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CONTENTS

INTRODUCTION

This PhD thesis is a collection of two empirical essays in Intellectual Property Economics. The first chapter corresponds to the paper “Patenting Strategies in the European Patent System”. The second chapter corresponds to the paper “Market Value of Patents and Trademarks”. The two chapters are preceded by this introduction summarizing the research.

The first chapter, titled “Patenting Strategies in the European Patent System” is co-authored with Georg von Graevenitz and Dietmar Harhoff.

In this study we analyze European Patenting System. The aim of the research is to shed the light on the firm’s choice between European Patent Office (EPO) and national patent offices (NPOs). We also seek to analyze which factors influence this choice. The European patent system consists of national offices and the European Patent Office, which cooperate on legal questions, while competing on fees and service quality. This competition could result in differentiation of the service offered by offices and in market segmentation, which might benefit patent applicants. To date there is little evidence on whether firms regularly choose between EPO and national offices, nor which parameters influence this choice. Such evidence is needed if the functioning of the EPS as a whole is to be assessed. We provide the first analysis of competition between patent offices within the EPS. The paper provides a recursive model of the two principal choices made by patent applicants in the EPS: the selection of examining offices and of jurisdictions in which patent protection is obtained. We then derive and estimate instrumental variables models to establish the relative importance of fees, grant rates, examination duration and firm and patent characteristics in these choices. We identify sectors and types of firms that predominantly rely on the national offices or the EPO, but we also identify significant levels of switching, driven by variation in grant rates across offices and by fee changes as well as variation in the duration of examination. We discuss implications of our work for theoretical and empirical analyses of patent systems, and we discuss how the likely introduction of a Unitary Patent and Unified Patent Court will affect the system and its governance mechanisms.

The second chapter is titled “Market Value of Patents and Trademarks”.

This is an empirical study analyzing the market value of top R&D investing companies in the world. The aim of this research is to analyze whether knowledge assets and Intellectual Property (IP) assets are significant factors affecting the value of the companies. Also, we study whether the global financial crisis of 2008 had a significant effect on how stock markets value firms’ investments in knowledge and branding as well as complementary investments in patents and trademarks. Building on data from European Intellectual Property Office (EUIPO) and European Patent Office (EPO) we construct a firm panel covering R&D, marketing and IP investments over the period 2005-2012. In addition, we estimate market value equations for the pre-crisis period years 2005-2008 and 2009-2012. Empirical findings suggest that there are interesting differences in which investments contributed to market value before and after 2008. First, investments in R&D contribute far more significantly to the market value after the crisis than before. Second, it becomes apparent that after the crisis patent quality arises as a significant factor which increases value of the companies. At the same time, patent quantity ceases to be an influencing factor in the market value equation after 2008.

Conference presentations

The paper corresponding to Chapter 1, "*Patenting Strategies in the European Patent System*", was presented at the 11th Annual Conference of the EPIP Association (European Policy for Intellectual Property), at Pembroke College at Oxford University on September 3-5, 2016. It was also presented at the 2nd TILEC Conference on "Competition, Standardization, and Innovation" at Tilburg Law and Economics Center (TILEC), Tilburg University, the Netherlands on 18-19 December, 2017.

The paper will be the object of a presentation during the 13th Annual Conference of the EPIP Association (European Policy for Intellectual Property) in Berlin, Germany, September 5-7, 2018.

The paper corresponding to Chapter 2, *"Market Value of Patents and Trademarks"*, has been accepted for presentation at the XXXIII Jornadas de Economía Industrial (JEI) Annual Conference to be held at the University of Barcelona on September 6-7, 2018. It has also been accepted for presentation at the 30th Annual Conference of the Italian Society of Public Economics (SIEP 2018), to be held at the University of Padua (Italy) on September 20-21, 2018.

Part of the results of this paper was presented at the IP Statistics for Decision Makers (IPSDM) Annual Conference in Mexico City, Mexico on November 14-15, 2017. The version of this paper will also be the object of presentation during the 13th Annual Conference of the EPIP Association (European Policy for Intellectual Property) in Berlin, Germany, September 5-7, 2018.

CHAPTER 1

PATENTING STRATEGIES IN THE EUROPEAN PATENT SYSTEM

A joint work with Georg von Graevenitz[1] and Dietmar Harhoff[2]

ABSTRACT

The European Patent System (EPS) consists of National Offices and the European Patent Office (EPO). The complexity of the system is mirrored in the complexity of strategic options available to patentees when selecting the route of patenting. To date there is little evidence on how firms choose between EPO and national offices, nor which parameters influence this choice. The paper provides a recursive model of the two principal choices made by patent applicants: the selection of examining offices and of jurisdictions in which patent protection is obtained. We then derive and estimate instrumental variables models to establish the relative importance of fees, grant rates, examination duration and firm and patent characteristics in these choices. We identify sectors and types of firms that predominantly rely on the national offices or the EPO. We also identify significant levels of switching, driven by variation in grant rates across offices and by fee changes as well as variation in the duration of examination. We discuss implications of our work for theoretical and empirical analyses of patent systems.

KEYWORDS: European Patent System, EPO, Patents, Patenting Strategies

JEL Classification: F53, K33, O34, O38

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[1] Queen Mary University of London, CCP and CREATe

[2] Max Planck Institute Munich

1. INTRODUCTION

European patent system (EPS) is very complex because of the multitude of institutional players involved. It is possible that incentives of these different players are in misalignment. Such complexity poses a challenge for the companies patenting in Europe. From strategic point of view this challenge might also pose an opportunity to benefit from the system. In Europe there is a choice not available in other markets, where only single patent office exists.

Companies that patent in Europe can shape their patenting strategies by choosing different filing routes[3]. Applicants can choose between applying to the European Patent Office (EPO) or specific national patent offices (NPOs). In addition, each patent granted by the EPO can be validated and enforced in multiple jurisdictions[4]. Geographical scope is the additional dimension adding to complexity of EPS. For instance, company may choose to protect its patent portfolio via EPO at all times. However, it may also file at the specific National Office, or opt for certain combination of several National Offices. In the post-grant stage company has to make another strategic decision on the number of the jurisdictions it wishes to uphold the valid patent right. We seek to explore the factors that influence companies' decisions on the filing route and the geographical breadth of their patent protection.

The European patent system (EPS) offers a range of options to applicants: fees vary across offices as do grant rates and the speed of examination. Legal rules governing the process of examination vary too. The timing of examination processes also differ considerably, ranging from deferred examination in Germany (which allows applicants to delay examination for up to seven years) to almost immediate examination in others. The way NPOs operate depend a lot on their financial model, i.e. whether they

[3] Filing routes and patenting process in the EPS are described with more detail in the Annex B.

[4] There are 38 Contracting States to the EPC, also called member states of the European Patent Organization: Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Monaco, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

are self-financing or are fully funded by the state, and their degree of autonomy in fee setting (Europe Economics, 2010). These policy parameters are set by governments and occur with little cross-country coordination. Given this lack of coordination one might expect competition for business to influence on how fees, grant rates and examination rules develop[5]. National offices may be competing with one another for the business of those applicants which only require patents in one or two countries in Europe to protect their inventions in the entire EPS.

EPO and national offices have co-existed since 1977 when the European Patent Organization[6] (EPOrg) was created under the European Patent Convention (EPC) of 1973. Thus, the relationship between EPO and NPOs is coordinated. National offices share revenues[7] from patents granted by the EPO once these are validated in a jurisdiction. Contracting States are involved in decisions about patent fees, search and examination quality and granting rules.

Currently, there is little to no evidence on how firms choose amongst the options the EPS provides. Recently, Hall and Helmers (2012) analyze applicant behavior in the context of accession to the European Patent Convention (EPC) between 2000 and 2008. Their analysis complements ours, but focuses purely on the choice between EPO-granted patents and patents granted by the accession countries' offices. Our paper provides the first effort to study which factors determine the office examining the patent and the number of countries in which the patent is then upheld within the entire EPS. To simplify the analysis, we focus on the largest ten national offices. We find that firms respond not only to fee changes, but also to relative grant rates and the duration of examination, when determining which office to turn to for examination. This choice subsequently affects how widely a patent is upheld.

[5] Patent offices are generally not run to maximize profits, but many do produce substantial surpluses that feed into government budgets. This leads to some pressure to keep these surpluses constant or to grow them.

[6] The European Patent Organization has two organs: the European Patent Office, which acts as its executive body, and the Administrative Council, which acts as its supervisory body as well as, to a limited extent, its legislative body. The actual legislative power to revise the European Patent Convention lies with the Contracting States themselves when meeting at a Conference of the Contracting States.

[7] The 50% share of renewal fees from EPC patents is transferred to NPOs.

The aim of this paper is to shed light on how firms respond to variation in fees, grant rates and examination durations within the EPS. To the best of our knowledge the principal choices of patent applicants in the EPS have not previously been described or analyzed at the firm level. These choices are where to have a patent application examined and how widely to uphold the patent once it is granted. This paper examines these two decisions and provides evidence on how decisions on fees and investment in examination at ten largest national offices and the EPO affect firms' decisions[8].

We construct data on patent applications and grants at EPO and the ten largest NPOs in Europe and matched applicant names across the resulting databases. The data contain information on the process of patent applications, grants, validations and citations based on PATSTAT[9] which is combined with data on patent office fees and on patent office behavior. The latter is constructed from the underlying PATSTAT data and the former fee data was collected by authors.

The principal findings of a descriptive analysis are that firms tend to use either a national office or the EPO, but seldom both at the same time for the examination of a patent. Nonetheless, there is evidence that firms switch between these alternatives over time. It is interesting to note that firms switch away from using the EPO almost as often as they switch to using it. We also find that firms with smaller portfolios tend to rely on NPOs more, but firms with portfolios of all sizes use both NPOs and the EPO. Finally, we document significant differences between technology areas, with applicants patenting in chemistry relying very significantly on the EPO while those active in mechanical engineering use NPOs more often.

