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On the price elasticity of demand for patents

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JEL Classifications: O30, O31, O38, O57

CEB Working Paper N° 08/031

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ULB

On the price elasticity of demand for patents*

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A slightly modified version is forthcoming in Oxford Bulletin of Economics and Statistics. Please consult the published paper.

Abstract

This paper provides an analysis of the impact of patent fees on the demand for patents. It presents a dataset of fees since 1980 at the European (EPO), the U.S. and the Japanese patent offices. Descriptive statistics show that fees have severely decreased at the EPO over the nineties, converging towards the level of fees in the U.S. and Japan. The estimation of dynamic panel data models suggests that the price elasticity of demand for patents is about -0.30. These results suggest that the laxity of fee policy at the EPO has significantly contributed to the rising propensity to patent.

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*The authors are grateful to Karin Hoisl, Paul Jensen, Keld Laursen, Laura Toschi, Nicolas van Zeebroeck and two anonymous referees as well as the Editor for useful comments. This paper has benefited from comments of the audience of various seminars and conferences including the 4th EPIP conference (Bologna), the 98th AEA conference (Tokyo) and the DRUID-DIME Winter 2009 PhD conference (Aalborg). Gaetan gratefully acknowledges financial support from the FRS-FNRS.

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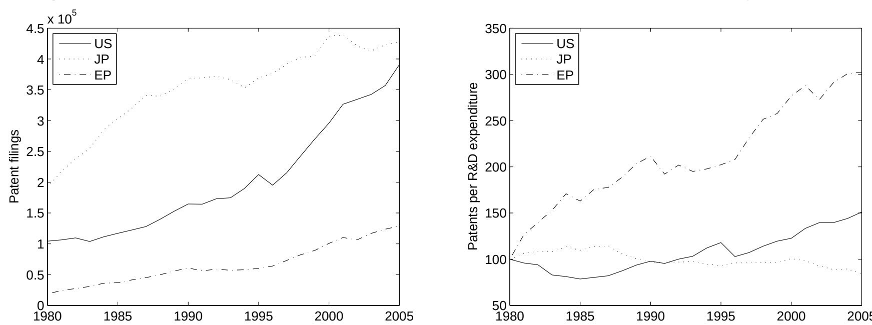
1 Introduction

In 2008 the total number of patent applications filed at the European Patent Office (EPO) again reached a new record of 146,150.[1] The United States Patent and Trademark Office (USPTO) as well as the Japan Patent Office (JPO) achieved a similar success, as illustrated by the spectacular 456,321 and 391,002 applications respectively filed that same year. The left-hand side of Figure 1 shows that increases in patent filings are common in patent offices. Constant record breaking is, however, not praised by all observers of patent systems. Many concerns are being raised, especially by economists, as witnessed by the recent contributions of Jaffe and Lerner (2004) and Bessen and Meurer (2008) for the U.S. patent system and Guellec and van Pottelsberghe (2007) for the European patent system. The worries are related to the number and quality of incoming patent applications as well as to the longer pendency of the substantive examination of patents which generate worrying backlogs, increasing the level of uncertainty on the market.

Figure 1: *Total patent applications and the apparent propensity to patent*



Notes: Left panel: JP, US and EP indicate the total number of yearly patent applications from 1980 to 2005 at the JPO, the USPTO and the EPO, respectively. Right panel: Total patent applications divided by total internal R&D expenditures (1980 = 100).
Sources: See Table 8 in Appendix B. Own computation.

The right-hand side of Figure 1 suggests that the boom in patent filings in the U.S. and in Europe is due to an increase in the number of patents filed per unit of R&D expenditure, and particularly so in Europe. The drop in the patents-to-R&D ratio at the JPO is partly due to a change in drafting practices that resulted in an increase in the average number of claims per patent since the late eighties.

Kortum and Lerner (1999) argue that the jump in patenting at the USPTO

[1] This figure does not include the PCT-International filings for which the EPO must "only" provide a search report. Had these filings been taken into account, the total number of applications would have been higher than 200,000. PCT stands for "Patent Cooperation Treaty". It provides a unified procedure for filing patent applications worldwide.

reflects '*an increase in US innovation spurred by changes in the management of research*' and a shift towards more applied activities. Guellec and van Pottelsberghe (2007) provide additional reasons. According to the authors, several factors explain the surge in patent filings observed since the mid-nineties in major patent offices. First, *new actors* came to the fore in the most advanced economies. IP awareness is rising amongst SMEs and the Bayh-Dole act regulation ratified in the U.S. in 1980 (or the like in Europe since the mid-1990s) fostered academic patenting. Second, the emergence of *new fields of research*, such as nanotechnologies and biotechnologies, has opened new patenting domains. Third, *new countries* such as China, Brazil and India have gradually entered the world patent system, partly stimulated by the Trade-Related Intellectual Property Rights (TRIPs) agreements. The fourth reason — and probably the most important one — is related to the emergence of *new patent strategies*. The use of patents is increasingly shifting from the traditional use of protecting one's own innovations to new types of uses (see e.g. Cohen et al., 2000; Guellec et al., 2007; Hall and Ziedonis, 2001; Rivette and Kline, 2000) and there is evidence of "excessive" patenting behavior adopted by a number of applicants.

Several factors have influenced applicants' behavior. Among them, the laxity of patent offices possibly plays a role. Encaoua et al. (2006, p. 1430) argue that '*the boom in patent applications [is concomitant with] a general sentiment of relaxation of patentability requirements [...] in certain jurisdictions.*' The argument is also echoed in Sanyal and Jaffe (2006) who show that the explosion of patenting in the U.S. can partly be attributed to lower examination standards at the USPTO. Inappropriate fee policies may as well have helped to push the trend upward: if the patenting process becomes cheaper, one would logically expect a higher demand for patents.

