the knowledge-based economy, Ed. The National Research Council. The National Academic Press.

Klemperer P., 1990. How broad should the scope of patent protection be? The RAND Journal of Economics, 29(1), 113-130.

Langinier C. and P. Marcoul, 2003. Patents, search of prior art, and revelation of information, Iowa State University, Department of Economics Staff General Research Papers No 10489.

Lemley M. A., 2001. Rational Ignorance at the Patent Office. Northwestern University Law Review, Vol. 95, No. 4.

Machlup F., 1958. An economic review of the patent system, Report to the US government.

Nordhaus W., 1969. Invention, growth and welfare: A theoretical treatment of technological change. M.I.T. monographs in economics, 10, 168 pp., M.I.T. Press, Cambridge, MA.

O'Donoghue T., 1998. A Patentability Requirement for Sequential Innovation, Rand Journal of Economics, 29(4), 654-679.

Penrose E.T., 1951. The economics of the international patent system, Johns Hopkins Press.

Scherer F.M., 1972. Nordhaus' theory of optimal patent life: a geometric reinterpretation, American Economic Review, 62, 422-427.

Scotchmer S., 1991. Standing on the shoulder of giants: cumulative research and the patent law, Journal of Economic Perspectives, 5(1), 29-41.

van Pottelsberghe de la Potterie, B., 2010. The quality factor in patent systems. ECARES Working Paper, 2010-027.

van Pottelsberghe de la Potterie B. and M. Mejer., 2010. The London agreement and the cost of patenting in Europe.European Journal of Law and Economics. 29(2). 211-237.

Yamauchi I. and S. Nagaoka, 2009. Reforms of patent examination request system in Japan: some lessons, IIR Working Paper.