We develop a simple model of the choice between NPOs and the EPO; and the choice of the number of jurisdictions in which patent protection is enacted. In this

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[8] There is a large literature on the impact of fees on applicants' choices, which is surveyed by Hall and Harhoff (2012). This literature demonstrates that application fees reduce demand for patents (Rassenfosse and Potterie, 2012) and the renewal fees impact significantly on when patents are allowed to lapse (Lanjouw, 1998; Serrano, 2010). We are not aware of work analyzing how fees impact the choice of the examining office within a regional patent system, but the work of Harhoff et al. (2009, 2016) on validation fees comes closest to this.

[9] PATSTAT database of April 2016.

recursive model the choice of whether or not to apply to the EPO is endogenous. The model can be estimated using an instrumental variables approach.

Due to the large number of potential variables that we could include in the model, we rely on recent data selection methods (Belloni et al., 2012, 2014; Chernozhukov et al., 2015) to select the subsets of variables. The recursive nature of the decision problem we study implies that factors such as, application fees, the EPO's grant rate, and the lag to a firm's previous patent applications, all affect the decision whether to apply to the EPO, but may be excluded from the decision on how widely to protect a granted patent.

Using these instruments we demonstrate that firms induced to avoid EPO either by relative costs or by lower EPO grant rates uphold the patent in fewer countries. To provide robustness we analyze three episodes during which applying to and holding patents at EPO became more expensive using difference-in-differences models. These models confirm that cost increases reduced applications at EPO and also reduced the number of countries in which patents were upheld.

The paper is structured as follows: Section 2 provides a descriptive analysis of patenting in the European Patent System. Section 3 sets out the two models. In addition to a discussion of the models, this section describes the estimation dataset. Section 4 discusses empirical results and Section 5 concludes. An Appendix provides detailed description of European Patent System; and further analysis of parallel patenting and documentation.

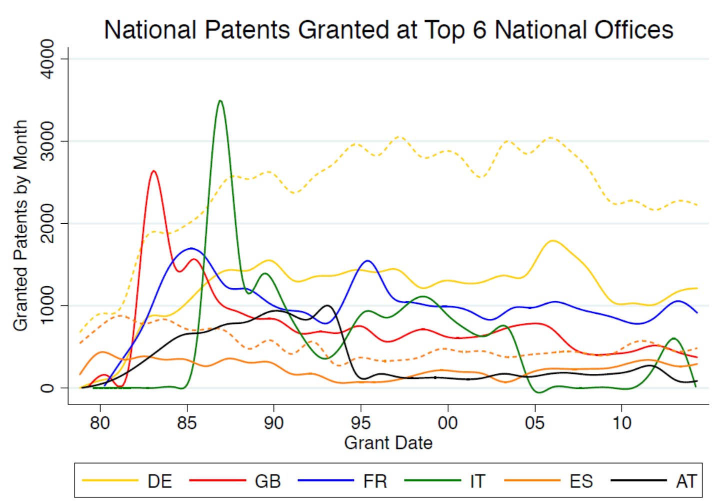
2. DESCRIPTIVE ANALYSIS

The supranational European Patent Office (EPO) and national patent offices (NPOs) have co-existed in Europe since 1977. This section provides descriptive analysis on how patent applicants use both types of office. We focus on the largest 10 national offices in terms of the number of patents granted.

The main question we address here is what role national offices have come to play in the European patent system. First, we demonstrate that the EPO has granted more patents in the territory served by each of the largest six offices than the national office since the middle of the 1980's. However demand for national patents has remained high and stable. Second, we show that applicants tend to use either a national office or the EPO at any given time, but that there is a significant amount of switching between these strategies both towards and away from reliance on the EPO. Third, we show that the national offices are more frequently used by applicants with small portfolios. Fourth, we document significant variation between offices in grant rates and exam durations. Fifth, we show that applicants at national offices usually seek patent protection in one or two countries only, while applicants at EPO seek protection in three or more jurisdictions. Finally, we show that demand for EPO patents differs significantly across technology areas. Overall this analysis shows that national offices continue to have a significant role in the European patent system.

We use PATSTAT data from April 2016. To construct the firm level measures, such as portfolio size and share of applications at EPO, applicants are aggregated into groups on the basis of their names with the help of Derwent[10] patent assignee codes.

Figure 1: National Granted Patents



Note Figure 1: National patent grant counts including utility models (DE, ES) shown as dashed lines. Data smoothed using a median cubic spline with 10 months per band. Variation in the grants reported by the Italian (IT) office is likely to reflect significant management problems at this office after 2004.

[10] The Derwent World Patents Index (DWPI) is a database containing patent applications and grants from 44 of the world's patent issuing authorities: https://clarivate.com/products/derwent-world-patents-index/

Figure 2: EPO Validated Patents

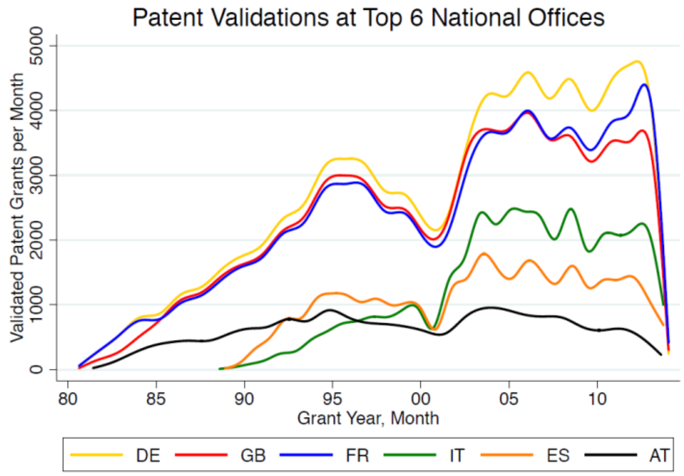


Figure 1 show how many patents have been granted by the six national offices, namely German, UK, French, Italian, Spanish and Austrian. These six offices grant most patents in Europe. This can be compared to the number of national patents that arise from validations of patents granted by the EPO in figure 2. Clearly, more patents granted by the EPO are validated in each of these countries than are granted by the national office. This could be the consequence of differences in grant rates across offices, a topic we return to below. The number of patents granted by national offices has been remarkably stable over the last two decades. In the same period the EPO significantly increased the number of grants, with the exception of a decline between 1995 and 2000. This period coincided with a marked increase in the duration of examination and a buildup of backlogs at EPO in the same period as figures 6 and 8 shows.

Figure 3: Distribution of Applicants' Patent Portfolios by Portfolio Size in 1995

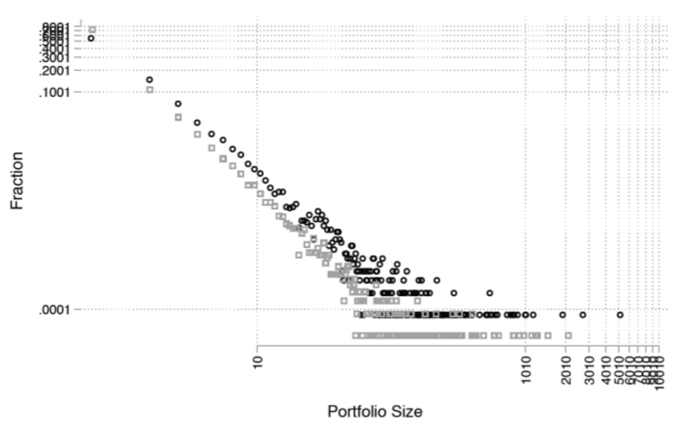
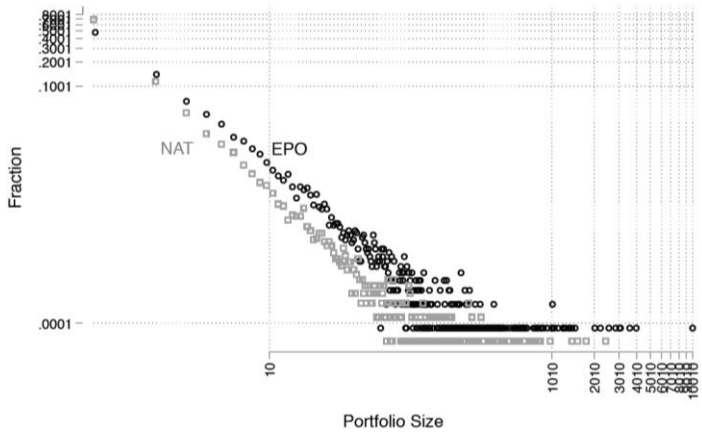


Figure 4: Distribution of Applicants' Patent Portfolios by Portfolio Size in 2010



Note Figure 3 and Figure 4: Log-log plot of fraction of firm or firm groups with patent portfolio of a given size based on all patents granted by EPO or NPOs up until the year indicated in the title. These plots demonstrate that very significant fractions of firms have small portfolios in both offices and that the size distribution of portfolios is close to a power law for a significant range of the data.

The most apparent difference between applicants that rely on EPO and those that rely on the NPOs is the size of each applicant's patent portfolio. Figures 3 and 4 show that the fraction of applicants with portfolio of one patent is higher at the national offices, both in 1995 and in 2010. The fraction of applicants with portfolios of more than one patent is always higher at EPO. That does not mean that applicants with very large patent portfolios shun NPOs. Further reasons for firms' decisions to switch to or away from EPO may have to do with the duration of examination and the grant rates at the different offices. We explore these two sources of variation next.