The objective of the present paper is to test this "fees" assumption. The contribution to the literature is twofold. First, the paper provides an analysis of patent fees since 1980 in three major patent offices: the EPO, the JPO and the USPTO. Second, it presents a first panel data analysis of the impact of fees on the demand for patents. Existing studies on the price elasticity of demand for patents are mainly performed at the cross-sectional level.[2] A limitation of this approach is that it assumes low adjustment costs, such that a change in any explanatory variable leads to an immediate adjustment in the number of patents applied for. Given that the main explanatory variable, R&D expenditure, is itself very stable, the output is relatively close to its long-run level with respect to that variable. However, the estimate of the price elasticity is more sensitive to this issue, as patenting fees are potentially more volatile. A key feature of this paper is thus the use of dynamic panel data models of patent applications, which allow to control for time invariant country characteristics and to estimate both short and long-run elasticities. On a more practical level, understanding the demand response for fee change is of interest to patent offices for operational reasons. Most of the patent offices are self-financed (Gans et al., 2004) and the

[2] See e.g. de Rassenfosse and van Pottelsberghe (2007) and Harhoff et al. (2009). A comprehensive literature review on the role of fees in patent systems is provided in de Rassenfosse and van Pottelsberghe (2010).

precise estimation of price elasticities is particularly interesting in this respect.

The paper is structured as follows. The next section describes the complex fee structure of patent offices and presents the working assumptions that are used to compute absolute and relative fees for the three patent offices. Section 3 analyzes the evolution and growth rates of fees since 1980. The econometric methodology is explained in Section 4, and the results are presented in Section 5. The last section concludes and puts forward policy implications.

The main findings are that relative patent fees (i.e. fees per claim per capita) have actually plummeted over the years since the mid-nineties in the three regions. Entry fees and cumulated fees up to the grant at the EPO have declined severely since the mid-1990s, which contributed to the boom in patenting observed in Europe. The quantitative analysis suggests that the fee elasticity of demand for patents is about -0.30.

2 Methodological approach

The fee structure in patent systems is particularly complex. From the filing of an application to the grant of a patent and its renewal, the assignee has to pay various fees at different points in time. The structure of fees in terms of schedule and scope varies substantially across patent offices, which makes international comparisons complex to implement. For instance, filing fees at the USPTO explicitly include the search and examination of the patent, and the whole process up to the grant lasts about 35 months. At the EPO, filing and search fees lead to a search report after 18 months. Then the applicant may withdraw its application or opt for a substantive examination and pay examination fees. The process up to the grant lasts about 5 years on average (van Zeebroeck, 2008). In addition firms may choose between various routes to reach a patent office (i.e. direct application, second filings or PCT applications), which affects patenting costs. Fees also vary according to the filing strategy adopted by firms: they may opt for an accelerated search request, send late replies, inflate the number of claims and pages or adopt a low quality drafting style.[3]

The patenting process can be summarized in four key steps, each being associated with specific fees and a particular timing: filing, search, examination and granting. The first step consists of the filing of a patent, which includes a filing fee and a search fee. When the search for prior art is performed and the search report published (in general 18 months after the filing of the patent), it is followed by the examination fees if a request for substantive examination is filed. Then, if the patent is granted, the assignee must pay granting and publication fees.

Comparing fees across patent offices therefore requires a cumulative approach. In what follows, two fee indicators are computed. The first one, entry fees, represents the short-term cost of entering the patenting process. It includes

[3] See van Pottelsberghe and François (2009) and van Pottelsberghe and Mejer (2010) for an in-depth comparison of the fee structure at the USPTO, the JPO and the EPO.

all the fees that must be paid during the first 18 months from the filing date and is generally composed of filing fees and search fees. At the USPTO, the examination is performed for all patents (except if the applicant pays a fee to defer examination) and filing fees actually encompass examination fees. The second indicator corresponds to the (cumulated) fees up to the grant. It represents the minimum level of fees to be borne by an applicant in order to have its patent granted. It encompasses entry fees, examination and granting fees. Table 1 summarizes the composition of the two indicators for the three patent offices.

Table 1: *Composition of fees indicators*

	Filing	> *Search*	> *Exam.*	> *Granting*	> *Renewal*
EPO	□ (*)	□			
	■	■	■	■	
JPO	□	□			
	■	■	■ (*)	■	
USPTO	□ (*)	□	□		
	■	■	■	■	

Notes: □ and ■ indicate the fees that are included in the first indicator (entry fees) and the second indicator (fees up to the grant), respectively. (*) indicates when claim-based fees have to be paid. At the EPO, the applicant has a maximum of six months from the publication of the search report (i.e. eighteen months after the priority date) to request a substantive examination. At the JPO, an applicant is allowed to wait for three years after the application date to request an examination.

Several working assumptions had to be used regarding the mode of interaction with the office and the drafting style; they are described in Appendix A. Amongst these are the average number of claims included in a patent.[4] As indicated in Table 1, all patent offices rely on claim-based fees, which may constitute an important share of total fees. We use the average number of claims per patent in each office to estimate claim-based fees. The fees are thus computed for a *representative* patent in each of the three offices. Fees are expressed in 2000 constant USD PPPs. Detailed data on fees and claims were provided directly by the EPO, the JPO and the USPTO. Data on exchange rates are taken from the International Monetary Fund's World Economic Outlook Database. Table 8 in Appendix B provides detailed information on the data sources.

The computations of entry fees and fees up to the grant are performed in absolute and relative terms. The relative measure follows the methodology put forward by van Pottelsberghe and François (2009). It consists of dividing the absolute fees by the average number of claims included in patent applications and the number of inhabitants in the geographical region covered by the patent system. Since the three offices rely on claim-based fees, and given that the

[4] Claims are the legal substance of a patent, the codified description of the invention that constitutes the scope of protection in case of a grant.

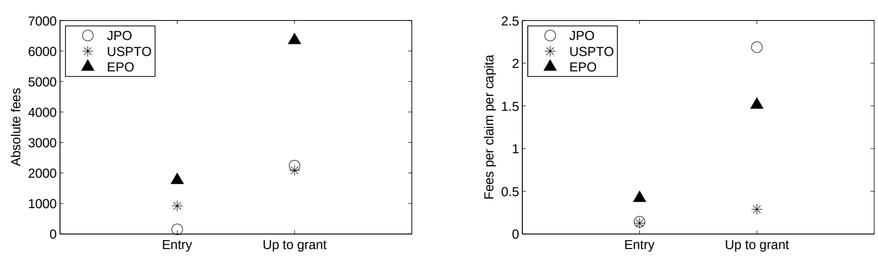
average number of claims varies substantially across the three offices and over time, it is appropriate to compute the fees per claim, the lowest common denominator of an invention. Similarly, a comprehensive international comparison should take into consideration the size of the geographical scope (i.e. a measure of the potential market covered by the patent office). From the point of view of the applicant, a larger market induces a lower fee per market unit. Regarding Europe, the size of the market has been limited to that of five countries (EPC-5): Germany, France, the United Kingdom, the Netherlands and Italy, the most frequently targeted countries (see van Pottelsberghe and van Zeebroeck, 2008). Note that fees could as well be expressed relative to the regions' GDP, but it would make little difference as the three economies are at a similar level of development.

Historical data on fees and claims are provided in Table 9 in Appendix B. It is important to keep in mind that fee indicators at the EPO are lower bounds of actual cumulated fees, as neither the fees requested by national patent offices for priority filings nor the PCT fees are accounted for. Priority filing fees vary substantially across countries, around a median of € 612 according to de Rassenfosse and van Pottelsberghe (2007). It is also important to remind that other costs are not considered in the present analysis, including the costs for drafting and prosecuting patents and translation costs. It is nearly impossible to provide reliable figures for this type of arms-length costs over a long period of time in the three geographical areas.

3 Descriptive statistics

This section provides a thorough analysis of the evolution of patent fees at the three offices. Figure 2 displays entry fees and total fees for the year 2007, in absolute and relative terms.

Figure 2: *Absolute and relative fees in 2007 in USD PPPs*

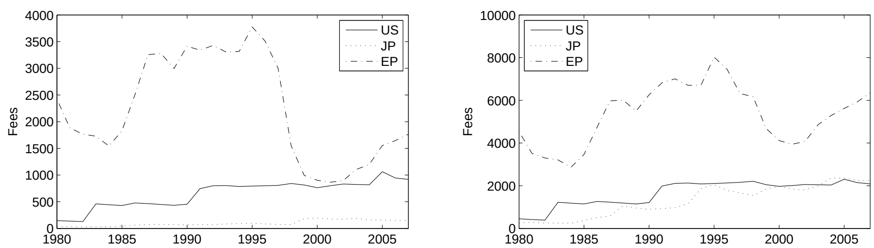


Notes: Relative fees are fees per claim per million capita. The population in 2007 in EPC-5, JP and the US are (in millions) 280, 128 and 302, respectively.
Sources: See Table 8 in Appendix B. Own computation.

The left-hand side of Figure 2, which presents the absolute level of fees, shows that the EPO is the most expensive office, being two to three times more expensive than the USPTO. Entry fees are particularly low at the JPO, whereas the EPO has particularly high fees up to the grant.[5] The picture looks quite different if relative measures are considered (fees per claim per million capita, presented in the right-hand side of Figure 2). In the short term, the average European patent is still about three times more expensive than the average U.S. or Japanese patent. However, as far as total fees are concerned, the combined impact of a low number of claims and a smaller population size makes Japan the most expensive market to protect, while the U.S. is by far the most affordable.

The evolution of absolute fees is depicted in Figure 3. A strong convergence between EPO and USPTO entry fees occurred (left panel): while they have been substantially decreasing since the mid-1990s at the EPO, they increased slightly at the USPTO. Fees at the JPO have been increasing as well but they remain low in absolute level. Fees up to the grant (right panel) have been increasing in the three offices, in particular at the JPO, with a compound annual growth rate (CAGR) of 8.4% since 1980. Japanese fees up to the grant have gradually caught up with their U.S. counterparts. The EPO had the smallest increase (with a CAGR of 1.3%), but still remains the most expensive office in absolute terms.

Figure 3: *Evolution of entry fees (left) and fees up to the grant (right)*



Notes: Fees are expressed in constant 2000 US PPPs.
Sources: See Table 8 in Appendix B. Own computation.

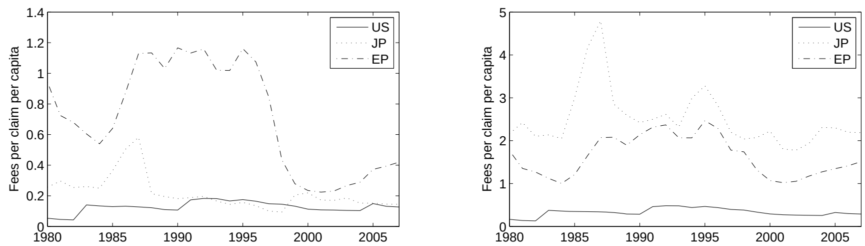
In an apparent desire to make the patent system more affordable, the EPO substantially decreased its patent fees at the end of the nineties, especially from 1997 to 1999. In 2000, Gert Kolle, Director for International Legal Affairs at the EPO, commented on the recent changes: '*Over the past three years we've reduced patent office costs considerably. Between 1997 and 1999, for instance, the filing fees for a European patent designating all 19 member states have fallen [by approximately 80%][...]. Likewise, the fees paid up to the point of grant during that period have fallen [by approximately 40%][...]. In total, EPO fees have been reduced by around 41%, and I believe we have now reached the point*

[5]These cumulated fees for the EPO do not include the translation costs and the validation fees that must be paid in each desired national patent office once the patent is granted by the EPO. If these costs were taken into account, an EPO patent would be 5 to 10 times more expensive than a USPTO patent, as shown by van Pottelsberghe and François (2009).

where the potential savings that can be made in patent office costs have been exhausted.'[6]

Figure 4 displays the evolution of relative fees (fees per claim per million inhabitants) over the whole period. Relative entry fees have been decreasing over time at the EPO and the JPO, despite a sharp increase in the mid-1980s in Europe. The differences in relative entry fees have been drastically reduced over time, but Europe is still the most expensive region in relative terms. As far as fees up to the grant are concerned, Japan remains the place with the most expensive fees in relative terms, followed by Europe in an intermediate position and the U.S. with the cheapest fees per claim per million capita.