Figure 5: Grant Rates at National Offices

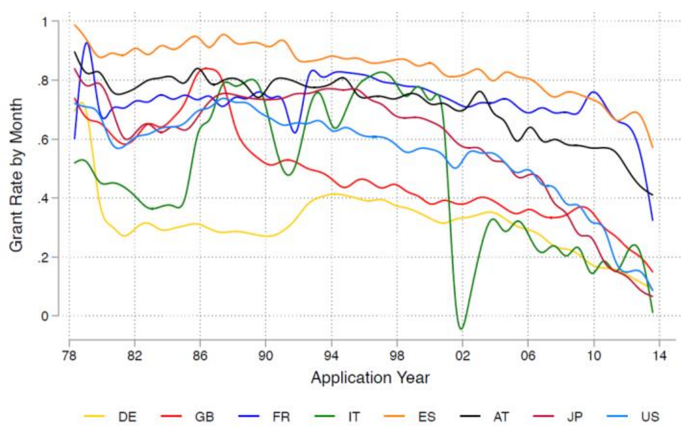
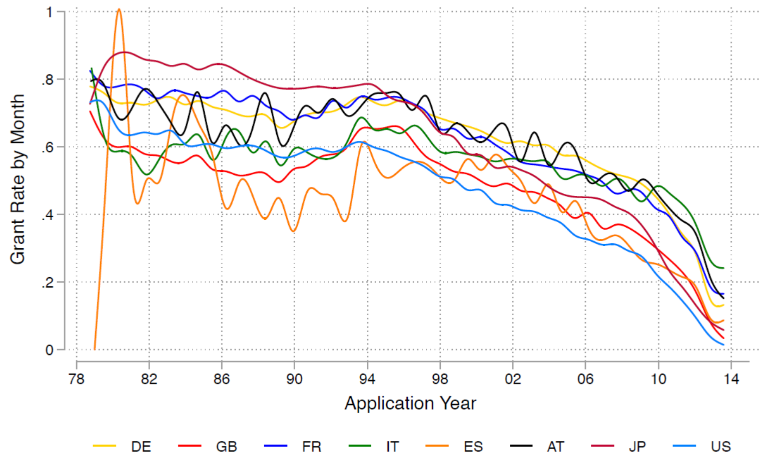


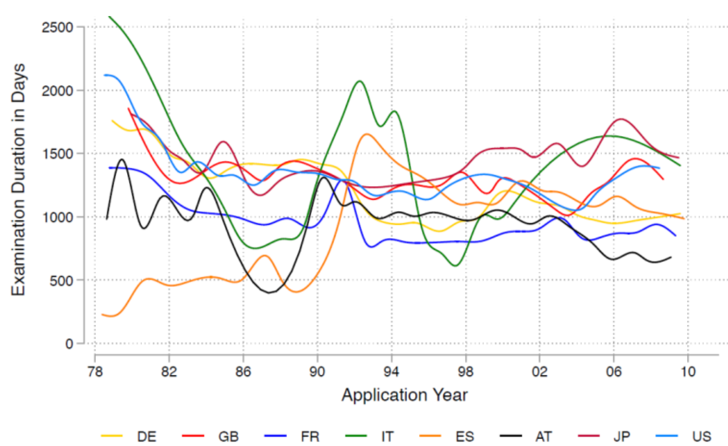
Figure 6: Grant Rates at EPO



Note Figure 5 and Figure 6: Grant rates are calculated for each monthly cohort and each country (office) of first filing or national office separately. Cohorts are defined by the month in which the patent application reached either the national office or EPO. Data smoothed using a median cubic spline with 12 months per band.

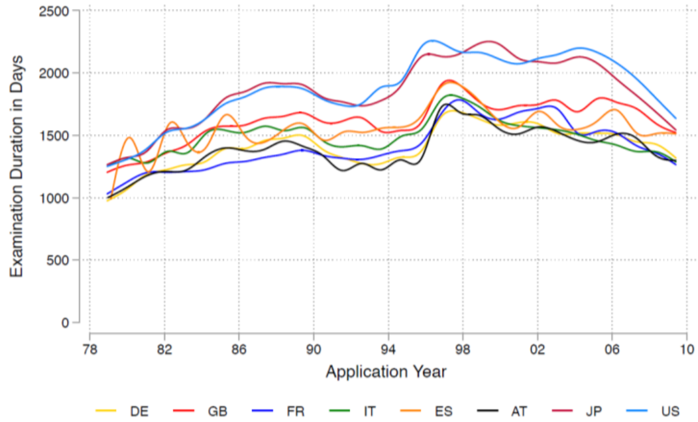
Figures 5 and 6 allow comparing the grant rates at EPO and at the eight top NPOs, i.e. at Germany, UK, France, Italy, Spain, Austria, Japan and USA. The basis of the comparison is the country of the applicant and the year of application of the patents. Note that the largest proportion of patents applied for at national offices originates within the home country and the majority of applicants from a country will also file in that country[11].

Figure 7: Examination Duration at National Offices



[11] This is not the case for Switzerland.

Figure 8: Examination Duration at EPO



Note Figure 7 and Figure 8: Durations are median examination durations within each monthly cohort. Cohorts are defined by the month in which the patent application reached either the national office or EPO. Data smoothed using a median cubic spline with 12 months per band.

The graphs numbered 5-8 provide some interesting results:

i. Applicants from Germany and the United Kingdom were least likely and applicants from Spain and France were most likely to obtain a patent from the national offices; Figure 12 in Appendix A.1 shows that this is driven by the grant rates at the national offices.

ii. Applicants from countries with lower grant rates at EPO were also likely to have taken longer to complete the examination of their patents; this may be due to industry effects and or selection effects. We don't observe this correlation at the national offices.

iii. Applicants at the national offices face significantly lower waiting times than applicants from the same countries at EPO; this again is likely to be partly due to industry effects.

iv. Grant rates at EPO started to decline for patents that reached EPO after 1997. These are also the cohorts the experienced the longest pendencies. EPO introduce measures to combat long pendency in 2002, which explain part of the fall in grant rates after this date (Harhoff and Wagner, 2009).

Overall, these results suggests that the EPO may have increased the attractiveness of applying to national offices by becoming comparatively stricter and taking longer to examine patents than national offices.

Figure 9: Distribution of Validations in Chemistry

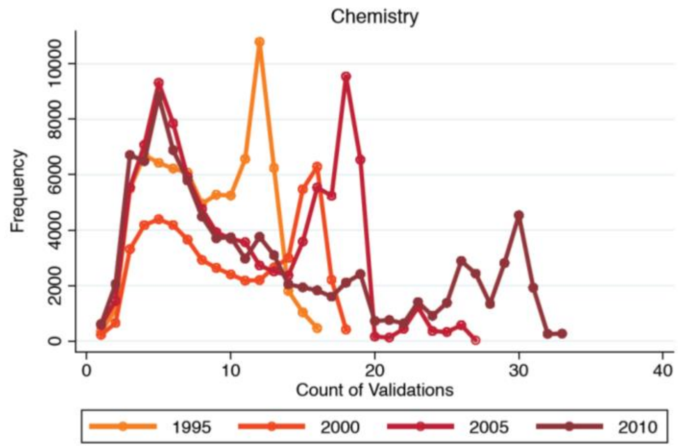
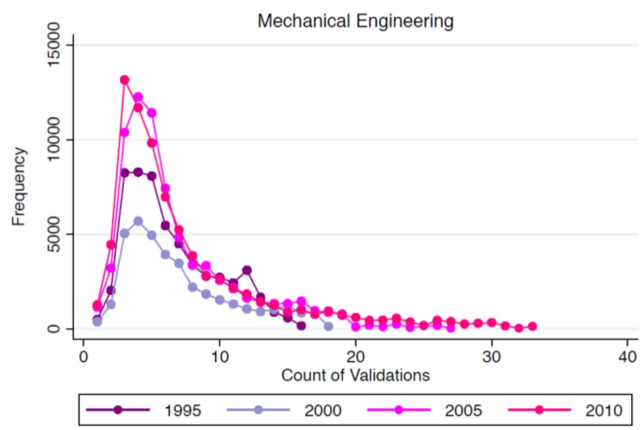


Figure 10: Distribution of Validations in Mechanical Engineering



Note Figure 9 and Figure 10: The number of countries in which patents could be validated increased between 1995 and 2010. This partly explains why the frequency distributions displayed here extend over a wider range over time.

Figures 9 and 10 show that technological area of invention can influence the patenting strategies. Many patents in Chemistry are validated in most if not all jurisdictions, whereas in Mechanical Engineering most patents are validated only in four or five jurisdictions. This reflects the fact that chemical inventions are more easily reengineered and require less scale to be used effectively. These differences across technologies in validation patterns at EPO are also reflected in the propensity of firms to apply to EPO. Our data suggests that in some of the technology areas subsumed under Chemistry the share of patents granted by EPO in Europe has reached 8 out of 10, whilst in most technology areas subsumed under mechanical engineering it has remained between 5 and 6 out of 10 patents. Patents in the latter categories are often only patented in a few countries, reducing the need to rely on the EPO.

Next section outlines the empirical model and data used in the empirical estimations.

3. EMPIRICAL MODEL AND DATA

In this section we derive the empirical model, discuss how it is estimated and describe the data we use.

3.1 MODEL

Firms seeking to obtain patent protection in a number of European countries have two principal avenues for this: they can apply only to EPO; or they can apply directly to the national patent offices of the countries they seek legal protection in.

In practice firms often do both. They first apply to one national office and subsequently they apply to EPO. Usually the national application is dropped later, but not always as we document in Appendix A.3. Irrespective of which office examines the application, the firm must make a second decision: how many patents it wants to uphold post-grant. If the firm applied to EPO, this is the decision in which countries to validate the patent. In case the firm only applied to national offices, this is the decision in how many countries to complete the application process. Analysis of our data suggests that firms on average apply for one more patent than is finally granted. This will sometimes be due to the fact that one of the national offices refused to grant the patent, but this is unlikely to be the only explanation for applications that do not turn into grants: we observe especially with larger patent families that mid-ranking offices like Sweden and

Italy make up a disproportionately large number of applications that do not become grants.

We model the decision process at firms as a two-step process: first firms determine whether to apply to the EPO at all and subsequently they determine how many granted patents they require. Firms are assumed to be product market competitors and patents protect a technology that reduces marginal costs[12]. We denote each firm's profits per unit sold as a function of own and rivals' average marginal costs. We assume that profits are decreasing in own marginal costs, *c*, and increasing in rivals' average marginal costs, *C*:

$$\pi(\mathrm{c},\mathrm{C}) \quad \text{where} \quad \frac{\partial\pi}{\partial c} < 0, \quad \frac{\partial\pi}{\partial C} > 0 \qquad \text{(P)}$$

Obtaining a patent allows the patent holder to increase profits by $\pi(\underline{c}, C) - \pi(c, C)$, where $\mathrm{c} - \underline{c} = \delta$.