Figure 4: *Evolution of relative entry fees (left) and fees up to the grant (right)*



Notes: Fees are expressed in constant 2000 US PPPs. Relative fees are fees per claim per million capita.
Sources: See Table 8 in Appendix B. Own computation.

Table 2 presents the compound annual growth rates of both absolute and relative fees in constant national currency, from 1980 to 1995 and from 1995 to 2007. It clearly shows that, since the mid-1990s, the EPO has achieved the sharpest decrease in both entry fees and fees up to the grant, in both absolute and relative terms. A particularly sharp decrease has occurred for EPO relative entry fees, with a drop of about 8% a year between 1995 and 2007 (and about 6% in absolute terms).[7]

The next section presents the econometric methodology that will be used to approximate the level and significance of the price elasticity of demand for

[6]Interview with Richard Poynder for Thomson Scientific: "Discussion of European Patent System", May 2000, http://thomsonreuters.com/. Note that the sharp decrease in short-term fees is exacerbated by the reallocation of designation fees from entry fees to fees up to the grant in 1998.

[7]It is important to keep in mind that the average growth rate of relative fees in Europe is an upper bound estimate, because we have assumed that the market size was "only" related to the 5 countries in which patents are validated after the grant by the EPO. However, it could be argued that the whole geographical area covered by the EPO should be taken into account, i.e. currently about 500 million inhabitants. Should this be the case, and given the fast increase in the number of EPO Member States (from 11 in the early eighties to 36 nowadays — that is more than one additional country every year), one would have observed a waterfall shape in the relative fees at the EPO over the past twenty years, which reinforces the idea that relative fees severely plummeted in Europe.

Table 2: *Compound annual growth rate (CAGR) of patent fees in constant 2000 local currency*

	1980-1995			*1995-2007*		
Absolute fees						
	JPO	*USPTO*	*EPO*	*JPO*	*USPTO*	*EPO*
Entry	2.04%	11.94%	1.38%	5.46%	1.24%	-6.17%
Up to grant	8.41%	10.84%	2.25%	2.68%	-0.07%	-1.96%
Fees per claim per million capita						
	*JPO**	*USPTO*	*EPO*	*JPO*	*USPTO*	*EPO*
Entry	-8.47%	8.25%	-0.20%	1.21%	-2.67%	-8.14%
Up to grant	-2.47%	7.18%	0.66%	-1.46%	-3.92%	-4.03%

Notes: (*) the CAGR prior to 1995 at the JPO has been computed for 7 years, from 1988 to 1995, due to the fact that only one claim per patent was allowed in Japan until 1988 (Kotabe, 1992).

patents.

4 Econometric methodology

The price elasticity of demand for patents can be estimated through a classical patent production function. Research efforts (R) lead to inventions and inventions possibly lead to patent applications (P^*) as a function of γ, which captures the rate at which research efforts lead to patents. In this model, patent fees (F) are a determinant of the propensity to patent and are thus included as such in the model[8]

$$P^* = \gamma R^{\beta_1} F^{\beta_2} \tag{1}$$

where β_1 is the elasticity of patents with respect to R&D expenditures and β_2 represents the price elasticity of demand for patents, which is expected to be negative.[9]

Two assumptions are made regarding the relationship between the three variables. First, it is assumed that fees are independent of the level of demand for patents. This assumption is not obvious because many patent offices are self-financed through fee income and could set a profit maximizing fee. However, application fees are only a fraction of total fees collected by patent offices;

[8] The focus here is more on the elasticity of the fees up to the grant than on entry fees. This assumption suggests that applicants are influenced more by the cumulated fees of the process they start. It could, however, be argued that some applicants may be interested only in short-term protection (i.e. a patent pending protection). Additional estimates of the elasticity of entry fees are therefore also reported.

[9] Patenting costs are not accounted for in R&D expenditures. There is thus no risk of double-counting when fees and R&D outlays are simultaneously included as explanatory variables.

renewal fees generally account for a substantial share of their income. Figure 3 provides a first evidence that patent fees do not react to the number of patent filings. It shows that patent fees stayed constant at the USPTO during the 90's whereas the demand increased substantially over the period. This assumption will be explicitly validated in Section 5 with a Granger causality test. The second assumption is that there exists a long-run equilibrium between the number of patents and R&D efforts. That is, we postulate that the variables are cointegrated. The extra-information provided by the cointegration between variables will be used to refine the econometric analysis. Again, this assumption will be formally validated in the next section.

In order to approximate the elasticities, two econometric models are used: a partial adjustment model and an error correction model. While the former is intuitive to differentiate between short- and long-run elasticities, the latter takes advantage of the co-integration between variables. Existing studies on the price elasticity of demand for patents are mainly performed on cross-sectional datasets. A limitation of this approach is that it assumes low adjustment costs, such that a change in any explanatory variable leads to an immediate adjustment in the number of patents applied for. Given that the main explanatory variable, R&D expenditure, is itself very stable, the output is relatively close to its long-run level with respect to that variable. However, the estimate of the price elasticity is more sensitive to this issue, as patent fees are potentially more volatile. It is therefore important to exploit the dynamic dimension of the demand function.

Partial adjustment model

The logarithmic transformation of the patent production function (1) produces the following additive model:

$$\ln P^*_{it} = \gamma_i + \beta_1 \ln R_{it} + \beta_2 \ln F_{it} + \varepsilon_{it} \tag{2}$$

R_{it} and F_{it} are both expressed in constant US PPPs of 2000. There are three countries ($i \in [1,3]$) and twenty-six years ($t \in [1,26]$). γ_i is assimilated to the country fixed effect in the regression and ε_{it} is the error term.

Equation (2) implicitly assumes that the demand for patents immediately adjusts to its long-run level P^*. There are many reasons to challenge this assumption and to assume that adjustment to any new equilibrium level occurs over several periods. First, the filing of patents is subject to a learning process: the current level of patents is likely to affect next year patenting activity. Second, the sequential and cumulative aspects of research and development projects imply that an invention patented in a given year may be improved and yield further patentable improvements in the subsequent years.[10] Dynamic models

[10]It can be argued that the R&D expenditure variable should be lagged so as to take into account the potential delay between the research activities and the occurrence of a patent. However, there is a strong contemporaneous relationship between R&D expenditures and patenting (Hall et al., 1986). In any case, the dynamic specification allows for a delayed impact of R&D expenditures over time.

can easily be recovered from equation (2) if one introduces a dynamic partial adjustment process of the form (see e.g. Nerlove, 1958):

$$\frac{P_{it}}{P_{i,t-1}} = \left(\frac{P^*_{it}}{P_{i,t-1}}\right)^{\lambda}, 0 < \lambda < 1 \tag{3}$$

where λ measures the rate of adjustment (the higher λ, the faster the adjustment). Taking the expression to the log and substituting for $\ln P^*$ into equation (2), we obtain the following partial adjustment equation:

$$\ln P_{it} = \gamma^s_i + (1-\lambda)\ln P_{i,t-1} + \beta^s_1 \ln R_{it} + \beta^s_2 \ln F_{it} + \nu_{it} \tag{4}$$

where β^s/λ equals β in equation (2) and represents the long-run elasticity; β^s represents the short-term elasticity. The inclusion of the lagged dependent variable in the model may result in biased estimates (see, for instance, Nickel, 1981). Therefore, three methods are used to correct for this source of bias. First, we rely on instrumental variables for the lagged number of patents. The instruments are the total number of inhabitants and the GDP per capita (capturing both the size and the level of technological development of the region). A second and alternative methodology consists of running a Kiviet-type regression (Kiviet, 1995) that directly removes the bias for the lagged estimator. The estimation method is based on Bruno (2005) which is particularly suited for a small number of individuals. The Arellano-Bond estimator is the third method used. It consists in estimating equation (4) in first difference and using the lagged dependent variable as an instrument.

Error correction model

An error correction model (ECM) can be used to exploit the cointegration between variables; it allows combining the long-run relationship and the short run effect. The error correction term is the residual from the estimated long-run relationship, that is, the difference between the observed and the estimated demand for patents in level:

$$e_{it} = \ln P^*_{it} + \hat{\gamma_i} - \hat{\beta}_1 \ln R_{it} - \hat{\beta}_2 \ln F_{it} \tag{5}$$

The correction term is then used as an adjustment process to capture long-run dynamics. The ECM is defined as the first difference of equation (2) plus last period's error correction term:

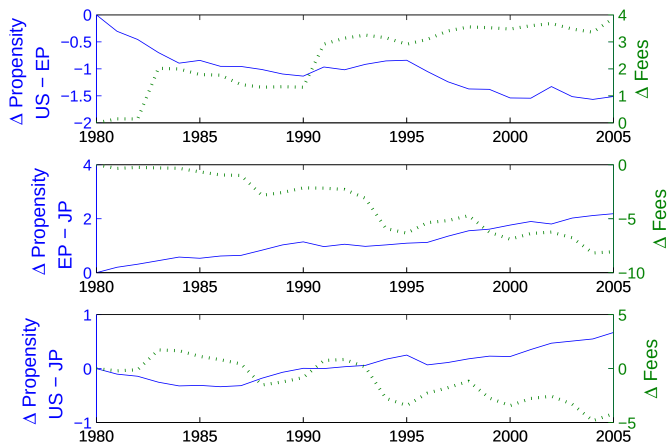
$$\Delta P^*_{it} = c_i + \alpha_1 \Delta \ln R_{it} + \alpha_2 \Delta \ln F_{it} - (\alpha_3 \ln P^*_{i,t-1} - \alpha_4 \ln R_{i,t-1} - \alpha_5 \ln F_{i,t-1}) + \nu_{it} \tag{6}$$

where α_3 may range from 0 (no adjustment) to -1 (full adjustment). Long-run effects for, say, fees are recovered by dividing α_5 by the adjustment coefficient α_3 (see Alogoskoufis and Smith, 1991, for a discussion). The econometric method used for the ECM is a Prais-Winsten regression, which corrects for the potential contemporaneous correlation of residuals. Equation (6) is estimated for both fees up to the grant and entry fees.

5 Empirical results

A first glimpse at the potential impact of changes in fees on the behavior of applicants is illustrated in Figure 5. Each panel plots the difference in the patent-to-R&D ratio (as a proxy for the propensity to patent) between two countries and the difference in the level of fees. The values are normalized to 1 in 1980, so that a difference in, say, relative fees in countries i and j greater than 0 actually means that fees in country i grew faster than fees in country j. It clearly appears that a negative trend in the difference in fees is associated with a positive trend in the difference in the patent-to-R&D ratio, and vice versa. In other words, countries in which patents became more expensive had a lower increase in their propensity to patent. These long-term graphical illustrations suggest that fees affect the behavior of applicants.