We assume that firms that have not obtained a patented technology are able to reengineer the technology. The technology can only be used by the rival in those countries in which the patent owner does not hold a patent and rivals' marginal costs are decreasing in the size of that market: $\tilde{c}(N - n)$, where *N* is the total number of EPO member countries and *n* is the number of countries in which a patent is in effect.

The size of the market, which firms are competing for, is determined by the market size in the largest country, *S*, and a concave function of the number of countries in which the patent is in effect, $\psi(n)$. We assume that this function is concave to reflect the fact that not all countries are of similar size.

The fixed costs of applying for a patent at a particular patent office *k* are denoted F_k and the probability of grant at this office is denoted by ω_k. The fixed costs of maintaining granted patents at each national office are denoted by γ_k.

[12] This is without loss of generality as we could also model technologies that protect higher quality in a similar fashion.

Application Stage

The decision whether or not to apply via the EPO depends on the number of countries in which the patent needs to be in effect. The EPO will be preferred if:

$$S\left[\omega_{EPO}\Psi(n)\left[\pi\left(\underline{c},C\right)-\pi\left(\underline{c},\underline{c}\right)\right]+\Psi(\mathrm{N})\pi\left(\underline{c},\underline{c}\right)\right]-F_{EPO} > S\left[\sum_{k=1}^{n}\omega_k\left[\Psi(\mathrm{k})-\Psi(\mathrm{k}-1)\right]\left[\pi\left(\underline{c},C\right)-\pi\left(\underline{c},\tilde{c}\right)\right]+\Psi(\mathrm{N})\pi\left(\underline{c},\tilde{c}\right)\right]-\sum_{k=1}^{n}F_k \qquad (1)$$

We reorganize the expression to identify factors leading a firm to prefer EPO:

$$\left(\omega_{EPO}\Psi(\mathrm{n})-\sum_{k=1}^{n}\omega_k\left[\Psi(\mathrm{k})-\Psi(\mathrm{k}-1)\right]\right)\left[\pi\left(\underline{c},C\right)-\pi\left(\underline{c},\tilde{c}\right)\right] - \left[\Psi(\mathrm{N})-\omega_{EPO}\Psi(\mathrm{n})\right]\left[\pi\left(\underline{c},\tilde{c}\right)-\pi\left(\underline{c},\underline{c}\right)\right] > \frac{F_{EPO}-\sum_{k=1}^{n}F_k}{S} \qquad (2)$$

The expression demonstrates that there are four factors determining whether firms prefer the EPO to the national route:

i) A higher grant rate at EPO attracts applicants; higher grant rates at the national offices reduce the attraction of EPO.

ii) If the sum of application fees at national offices exceed the EPO's application fee this increases the attraction of the EPO.

iii) If rival firms cannot themselves introduce the innovation absent patent protection or if it is difficult to reduce marginal costs much below those before the innovation arose because of a lack of scale economies $\tilde{c} \approx C$, then the positive first term is small or zero and firms will not need to use the EPO. In contrast, where it is easy to reduce marginal costs to those of the innovator absent patent protection or where scale economies are not required to achieve this outcome ($\tilde{c} \approx \underline{c}$) the negative second term is small or zero and firms will find using EPO attractive.

iv) If the market for the technology is larger within each jurisdiction *(S)*, then firms are more likely to prefer the EPO as the importance of application fees in determining which type of office to prefer shrinks.

The effects of grant rates and application fees can be tested directly in the results set out below. Further, a technology and year specific proxy for reliance on the EPO captures an element of whether firms usually rely on patents in many jurisdictions for each technology. Finally, we proxy the market for a technology at the patent level and at the firm level using patent citation measures.[13]

Grant Stage

At this stage firms choose the number of countries in which to hold a patent. Firms must decide which national patents they have applied for to pursue, if they follow the national route. Firms which applied to EPO must decide which countries to validate patents in. We model this as a decision on the number of countries in which to hold a patent. Once it is clear that a patent will be granted by EPO or by a set of national offices the firm chooses the number of countries *n* that maximizes the value of patent protection for its innovation:

$$max_n V_{EPO} = S\Psi(\mathrm{n})\left[\pi\left(\underline{c}, C\right) + [\Psi(\mathrm{N}) - \Psi(\mathrm{n})]\pi\left(\underline{c}, \tilde{c}\right)\right] - n\gamma_k \tag{3}$$

The optimal number of countries in which to hold a patent is determined by the first order condition:

$$S\frac{\partial\Psi}{\partial n}\left[\pi\left(\underline{c}, C\right) - \pi\left(\underline{c}, \tilde{c}\right)\right] - S\Psi(\mathrm{n})\frac{\partial\pi}{\partial\tilde{c}}\frac{\partial\tilde{c}}{\partial n} - \gamma_k = 0 \tag{4}$$

$$\Leftrightarrow S\Psi(\mathrm{n})\frac{1}{n}\left[\epsilon_{\Psi,\mathrm{n}}\left[\pi\left(\underline{c}, C\right) - \pi\left(\underline{c}, \tilde{c}\right)\right] - \pi\left(\underline{c}, \tilde{c}\right)\epsilon_{\pi,\tilde{c}}\epsilon_{\tilde{c},n}\right] - \gamma_k = 0 \tag{5}$$

[13] Citation measures have been used widely to proxy patent value: Trajtenberg (1990); Harhoff et al. (1999); Lanjouw and Schankerman (2004); Hall et al. (2005).

Here the first term represents the benefit from adding a further jurisdiction to the set of countries under patent protection. The second term captures the fact that as the set of countries of patent protection grows; rivals' marginal costs in unprotected jurisdictions can increase as scale economies decrease. Finally, the third term captures the effect of validation and translation fees that increase linearly as the set of countries to validate in grows.

The elasticity of rivals' marginal costs w.r.t. the number of jurisdictions in which a patent is in effect $(\epsilon_{\tilde{c},n})$ captures whether and how effectively a patenting firm is able to raise rivals' costs by protecting core markets. If this parameter is large, as may be the case when a technology is very costly to introduce and requires large markets to be profitable, then the patenting firm will not need to patent in many countries. In contrast, where this parameter is small, as will typically be the case in markets for pharmaceutical and chemical products, then the set of countries that a firm must patent in will be large.

3.2 ESTIMATION

Our model encompasses two sequential decisions, which can be estimated jointly in a recursive model: first firms decide whether or not to apply only to national offices and later they decide on the number of jurisdictions in which to hold patents.

Choice on whether to file a patent application at the EPO or at National Office (one or several) is the first principal choice of the applicant. The second principal choice is the decision on how many patents to maintain valid once they are granted by EPO or NPO. In case the application is made via EPO, company chooses the in which countries to validate the patent. In case application was filed directly at NPOs, company has to decide whether to maintain the granted patent in the particular NPO.

Estimation is complicated by the fact that the dependent variable in the first stage model is dichotomous and in the second stage the dependent variable is the number of countries each firm has chosen to uphold its patents in. The range of this variable is between 1 and 34. We treat this variable as an ordinal dependent variable, which is a compromise. It is not a count variable since the decision to validate a specific patent in one country in Europe is not independent of the decision to validate in a further country. Ideally we would treat every combination of countries as a separate outcome, but we would then end up with an impossibly large number of outcomes. One way of grouping outcomes is to focus only on how many countries are selected by the firm, which may be justified by the discrete increase in the renewal costs every time a further country is added. This then leads us to treating the dependent variable as ordinal; since we cannot assume that adding one to a list of territories has the same cost implications as adding another.

We provide results from estimating the recursive system outlined above using linear instrumental variables models on a logarithmically transformed dependent variable[14]. We have found that estimating the model with maximum likelihood requires us to reduce the number of variables we include in the models, so we do not report these results. Due to the recursive nature of the decision problem we model, the application fee, the EPO's grant rate and the lag between successive patent applications by the firm are exogenous to the decision how many countries to select for patent protection. These are the instruments we use to identify exogenous variation in the choice of examining office.

A further complication arises in our setting: we have a large number of cost related variables and observe frequent changes to offices' cost schedules. As schedules change between application and grant of each patent we include measures of costs at both times, which further increases the number of potential variables. Theory provides no guidance on which of the many measures to include in the empirical model. We select the variables to include in both models using the variable selection procedure outlined by Belloni et al. (2014) for their reproduction of results from Acemoglu et al. (2001). This procedure requires identification of a set of baseline covariates, which we discuss in the following subsection. Belloni et al. (2012, 2014) suggest using LASSO[15] for the purpose of paring down the baseline covariates to a set which is used for estimation. They also provide an algorithm for this purpose, which adjusts the free

[14] Estimated using ivreg2 in Stata.

[15] Least Absolute Shrinkage and Selection Operator (in statistics and machine learning).

penalty parameter in LASSO that would otherwise require further analysis[16]. The discussion above shows that firms will need to patent widely in case they operate in markets in which a new technology can be easily reengineered and where the resulting product can be profitably produced in small scale operations. The degree to which reengineering is cheap and the scale of production and sales needed to cover costs of entry or upgrading to a new technology will determine exactly how widely firms patent. Where we fail to measure these two dimensions of a technology well it is likely that the decision to rely on EPO will be endogenous in the second stage regression, which is why we instrument this variable.

The model we estimate is:

$$D_{EPO,i} = \beta_O + \beta_F F_O + \beta_{\omega EPO}\omega_{EPO} + \beta'_{\omega NAT}\omega_{NAT} + \beta_q q_i + \beta'_f \boldsymbol{X}_{f,i} + \beta'_O \boldsymbol{X}_O + \beta'_A \boldsymbol{D}_A + \beta'_T \boldsymbol{D}_T + v_i \qquad (6)$$

$$n_i = \gamma_O + \gamma_{EPO} D_{EPO,i} + \beta_{\omega EPO} + \beta'_{\omega NAT}\omega_{NAT} + \gamma_q q_i + \gamma'_f \boldsymbol{X}_{f,i} + \gamma'_O \boldsymbol{X}_O \gamma'_A \boldsymbol{D}_A + \gamma'_T D_T + u_i \qquad (7)$$

where $D_{EPO,i}$ = 1 if the application goes to EPO and n_i is the number of countries the granted patent is effective in. ω_k are lagged grant rates, q_i is patent quality, X_f is a vector of firm characteristics, F_O is a vector of patent office application fees, X_O is a vector of patent office characteristics and $D_O;D_A;D_T$ are vectors of priority office, technology area and time dummies.