Figure 5: *Bilateral differences in the evolutions of the propensity to patent and fees, 1980-2005*



Notes: Δ Propensity (solid line) is defined as the difference between the propensity to patent in country i and the propensity to patent in country j, relative to the base year 1980 (=1) [e.g. propensity_eu(t)/propensity_eu(1) - propensity_jp(t)/propensity_jp(1)], reported on the left-hand scale. Δ Fees (dashed line), reported on the right-hand scale, are defined similarly with fees up to the grant.

Before assessing the magnitude of applicants' sensibility to fees, we formally test the assumptions underlying the regression models. First, we investigate the dynamics of price adjustment. The assumption that fees are independent from the total number of patents processed is tested with a Granger causality test between the level of fees and the number of patents applied for. The optimal number of lags p for the unrestricted regression was determined for each patent office using the Schwarz' Bayesian Information Criterion. A Granger causality test was then performed using a restricted regression with p lagged value of both the fees up to the grant and the total number of patent applications. Results are presented in Table 3.

Table 3: *Granger causality test*

	Nb of lags (p)	*F-value*	*p-value*
JPO	1	2.71	0.11
USPTO	1	1.17	0.29
EPO	2	1.14	0.34

It appears that the past demand for patents does not help to predict the level of patent fees in any of the three regions. The hypothesis that the level of demand causes in the Granger sense the level of fees is rejected for all three country-series. As a consequence, patent fees can fairly be treated as exogenously determined in the regressions.

The assumption that the variables are cointegrated is tested in two steps. First, we test for the presence of homogeneous autoregressive roots. Second, we perform panel cointegration tests. A large literature on unit roots in panel data has recently emerged and several statistical tests have been proposed. We implement three tests proposed by Levin et al. (2002), Im et al. (2003) and Maddala and Wu (1999) which all assume independence across units. They are denoted LLC, IPS and MW, respectively. The disturbances of autoregressive models are assumed to have a zero mean, finite variance and might exhibit autocorrelation. In each case, the null hypothesis is that of a unit root for all individuals. LLC is performed under the restrictive alternative of an homogeneous autoregressive root. IPS extends LLC in that the alternative allows both for heterogeneous roots and for heterogeneous presence of a unit root (i.e. the alternative is that there might be a unit root for some individuals, but not for all). The test statistic is based on the ADF statistics averaged across the individuals. Finally, MW is closely related to IPS but relies on combining the level of p-values of the independent unit root tests (see Hurlin and Mignon, 2006, for an excellent overview of unit root tests for panel data). Table 4 summarizes the various results.

Table 4: *Panel unit root tests*

	*P**		*R*		*F*	
	Value	*p-value*	*Value*	*p-value*	*Value*	*p-value*
LLC	0.92	0.82	0.03	0.51	0.16	0.56
IPS	3.09	0.99	2.23	0.99	0.13	0.55
MW	9.25	0.16	0.89	0.99	5.00	0.54

Notes: Individual effects included. LLC: corrected t-stat reported. IPS: W_{tbar} reported. MW: Fisher statistic based on individual ADF statistics and their associated p-value pooled test statistic. A Matlab code is available from C. Hurlin.

None of the tests leads to a rejection of the null hypothesis of a homogeneous autoregressive root; all the series are therefore non-stationary. Then, a potential co-integration relationship between the variables was tested using the four panel-data tests proposed by Westerlund (2007). Two tests (labeled G) are performed under the alternative that the panel is co-integrated as a whole, while the two other tests (labeled P) are designed under the alternative that there is at least one individual that is co-integrated. In all cases, the null is of no co-integration. The results are presented in Table 5.

Table 5: *Panel co-integration tests*

	Value	*p-value**	*p-value*†
G_τ	-2.93	0.05	0.09
G_α	-12.72	0.16	0.02
P_τ	-3.42	0.33	0.27
P_α	-10.46	0.07	0.05

Notes: The tests are implemented with a constant. The lags in the error correction equation are chosen according to the Akaike information criterion. (*) p-values under the normal distribution. (†) p-values based on the bootstrapped distribution (400 runs). τ and α indicate different test statistics. See Persyn and Westerlund (2008) for further methodological details.

The null hypothesis of no co-integration is rejected under the test α, and the G values indicate that the panel is co-integrated as a whole. The result bears an interesting insight into the R&D-patent relationship, as it suggests that there is a long-run equilibrium level between the number of patents and R&D efforts, taking into account other determinants of patent filings such as the level of patent fees.

Table 6 presents the estimated parameters of both the partial adjustment model and the error correction model.

Table 6: *Estimates of the parameters of the patent production function*

Model	*Partial Adjustment*			*ECM*	
Dep. Var.	$\ln P_t$	$\ln P_t$	$\Delta \ln P_t$	$\Delta \ln P_t$	$\Delta \ln P_t$
Fees	Grant	Grant	Grant	Grant	Entry
Est. method	IFGLS	LSDV C.B.	GMM	Prais-Winsten	Prais-Winsten
	A	B	C	D	E
$\ln P_{t-1}$	0.719***	0.855***		-0.114**	-0.071*
	(8.50)	*(19.16)*		*(2.31)*	*(1.63)*
$\Delta \ln P_{t-1}$			0.568***		
			(9.75)		
$\ln R_t$	0.409***	0.283***			
	(3.52)	*(3.29)*			
$\Delta \ln R_t$			0.413***	0.548***	0.520*
			(4.06)	*(2.62)*	*(2.38)*
$\ln R_{t-1}$				0.189*	0.068
				(1.79)	*(0.87)*
$\ln F_t$	-0.060***	-0.071***			
	(2.80)	*(3.82)*			
$\Delta \ln F_t$			-0.067***	-0.121***	-0.070***
			(4.02)	*(4.06)*	*(2.83)*
$\ln F_{t-1}$				-0.073***	-0.008
				(3.63)	*(0.56)*
Country FE	Yes	Yes	Yes	Yes	Yes
AR(1)	0.00	0.12	0.00	-	-
AR(2)	-	-	0.60	-	-
Adj. R^2	0.90	0.98	0.71	0.20	0.09
Observations	75	75	72	75	75