3.3 DATA

The data we use is based on PATSTAT 2016, April. We rely on the population of patents applied and granted by EPO as well as the populations of patents applied at and granted by the largest ten EU national patent offices. Below tables 1 and 2 are constructed for 1,947,246 patents granted at EPO or the national offices between 1990 and 2012. Table 2 sets out statistics for the number of jurisdictions depending on whether patents were granted at EPO or at national offices.

[16] The algorithm is available at C. Hansen.

Table 1: Descriptive Statistics

Variable	Mean	SD	Median	Min	Max
Jurisdictions	3,131	3,486	2	1	34
Grant by EPO (1/0)	0,480		0	0	1
Lag between applications / 30	6,508	21,050	0,2	0	402,5
National grant (1/0)	0,785		0	0	1
Entry (1/0)	0,249		0	0	1
Simultaneous application (1/0)	0,292		0	0	1
Portfolio in area at EPO / 100	1,528	3,896	0,06	0	47,75
Portfolio in area / 100	3,436	8,804	0,1625	0,000303	104,1
Others' share at EPO	0,509	0,134	0,5012	0,07407	0,08976
Citations to Portfolio at USPTO / 100	0,025	0,092	0,00963	0	43,84
EPO Citations, 3 years	0,636	1,631	0	0	211
No EPO Citations (1/0)	0,351		0	0	1
No USPTO Citations (1/0)	0,353		0	0	1

Table 2: Descriptive Statistics of EPO Granted Patents

Grant by EPO	N	Mean	Median	Min	Max
Yes	934.044	5,241	4	1	34
No	1.013.202	1,185	1	1	17
Total	1.947.246	3,131	2	1	34

Dependent Variables and Instruments

The dependent variable for the second stage model is the count of jurisdictions in which a firm obtains granted patents for each patent family (n_i). We count the number of national patents granted, if the firm does not submit the patent to EPO. Where the firm submits the patent to EPO, we count the number of validated patents for which the firm has paid renewal fees at least once to a national office. Table 2 shows that the mean patent family, which is restricted to the national offices contains 1,18 patents, whilst at EPO it contains 5,2 patents. Our descriptive analysis above has already demonstrated that these averages mask significant differences in composition across applicant countries, technologies and firm types.

The endogenous variable is the dummy variable encoding whether a patent was granted by EPO $(D_{EPO,i})$. This variable is instrumented using application fees set by the German (DPMA), French (INPI) and UK offices (UKIPO) (F_O) as well as EPO. These national offices handle two-thirds of all national applications arriving at the top ten national offices. As we document in Appendix A.2 on average one or more application fees change every 7 months over the 23 years of our data. Fees are those valid in the month preceding the application in Euros.

Another instrument is provided by the grant rate at EPO at the time of application: once the firm has decided to apply also to EPO, the decision on where to uphold the patent is not affected by this rate. We use the average grant rate of the four quarters preceding the application date to capture firms' expectations of the probability that EPO will grant a patent application.

A further instrument is derived from the lag between the current application and any preceding application in the same technology area by the firm. This is a strong predictor of whether the firm will apply to EPO as it captures the degree of obsolescence of the firm's most recent patents. This variable is not correlated with the decision made regarding the number of jurisdictions in which to protect the patent once it is granted as that decision is taken several years after the application decision for the focal patent. At this later date all firms' patent portfolios will have changed and as a result the degree of obsolescence of the firm's portfolio will no longer be correlated with the application lag. There are two circumstances in which the application lag is more likely correlated to the degree of obsolescence: when firms first apply for a patent at any office and when firms submit multiple patents within one week. Therefore we introduce an entry dummy and a simultaneity dummy. These dummies are included amongst the covariates and are not used to instrument the decision to apply to EPO at stage one. In our data a quarter of patents result from entry and 30% of patents are part of a simultaneous application event.

Covariates

Here we discuss the construction of the covariates noted in the previous section. This discussion encompasses all potential covariates which we introduce into the variable selection stage. We note below which variables were selected for the instrumental variables model.

Grant rate, (ω_k): using data on applications and grants we construct quarterly grant rates at the technology area level for DPMA, INPI and UKIPO. Grant rate is defined as number of grants divided by number of applications. Grant rates are calculated for each monthly cohort and each country (office) of first filing or national office separately. Cohorts are defined by the month in which the patent application reached either the national office or EPO. We use the average grant rate of the four quarters preceding the application date to capture firms' expectations of the probability that each office will grant a patent application.

Rivals' EPO Share, (X_f): the average share of patents other firms submitted to EPO by quarter and technology area. This serves as a proxy for the need to protect a technology widely by patenting in multiple countries.

Portfolio Size, (X_f): covariates include both the logarithm of the size of each firm's overall patent portfolio at the time of filing and the logarithm of the size of the firm's portfolio of EPO patents. These portfolios are relative to each technology area a firm is active in and are constructed as cumulative sums.

Citations to Portfolio, (X_f): These are measures of the mean level of forward citations at the technology area level after 3 years to the firm's patent portfolio in Europe at the time of filing. They provide a proxy for the technological importance of the firm's inventions in the past. We use data from USPTO and EPO to construct these measures.

Multiple grant dummy, (X_f): This dummy identifies all granted patents after the first in each patent family. In many cases firms initially apply to a national office and later to EPO and will then drop their national application. This dummy captures cases in which the initial application is not dropped and cases in which a family includes multiple granted patents at the same office.

Patent Quality, (q_i): we use forward citations to patents in the same patent family at USPTO to capture the value of the underlying innovation. This measure is not always available, so we also introduce dummy variables to capture the fact that there are no citations for specific patents. This group of measures provides a proxy for the technological importance and the market size for the innovation at the patent level.

Renewal Fees, *(X_O)*: these are the fees charged for renewal by EPO, DPMA, INPI and UKIPO. We introduce this data in two ways: we include annual fee levels for the level of the renewal fees at the time of application and we match in the renewal fees at the three national offices in the first second and third year after the grant date. These fee levels depend on the examination duration of the patent. We also calculate the slope of the renewal fee schedules for the years 15-17 and 18-20 at the time of grant. By adding data on fees at time of application and at time of grant we seek to capture effects of changes in fees while patents are under examination.

Examination Duration, *(X_O)*: We construct exam durations from the populations of applications at EPO and the national offices by technology area and quarter. We use the average of the median examination durations in the four quarters before the patent application date.

Priority Office dummies: derived from PATSTAT data. This variable is generally a strong proxy for the applicant firm's country of origin.

Technology area dummies: patents are classified using the IPC classification, allowing us to analyze differences in patenting activities across different technologies. The categorization used is based on an updated version of the OST-INPI/FhG-ISI technology classification, which divides the domain of patentable technologies into 35 distinct technology areas.

Time dummies: using data on the date of patent application and the date of patent grant we construct dummies to capture time fixed effects. These are annual dummies.

As noted in the previous section we apply the LASSO selection algorithm suggested by Belloni et al. (2012, 2014) to select which subset of the above covariates to include in our models. In order to do this, we regress the dependent variable, the endogenous variable and each of our potential instruments on all covariates. We then construct the union of all the sets of covariates selected by LASSO from each of these regressions.

The following covariates are included in all models reported below: a time trend, the grant rates at EPO and the offices of Germany, France and the UK; the duration of examination at the three national offices; the share of rivals' patents going to EPO; firms' portfolio at EPO; the citations to the total portfolio received at USPTO; citations received by the focal patent at EPO after 3 years and dummies indicating whether no citations were found at either EPO or USPTO; dummies indicating whether the focal patent was the first patent by the applicant in that technology area, whether the patent was one of a group of applications and whether the patent was not the first granted within a patent family. Also included are covariates capturing renewal fees in the first year after grant at DPMA and UKIPO and renewal fees in years two and three at UKIPO. The slopes of renewal fee schedules at all national offices are also included as well as renewal fees at the time of application in years 3-7 and 19 at DPMA, years 2-5,8 and 20 at INPI, years 5,7,8 and 19 at UKIPO and years 3,5,6 and 19 at EPO. All models include application year, grant year, technology area and applicant country fixed effects.

4. EMPIRICAL RESULTS

Next, we discuss the empirical results from estimation of the empirical model set out in Section (3.1). First stage results from linear probability models are set out in Table 3. Second stage results are set out in Table 4. These are obtained from two stage GMM estimation. Here the dependent variable is the natural logarithm of the number of countries a patent is obtained in for each patent family.

Tables 3 and 4 each report six models. Columns 2-6 in each table provide corresponding first and second stage results. Column 1 in table 3 provides a first stage in which we include all instruments together. We do not use this specification in the second stage models we report in Table 4, as each set of instruments is likely to identify changes in behavior by separate subsets of firms. Column 1 of Table 4 is an OLS model in which the potential endogeneity of the decision to apply to EPO is ignored.

At the bottom of Table 4 we provide statistics on underidentification, weak identification and exogeneity of the instruments. With a few minor exceptions the results we report are quite stable across these five models. Of the three sets of instruments we use, the combination of portfolio size and application lag is least likely to be biased as a result of weak identification of the endogenous variable. The application fee instruments are most likely to suffer from some weakness. Each set of instruments is coherent as the Hansen tests demonstrate (Parente and Silva, 2012)[17]. Note that we select covariates included in both the first and second stages using LASSO as proposed by Belloni et al. (2012, 2014). Therefore, it may be that variables are not significant in the first or second stage models, but are included nonetheless to ensure that the entire model provides reliable results. We now discuss the results of the first stage models and then turn to the second stage results.

First Stage Model: Application to EPO

Table 3 shows that the instruments we use have the expected effects on the decision to apply to EPO: higher fees at national offices increase applications, as do higher grant rates at EPO. Meanwhile longer examinations reduce applications to EPO as do larger overall portfolios at the firm level. The application fee at DPMA, the examination duration at EPO and the firm level instruments have significant effects on the decision to apply to EPO at the 1% significance level.

The results demonstrate that firms which rely on the German patent office (DPMA) react to fee changes there and that all firms take into account the duration of examination at EPO when choosing where to apply. We also observe that in some cases the grant rate at the UK patent office (UKIPO) affects firms' decisions whether or not to apply to EPO. This shows that there is implicitly competition between some national offices and the EPO for applicants.

[17] Parente and Silva (2012) point out that the Hansen and Sargan tests do not allow one to test whether the instruments used are valid, but solely help to establish the coherency of the instruments used.

Table 3: First Stage Model Results: Application to EPO

	(1)	(2)	(3)	(4)	(5)	(6)
DE Application Fee	0.0249***	0.0277***				
	(0.0063)	(0.0062)				
UK Application Fee	0.0010	0.0019				
	(0.0020)	(0.0021)				
ln Portfolio in area	−0.0029***		−0.0029***			
	(0.0002)		(0.0002)			
Lag	0.0006***		0.0006***	0.0035***		
	(0.0002)		(0.0002)	(0.0002)		
Examination dur. EPO	−0.0002***				−0.0002***	−0.0002***
	(0.0001)				(0.0001)	(0.0001)
Grant rate EPO	0.0196				0.0180	
	(0.0116)				(0.0122)	
Grant rate UK	−0.0092*	−0.0079	−0.0074	−0.0079	−0.0096*	−0.0078
	(0.0038)	(0.0044)	(0.0043)	(0.0044)	(0.0039)	(0.0044)
Time trend	−0.0054***	−0.0055***	−0.0055***	−0.0056***	−0.0055***	−0.0058***
	(0.0009)	(0.0008)	(0.0008)	(0.0008)	(0.0010)	(0.0009)
Rivals' EPO Share	0.0129	0.0172**	0.0208***	0.0181**	0.0098	0.0173**
	(0.0076)	(0.0061)	(0.0056)	(0.0060)	(0.0081)	(0.0061)
Entry (1/0)	−0.0107***	−0.0024***	−0.0108***	0.0036***	−0.0024***	−0.0024***
	(0.0013)	(0.0007)	(0.0013)	(0.0007)	(0.0007)	(0.0007)
Simultaneous appl. (1/0)	−0.0111***	−0.0169***	−0.0111***	−0.0126***	−0.0169***	−0.0168***
	(0.0009)	(0.0013)	(0.0009)	(0.0011)	(0.0013)	(0.0013)
Multiple grant (1/0)	0.0231***	0.0233***	0.0231***	0.0238***	0.0233***	0.0233***
	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)
No citations EPO	−0.0052***	−0.0053***	−0.0052***	−0.0052***	−0.0053***	−0.0053***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
No citations USPTO	−0.0088***	−0.0081***	−0.0088***	−0.0085***	−0.0081***	−0.0081***
	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Citations EPO, 3 yrs	0.0009***	0.0009***	0.0009***	0.0009***	0.0009***	0.0009***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
US Citations to Portfol	0.0080**	0.0104**	0.0080**	0.0105**	0.0103**	0.0102**
	(0.0028)	(0.0034)	(0.0028)	(0.0033)	(0.0033)	(0.0033)
DE Renewal Fee, 5 years	−0.0189**	−0.0193**	−0.0076	−0.0074	−0.0081	−0.0083
	(0.0071)	(0.0069)	(0.0048)	(0.0048)	(0.0049)	(0.0049)
FR Renewal Fee, 5 years	0.0035	0.0041	−0.0052	−0.0049	−0.0045	−0.0044
	(0.0035)	(0.0036)	(0.0039)	(0.0039)	(0.0039)	(0.0039)
UK Renewal Fee, 5 years	0.0010**	0.0010**	0.0008**	0.0008**	0.0008**	0.0008**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
ln Portfolio at EPO	92.0342***	91.9677***	92.0439***	91.9705***	91.9604***	91.9656***
	(0.9243)	(0.9310)	(0.9241)	(0.9292)	(0.9307)	(0.9312)
Constant	10.7418***	10.9608***	11.2005***	11.3438***	11.1567***	11.8107***
	(1.8721)	(1.6566)	(1.6947)	(1.7134)	(1.9558)	(1.7829)
R^2	0.9545	0.9544	0.9545	0.9544	0.9544	0.9544

Note Table 3: ***, **, * denote significance at the 0.1%, 1%, 5% level. We report robust standard errors, clustered at the firm level.

In addition to this we find that there are strong industry level effects: if rivals apply to EPO more, so does the focal firm. Finally, the data indicate that over time the likelihood of an application to EPO is falling. Over 10 years the probability of an application to EPO falls by 5%. This effect is very robust to the choice of instruments.

Table 3 also shows that conditional on all other variables new entrants into the European patent system tend to avoid EPO and that firms making simultaneous applications rely less on EPO. On the other hand, firms are more likely to use EPO for patents that receive more citations. Also, firms whose portfolios are more heavily cited at USPTO are more likely to rely on EPO. Firms that have more experience applying to EPO are more likely to apply there again.

Second Stage Model: Number of Jurisdictions

Turning to Table 4 we analyze which covariates affect the number of jurisdictions in which a firm upholds its patent post-grant. Applications filed to EPO can result in patent grants. The granted patents then can be validated in a number of jurisdictions. Thus, one patent granted by EPO can constitute a larger set of patent family, depending on how many jurisdictions it gets validated in. Descriptive results indicate that a patent examined by EPO is validated in 4 countries at the median and 5.24 at the mean, whilst patent families not examined by EPO contain 1 patent at the median and 1.19 at the mean. Ignoring the endogeneity of the decision to apply to EPO, estimates suggest that EPO families contain on average 3.3 additional jurisdictions. Instrumenting the decision to apply to EPO yields higher estimates of the difference in family size ranging from 5 to 14 depending on which set of instruments is used[18].

There is no trend in the count of the number of countries a firm seeks to uphold its patents in. This contrasts with the significant trend in the popularity of EPO, suggesting that applicants who have chosen EPO have selected slightly more countries to validate patents in over time. As predicted by our model, firms in industries in which their rivals chose to hold patents in more countries also validate patents more widely.

[18] This range of effects is not surprising given that the instruments are likely to identify decisions made by different subsets of firms.

Table 4: Second Stage Model Results: Logarithm of Number of Jurisdictions

	(OLS)	(IV1)	(IV2)	(IV2a)	(IV3)	(IV3a)
Application to EPO (1/0)	1.1909***	2.0763*	2.6204***	1.7053***	2.6708***	2.4278*
	(0.0115)	(0.8295)	(0.5792)	(0.5174)	(0.7357)	(0.9857)
Trend, appl. years	−0.0044*	0.0003	0.0036	−0.0035	0.0036	0.0024
	(0.0017)	(0.0051)	(0.0035)	(0.0032)	(0.0041)	(0.0052)
Rivals' EPO Share	0.1147***	0.0993***	0.0914**	0.1114**	0.0869**	0.0935**
	(0.0288)	(0.0296)	(0.0282)	(0.0381)	(0.0290)	(0.0345)
Entry (1/0)	−0.0218***	−0.0195***	−0.0185***	−0.0321***	−0.0183***	−0.0189***
	(0.0036)	(0.0043)	(0.0050)	(0.0046)	(0.0043)	(0.0045)
Simultaneous appl. (1/0)	0.0173***	0.0311*	0.0422***	0.0462***	0.0419***	0.0381*
	(0.0047)	(0.0149)	(0.0075)	(0.0065)	(0.0115)	(0.0155)
Multiple grant (1/0)	0.2415***	0.2223***	0.2080***	0.3264***	0.2081***	0.2126***
	(0.0137)	(0.0234)	(0.0147)	(0.0157)	(0.0229)	(0.0260)
No citations EPO	−0.0505***	−0.0461***	−0.0429***	−0.0538***	−0.0428***	−0.0440***
	(0.0014)	(0.0046)	(0.0035)	(0.0035)	(0.0041)	(0.0051)
No citations USPTO	−0.0310***	−0.0241**	−0.0192**	−0.0498***	−0.0192**	−0.0210**
	(0.0026)	(0.0075)	(0.0061)	(0.0058)	(0.0064)	(0.0081)
Citations EPO, 3 years	0.0167***	0.0159***	0.0154***	0.0144***	0.0154***	0.0156***
	(0.0007)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0011)
Ren. fee, grant, DE, y1	0.0003***	0.0003***	0.0004***	0.0003***	0.0004***	0.0004***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0001)
Ren. fee, grant, UKIPO, y1	−0.0002***	−0.0002***	−0.0002***	−0.0002***	−0.0002***	−0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Ren. fee, grant, UKIPO, y2	−0.0002***	−0.0002***	−0.0001***	−0.0002***	−0.0001***	−0.0001**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DE Examination Duration	−0.0004***	−0.0004***	−0.0004***	−0.0004***	−0.0004***	−0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
GB Examination Duration	0.0006**	0.0007**	0.0007***	0.0007***	0.0007***	0.0007***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Grant rate DE	−0.1399***	−0.1389***	−0.1411***	−0.1153**	−0.1379***	−0.1415***
	(0.0369)	(0.0374)	(0.0381)	(0.0428)	(0.0366)	(0.0377)
Grant rate GB	−0.1230***	−0.1164***	−0.1110***	−0.1131***	−0.1130***	−0.1132***
	(0.0170)	(0.0188)	(0.0178)	(0.0182)	(0.0167)	(0.0166)
EPO Application Fee	−0.0014	−0.0018*	−0.0020*	−0.0016	−0.0020*	−0.0019*
	(0.0007)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
FR Application Fee	−0.0283**	−0.0295**	−0.0304*	−0.0298*	−0.0303*	−0.0301*
	(0.0109)	(0.0114)	(0.0120)	(0.0120)	(0.0120)	(0.0117)
Log-likelihood	-1,251,679	-1,291,873	-1,353,163	-1,389,833	-1,360,062	-1,328,632
Instruments		Fees UK, DE	Size, Lag	Lag	Dur., Prop.	Dur.
Kleibergen-Paap rk LM		18.1760	208.2956	163.2705	17.0769	15.7128
p value		0.0001	0.0000	0.0000	0.0002	0.0001
Kleibergen-Paap rk Wald F		10.1483	211.5921	239.9970	10.8965	19.5504
Hansen J statistic		1.7484	0.0712	–	0.1265	–
p value		0.1861	0.7896		0.7221	

Note Table 4: ***, **, * denote significance at the 0.1%, 1%, 5% level. We report robust standard errors, clustered at the firm level. All models contain application year, grant year, first authority and technology area fixed effects. Instruments used are the application fees at UKIPO and DPMA; examination duration at EPO; the grant rate at EPO; and the logarithm of the lag between applications at the firm area level.