Notes: The dependent variable is the number of patents applied for at the JPO, the USPTO or the EPO, in level ($\ln P_t$) or in first difference ($\Delta \ln P_t$). The econometric methods are for column A: iterated FGLS to correct for autocorrelation of residuals and contemporaneous panel correlation. The variables $CAPITA$ and GDP_CAP are used as instrumental variables for the lagged number of patents; column B: least square dummy variable correcting for bias (LSDV C.B.) with bootstrapped standard errors (Bruno, 2005); column C: Arellano-Bond difference GMM (one step) with one lag of the dependent variable (p-value for the Sargan test = 1.00); columns D and E: Prais-Winsten regression, correcting for contemporaneous correlation of residuals. AR(1) and AR(2) report the p-values for the null-hypothesis of no autocorrelation of order 1 and 2, respectively. ***, ** and * indicate significance at the 1, 5 and 10 percent probability threshold, respectively.

Estimations of the parameters of the partial adjustment model are presented in columns A to C, and estimations of the parameters of the error correction model are presented in columns D and E. The regressions are estimated with (absolute) fees up to the grant (columns A to D). For completeness, column E reports to elasticity of (absolute) entry fees.[11] The estimated price elasticity is always negative and significant and suggests short-term elasticities of fees up to the grant that vary between -0.06 and -0.12. Long-run elasticities must be computed from the estimated parameters and multipliers; they are displayed in Table 7. They range from -0.15 to -0.49, with an average of about -0.30. The results are in line with the price elasticities estimated by de Rassenfosse and van Pottelsberghe (2007, 2009) with cross sections of countries. They report elasticities that vary between -0.45 and -0.56, which is slightly higher than the present long-run estimates. The results confirm that patents are an inelastic good. The long-term patent elasticity of R&D expenditures is about 1.50. Yet, one has to be cautious not the interpret this parameter at face value since the variable captures the potential of a region both in terms of research output and market attractiveness. If entry fees are taken into account, column E of Table 6 shows that the short term elasticity is -0.07. Interestingly, the long-term effect of entry fees is not significant as indicated in Table 7.

Table 7: *Long-term elasticities*

	A	B	C	D	Mean A to D	E
R&D	1.45***	1.96***	0.95***	1.65***	1.50	0.95*
	(0.28)	*(0.26)*	*(0.19)*	*(0.37)*		*(0.59)*
Fees	-0.21**	-0.49***	-0.15***	-0.36***	-0.30	-0.12
	(-0.16)	*(-0.09)*	*(-0.04)*	*(-0.12)*		*(-0.18)*

Notes: Elasticities estimated from the regression results of Table 6. Standard errors are in parenthesis. ***, **, * indicate significance at the 1, 5 and 10 percent probability threshold, respectively.

The models presented in Table 6 were also estimated with time dummies to account for a change in the propensity to patent over time. Regressions were run with time dummies of 3, 4 and 5 years interval. Only the 4 and 5-years time dummies were significant for some models but the estimated price elasticities were very robust to the inclusion of time effects. Fees were also interacted with time dummies but the interaction term was not significant, suggesting that the impact of fees have been roughly stable over time. Similarly, time dummies were interacted with R&D expenditures but with no significant effect.

The results of Table 7 can be used to estimate the total impact that the fee policy adopted by the EPO had on the overall propensity to patent. Given a mean price elasticity of -0.30, roughly 20% of the increase in patent filings

[11]Note that the econometric models are estimated with absolute fees and not relative fees. Absolute fees are the fees that applicants have to pay.

over the period 1995 to 2001 can be attributed to the decrease in fees.[12] This estimate is more conservative than that of Eaton et al. (2004), who attribute 60% of the increase in the number of EPO patents over the nineties to the decline in the overall cost of seeking protection at the EPO.

6 Concluding remarks

The main objective of this paper is to assess whether fees could be one factor underlying the boom in patent applications observed over the past two decades. The paper focuses on the demand for patent at the patent offices of three main regions, namely Europe (EPO), the U.S. (USPTO) and Japan (JPO). Entry fees and fees up to the grant have been computed for a period ranging from 1980 to 2007. This unique dataset clearly shows that the EPO has operated the sharpest decrease in patent fees since the mid-1990s, in both absolute and relative terms (fees per claim per capita), and for both entry fees and fees up to grant. The USPTO has maintained nearly stable absolute fees since 1995, but has experienced a slight drop in relative fees. Despite this convergence, the EPO still charges fees that are two to three times higher than those of the USPTO in 2007.

The second contribution to the literature is to test empirically the intuition that fees affect the filing behavior of applicants. This is performed through an in-depth quantitative analysis aiming at evaluating the amplitude and significance of the price elasticity of demand for patents. The estimation of dynamic panel-data models of patent applications underlines the prime role of research activities, and a significant price elasticity of demand for patents of about -0.30. This result is in line with (albeit lower than) the few existing estimates based on cross-sectional analyses.

The impact of fees is estimated from the aggregate demand for patents. Another approach would have consisted in estimating the elasticity at the firm level, where individual characteristics may imply a large difference in the reaction to change in fees among firms. Yet, that approach would be restricted to a very limited time range and would hide the aggregate effect. As the focus on the present study is on the policy dimension, we believe that the aggregate approach is the best suited. It is nevertheless important to keep in mind that important behavioral differences might be observed across firms according to their size, their wealth or their industry.

The empirical exercise confirms that fees can actually be taken as a factor influencing the propensity to patent, and hence can be considered as an effective policy leverage by policy makers. The sharp drop in fees orchestrated by the EPO, in both absolute and relative terms, and the stable, though very inexpensive, fee policy of the USPTO, combined with the negative and significant

[12]Fees decreased by 50% (from 8,025 USD PPP in 1995 to 3,942 USD PPP in 2001), which implies a 15% increase of patent applications. Meanwhile, patent applications actually increased by 80%, so that roughly one fifth (15/80) of the growth in patent applications can be attributed to the decrease in patent fees.

price elasticity of demand for patents, certainly did contribute to the observed increase in patent filings. About 20% of the growth of patent applications at the EPO in the mid-nineties can be attributed to the fee policy adopted over that period. Part of the solution to the current backlog crisis would therefore be to adopt a more stringent fee policy. As the fee elasticity is much smaller than unity such a policy would further reinforce the funding model of the EPO.

Whether an increase in fees is socially desirable remains an open question. To the best of our knowledge, there exists no study that explicitly looks at this issue. A useful extension to the present work would thus be to investigate whether higher fees weed out low quality patents.

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A Working assumptions

Each patent office has its own fee structure, which makes international comparisons a difficult exercise. The assumptions made for the empirical analysis seek to make the results reasonably comparable. The present appendix provides the list of working assumptions that were made when measuring absolute and relative fees, for both entry fees and fees up to the grant.

- The applicant is assumed to be a large entity (SMEs have reduced fees in the USA and Japan, but large firms still account for the most important share of applications);
- No late payments, paper filing (as opposed to electronic filings, which are slightly less expensive);
- A change in price during the year is assumed to be effective the next year if it was implemented after June 30. If it was implemented on or before June 30, it is assumed effective at the beginning of the year.
- Modification in the timing of fees has been taken into account when the information was provided by the patent office. Otherwise, it is assumed not to have changed over time. At the EPO, designation fees were included in entry fees before 1998, and in total cumulated fees up to the grant for the subsequent years.

Other country-specific assumptions are:

1. USPTO-related assumptions:
    - Three independent claims have been considered
2. EPO-related assumptions:
    - Euro-direct fees have been considered (the PCT route generally induces slightly higher fees);
    - Use of European Search Report since 2005;
    - Five countries were taken into consideration to compute the relative fees: Germany, France, the United Kingdom, Italy and the Netherlands.
    - Exchange rates and inflation for EPC countries are based on German macroeconomic data and provided by Eurostat.

B Data sources

Table 8: *Data sources and variables description*

Variable	***Description***	***Source***
P	Total number of yearly patent applications defined as sum of resident and non-resident applications. (EPO: Eurodirect + PCT regional filings)	Provided by patent offices (EPO, JPO, USPTO)
R	Total internal R&D expenditures (EPO: R&D expenditures are computed for each year as the sum of R&D expenditures of the EPC Member States)	OECD Main Science and Technology Indicators
F	Fees for a representative patent. See main text and Appendix A for methodological details	EPO, USPTO, JPO. US.. fees from 1980 to 1982 come from House Report No. 96-1307, 96th Cong., 2d Sess. (1980)
$CLAIMS$	Average number of claims per patent	EPO, USPTO, JPO
$RATES$	Exchange rates from (current) national currency to constant national currency and constant US PPPs.	International Monetary Fund World Economic Outlook (IMF-WEO)
$CAPITA$	Million of inhabitants	IMF-WEO
GDP_CAP	GDP per capita	OECD Statistical Portal

Table 9: *Patent fees in current local currency*

	JPO (¥)			*USPTO (US $)*			*EPO (€)*		
	Entry	UTG	Cl.*	Entry	UTG	Cl.	Entry	UTP	Cl.
1980	5,400	45,400	1	79	243	12	1,288	2,407	10
1981	6,300	52,300	1	81	245	13	1,293	2,417	10
1982	6,300	52,300	1	81	245	13	1,368	2,557	10
1983	6,300	52,300	1	300	800	14	1,453	2,698	11
1984	6,300	52,300	1	300	800	14	1,474	2,737	11
1985	9,500	78,800	1	300	800	14	1,839	3,479	11
1986	9,500	78,800	1	340	900	15	1,924	3,639	11
1987	9,500	78,800	1	340	900	15	2,112	3,874	11
1988	9,500	127,000	3	340	900	15	2,109	3,869	11
1989	9,500	127,000	3	340	900	16	2,113	3,877	11
1990	9,500	127,000	3	370	990	17	2,132	3,911	11
1991	9,500	127,000	3	630	1,680	17	2,453	5,013	11
1992	9,500	127,000	3	690	1,820	17	2,490	5,088	11
1993	9,500	133,300	4	710	1,880	17	2,639	5,350	12
1994	9,500	198,100	5	710	1,880	18	2,655	5,383	12
1995	9,500	198,100	5	730	1,940	17	2,727	5,796	12
1996	9,500	198,100	5	750	2,000	18	2,676	5,687	12
1997	9,500	207,100	6	770	2,060	20	2,642	5,569	13
1998	9,500	207,100	6	812	2,132	21	1,391	5,556	13
1999	21,000	212,900	7	796	2,006	22	938	4,414	13
2000	21,000	212,900	7	762	1,972	24	978	4,454	14
2001	21,000	219,800	8	818	2,058	26	978	4,454	14
2002	21,000	219,800	8	866	2,146	27	975	4,430	14
2003	21,000	219,800	8	876	2,176	27	1,015	4,470	15
2004	16,000	242,100	8	896	2,226	27	1,015	4,470	15
2005	16,000	242,100	8	1,200	2,600	24	1,320	4,775	15
2006	16,000	242,100	8	1,100	2,500	24	1,395	5,020	15
2007	16,000	242,100	8	1,100	2,500	24	1,395	5,020	15

Notes: UTG stands for "Up to grant" and Cl. for the number of claims. *: Prior to 1988, there was only one claim per patent in Japan (Kotabe, 1992). Data on the number of claims in 2006 and 2007 at the USPTO and from 2005 to 2007 at the EPO was missing and has been set constant. See Appendix A for methodological details.