Turning to the interaction between offices, we find that the grant rates of UKIPO and DPMA affect the number of countries in which firms own patents. Specifically, if these national offices have granted patents more readily, the number of jurisdictions in which a patent is held falls. One might expect the effect of the national office's grant rates to work only through the decision to apply to EPO: then there would be no effect of grant rates on the number of countries in which a patent is held. However, if national offices' grant rates are higher, firms will expect their applications to succeed more readily at NPOs, which will lead to fewer parallel applications and smaller patent families.

Firms making simultaneous applications protect innovations in more jurisdictions, whilst entrants seek protection in fewer jurisdictions. More highly cited patents are protected in more jurisdictions and firms whose portfolios are more heavily cited at USPTO seek patent protection in more jurisdictions. The grant rates at UKIPO and DPMA may affect some firms' choices: the higher grant rate at these NPOs reduces the patent families.

We also observe a division of labor between the national offices and EPO: new applicants and those whose peers tend to apply to few offices rely on national offices, whilst those with more cited patents tend to rely on EPO.

Obtaining a clear result on costs is harder than might be expected. When application fee increases at DPMA, it results in shift of applications to EPO. This is not the case for INPI or UKIPO however. Rather application fee increases at INPI reduce the range of countries in which firms uphold their patents. Our detailed analysis of three fee change episodes below reinforces this finding. We also observe that at the time of application higher renewal fees at UKIPO shift applications to EPO. At the time of grant, higher renewal fees at UKIPO reduce the size of the set of countries in which firms hold patents, suggesting that firms compensate for the fee increases by reducing the set of patents they uphold. However, our results also show that higher renewal fees at time of grant at DPMA increase the set of countries in which patents are held. These results demonstrate that firms, which primarily apply to the German, French and UK offices react to fee changes at these offices in different ways.

Difference-in-Differences Model

We complement our results from the IV models with difference-in-differences regressions which focus on three episodes during which national office fees and fees at EPO diverged:

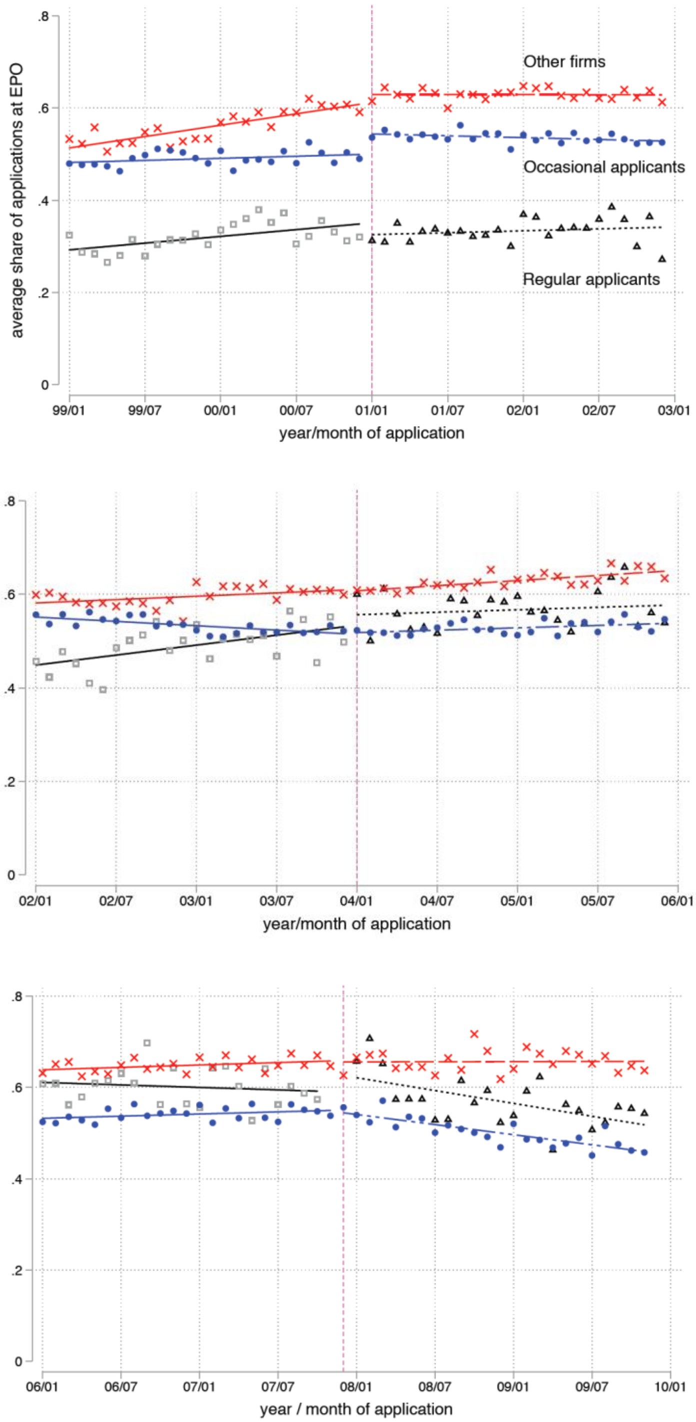
i) in 2001 INPI lowered application and renewal fees, whilst EPO application and renewal fees remained constant;
ii) in 2004 UKIPO lowered and EPO raised their application fees, while all other fees remained fixed;
iii) in 2008 UKIPO lowered both application and renewal fees whilst EPO raised both.

To analyze the effects of the fee changes applicants are split into three groups:

i) those that regularly (33% or more) applied to the national office changing its fees;
ii) those that occasionally applied to this office (at least 4 applications and not regular) in the period between 2 years before and 1 year before the fee change;
iii) those that fall into neither group.

The latter is always the largest group and contains over 50% of all observations. The first group is the smallest: for INPI it contains 5.7% of observations while at UKIPO it only contains around 3.3% of observations, this explains the greater variance in the middle and bottom hand panel of Figure 11 for this group.

Figure 11: Share of Applications at EPO by Group



Note Figure 11: The three panels depict monthly average application shares by group for 2 years before and 2 years after each fee change event we study. The vertical dashed lines indicate when fees changed. The first panel depicts effects of fees changing at INPI in 2001; the other two panels depict effects of fees changing at UKIPO in 2004 and 2008.

Tables 5 and 6 show results from differences-in-differences models. The fee changes we study are announced ahead of time, but identification of the causal effect of the fee changes on applications (Table 5) and the number of jurisdictions in which patents were held (Table 6) requires that trends in the dependent variables were sufficiently similar before the fee changes. We examine this assumption graphically in Figure 11. Overall, the figures indicate that the trend in share of EPO applications for the firms which regularly apply to EPO and the control group (others) is parallel in the first two graphs. In the last graph it is the trend for the occasional applicants at UKIPO that parallels that for the control group.

The difference-in-differences regressions test whether the fee changes made either the regular or the occasional users of the national office less likely to use EPO than the control group (Table 5) and whether it changed the number of jurisdictions either group applied to relative to the control group (Table 6).

Table 5: Difference-in-Differences: Application to EPO

	(INPI)	(INPIb)	(UKIPO1)	(UKIPO1b)	(UKIPO2)	(UKIPO2b)
Treatment (1/0)	0.0015	0.0011	0.0055	−0.0024	−0.0523***	0.0015
	(0.0098)	(0.0090)	(0.0037)	(0.0025)	(0.0030)	(0.0012)
Regular (1/0)	−0.1547***	−0.0052	−0.0271	−0.0062	0.0201	−0.0045
	(0.0217)	(0.0030)	(0.0223)	(0.0033)	(0.0445)	(0.0040)
Occasional (1/0)	0.0249	−0.0007	0.0270*	−0.0010	0.0549***	0.0036
	(0.0131)	(0.0015)	(0.0129)	(0.0012)	(0.0148)	(0.0028)
Treatment×	0.0442	0.0036	0.0396*	0.0047	−0.0201	0.0033
Regular	(0.0231)	(0.0025)	(0.0170)	(0.0029)	(0.0209)	(0.0028)
Treatment×	0.0202*	0.0025	0.0123	0.0020	0.0192*	−0.0007
Occasional	(0.0085)	(0.0014)	(0.0071)	(0.0016)	(0.0082)	(0.0016)
Covariates	NO	YES	NO	YES	NO	YES
EPO Examination Duration		−0.0003**		−0.0002		−0.0000
		(0.0001)		(0.0001)		(0.0002)
ln Portfolio in area		−0.0035***		−0.0029***		−0.0028***
		(0.0004)		(0.0004)		(0.0005)
Lag		0.0007**		0.0012***		0.0014***
		(0.0002)		(0.0003)		(0.0003)
Constant	0.6739***	0.4648	0.6865***	−1.1903	0.6561***	0.1292
	(0.0160)	(0.3883)	(0.0161)	(3.1574)	(0.0224)	(1.9893)
N	453,116	453,116	398,780	398,780	300,040	300,040
R^2	.2708	.9482	.2612	.9466	.2760	.9472

Note Table 5: ***, **, * denote significance at the 0.1%, 1%, 5% level. We report robust standard errors, clustered at the firm level. All models contain application year, first authority and technology area fixed effects.

The results in Table 5 show that none of the three fee change episodes we analyze leads to any changes in firms' decisions whether to apply to EPO or not. Graphically, the last fee change at UKIPO seems most promising, but the results set out in Table 5 suggest that the propensity to apply to EPO is not affected by any of these fee shifts.

Table 6: Difference-in-Differences: Logarithm of Number of Jurisdictions

	(INPI)	(INPIb)	(UKIPO1)	(UKIPO1b)	(UKIPO2)	(UKIPO2b)
Treatment (1/0)	0.0058	0.0126	−0.0183***	−0.0050	−0.0230***	−0.0018
	(0.0095)	(0.0134)	(0.0040)	(0.0058)	(0.0033)	(0.0065)
Regular (1/0)	0.0953***	−0.0028	−0.0757*	−0.1276***	−0.1224***	−0.1483***
	(0.0184)	(0.0209)	(0.0374)	(0.0311)	(0.0265)	(0.0249)
Occasional (1/0)	0.0341**	−0.0111	−0.0231*	−0.0667***	−0.0507***	−0.0790***
	(0.0127)	(0.0114)	(0.0103)	(0.0093)	(0.0125)	(0.0116)
Treatment×	−0.0060	0.0027	−0.0153	−0.0093	0.0016	0.0038
Regular	(0.0188)	(0.0200)	(0.0128)	(0.0117)	(0.0169)	(0.0159)
Treatment×	−0.0403***	−0.0305***	0.0010	0.0019	0.0018	−0.0005
Occasional	(0.0077)	(0.0067)	(0.0061)	(0.0058)	(0.0086)	(0.0075)
Application to EPO	1.1605***	1.1336***	1.1786***	1.1595***	1.1913***	1.1638***
	(0.0126)	(0.0140)	(0.0116)	(0.0150)	(0.0123)	(0.0158)
Covariates	NO	YES	NO	YES	NO	YES
Constant	0.2739***	−15.1824	0.2906***	12.7707	0.2372***	37.0520***
	(0.0238)	(31.2270)	(0.0238)	(6.7310)	(0.0313)	(7.4096)
N	453,116	453,116	398,780	398,780	300,040	300,040
R^2	.6339	.6535	.6294	.6485	.6394	.6541

Note Table 6: ***, **, * denote significance at the 0.1%, 1%, 5% level. We report robust standard errors, clustered at the firm level. All models contain application year, first authority and technology area fixed effects.

The effect of the fee changes on the number of jurisdictions, in which firms hold patents, as set out in Table 6, is more complex. First, it is important to note again that in 2001 and 2008 both application and renewal fees changed, whereas in 2004 only the application fees changed. Hence, we are most likely to observe effects on the number of jurisdictions for the 2001 and 2008 events. In the case of INPI, we observe no significant difference in the breadth of the set of countries in which firms protect their patents between the three groups of firms we identify. At UKIPO this is different, with the regular users of that office, protecting their patents in fewer jurisdictions than the occasional users. Both groups protect their patents in fewer jurisdictions than the control group.

This is the case in 2004 and 2008. We also observe that in 2001 the occasional applicants at INPI reduced the size of their patent families in response to the fee change at INPI, while the regular users of INPI behaved like the control group. In contrast to this in 2008, when UKIPO reduced all their fees in the face of rising fees at EPO this induces no significant changes in firm behavior.

The impact of patenting fees on applicants was studied by other economists before. Early evidence was mainly conducted in the form of surveys of applicants and company IP managers. For example, Cohen et al. (2000) report that 40% of US manufacturing firms in their sample indicated high applications cost as a reason for not patenting. The high cost of patents as a motive not to patent is also reported in the surveys analyzed by Thumm (2004), Peeters and van Pottelsberghe (2006), and Graham et al. (2010).

Empirical studies that focus on patent application fees come up with differing results. For instance, MacLeod et al. (2003) and Nicholas (2010) examine the impact of substantial reduction (84%) in the cost of obtaining a patent in the UK in 1883 which led to 150% surge in patent grants. Adams et al. (1997) and Landes and Posner (2004) conduct quantitative studies based on USPTO patent applications in the 90s. They provide econometric evidence supporting the argument that demand for patents is either inelastic or only marginally elastic. On the other hand, a negative effect on patent filings induced by higher fees is found by Rassenfosse and van Pottelsberghe (2012).

Certain fees, such as renewal, validation or translation fees, are only relevant in the patent post-grant stage. Specific to the European system are the validation fees, as they must be paid for each state in which patent protection is sought by the applicant. Validation process also requires translation of the patent in the country's official language, resulting in additional expense for the company. There is a growing body of the literature analyzing the post-grant stage fees and fee changes on applicants.

Harhoff et al. (2009, 2016) find that all types of fees – validation, renewal and translation, play an important role and affect the validation behavior of applicants. Their results suggest that lower fees would result in significant increase in the number of patents validated in each European country, while lower translation fees encourage patent applications. This is confirmed by Danguy and van Pottelsberghe (2009) estimate the impact of renewal fees on patents for 15 European countries, the US and Japan, finding that an increase in renewal fees reduces the patent renewal rate. Van Pottelsberghe and Mejer (2008) provide evidence suggesting that the propensity to patent is affected by change in translation costs induced by London Agreement, although through an inelastic price elasticity of -0.4.

Our findings confirm the earlier studies' results, indicating that increase in application and renewal fees has negative effect on the number of validations, yet the effect is only marginal. Overall, we agree with most of the authors expressed emphasis for the need for more economic studies in this area.

The next section provides the conclusion of this chapter.

5. CONCLUSIONS

The European patent system is the most complex and also the most significant regional patent system in the world (Hall and Helmers, 2012). Companies which patent in Europe are presented with the choice whether to file application at the EPO or directly at the National Offices. Their decision is driven by various factors. In this paper we aim to identify and observe the impact these factors have on firms' patenting strategies.

We distinguish between two types of the measures in empirical analysis. First, patent office measures are considered: grant rates, examination durations and fees. Second, firm-level measures are taken into account: portfolio size, rivals' EPO share, citations to patent portfolio, and the dummy indicating whether company is an entrant.

Firms react to fee changes and variation in grant rates and examination durations when choosing which office to use. The higher grant rate at EPO increases the applicants' propensity to file at EPO instead of National Offices. Conversely, the longer lasting patent examination at EPO, reduce the applicants inclination to file there. Also, the higher patenting fees and National Office proved to have effect on applicants, encouraging their propensity to file at EPO.

When making a decision on where to patent, companies respond also to their rival's behavior. Empirical analysis confirms that if competitors have higher share of their patent portfolio protected via EPO, firms tend to mimic their behavior by filing more often at the EPO as well as they tend to validate more broadly once patents are granted.

Entrant firms, the ones that patent for the first time, have higher likelihood to seek protection at the National Office. These firms also have smaller patent families. On the other hand, the incumbent companies, i.e. the ones which have higher share of their portfolios protected at EPO already, tend to file their subsequent applications at EPO again.

In order to observe the quality of the patents, we use patent citations at EPO as a proxy for the technological importance of the firm's inventions in the past. In addition, we use forward citations to patents in the same patent family at USPTO to capture the value of the invention. Our findings suggest that firms which patents are more cited at EPO or USPTO have higher likelihood to patent at the EPO. These firms also validate their granted patents in more jurisdictions.

The results we document may be helpful in predicting how applicants will behave in the context of the Unified Patent system in the future. The existing European patent system does not yet provide patent protection with automatic legal effect in all EU member countries[19]. In 2013 majority of the members of the European Union signed an intergovernmental treaty to set up a Unified Patent Court (UPC) for Europe and to create the Unitary Patent (UP). Unitary patent is going to be examined by the European Patent Office and valid in the whole territory of the 26 cooperating states once granted. This represents a significant institutional innovation in Europe. It is entirely unclear how firms will adapt to the new options that the UP and the UPC present to them. The current and the future variation in policies at the national level create an interesting laboratory for further study. These are questions for future work using national and EPO patent data in conjunction.

It is important to stress the fact that in our study we only observe the factors related to patent offices and the attributes of firm's patent portfolios when assessing companies' decisions where to patent. It is well worth noting that there are cases in which the relevance of fees, grant rates and examination durations might not be the

[19] A contrast is provided by the examination of trade marks in Europe, which is either national for national rights or at the European level for a right valid in all member states.

main drivers in shaping firms' patenting strategies. Factors outside the patent system, such as product markets, technological innovation landscape, management issues of firm's other Intellectual Property assets, etc. might come into play. In addition, the element of the length of the pre-examination and pre-grant period can have an important role determining firm's choice of the patent office. As suggested by Jell et al. (2014), motives related to gaining time to make decisions increase patent pendency periods. Deferred patent examination can benefit applicants if they require more time to make a decision on validations. Hence, firms might be motivated to choose EPO or a certain national office if they expect they will gain more time until the examination, by selecting such application route. On the other hand, as suggested by Marco (2005), patent value depends not only upon the underlying technology but also upon the degree of uncertainty over the property right. When the certainty related to patent grant is a motivating issue and firms seek to expedite the grant process, the more reliable office with less deferred examination and higher grant rates can be chosen. European Patent System provides its applicants with the option to select the application route.

Analysis of additional factors influencing patenting strategies could be a relevant and interesting direction for future research complementing our current analysis.

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LIST OF ABBREVIATIONS

AT – Austria

DE – Germany

DPMA – Das Deutsche *Patent* und Markenamt – German Patent and Trademark Office

DWPI – Derwent World Patents Index

EPC – European Patent Convention

EPO – European Patent Office

EPOrg – European Patent Organization

EPS – European Patent System

ES – Spain

FR – France

GB – United Kingdom

GMM – Generalized Method of Moments

INPI – Institut National de la Propriété Industrielle – French National Industrial Property Institute

IPC – International Patent Classification

IT – Italy

JP - Japan

LASSO - Least Absolute Shrinkage and Selection Operator (in statistics and machine learning)

NPO – National Patent Office

OLS – Ordinary Least Squares

PATSTAT – EPO Worldwide Patent Statistical Database

UKIPO – The Intellectual Property Office of the United Kingdom

UP – Unitary Patent

UPC – Unified Patent Court

US – United States of America

USPTO – United States Patent and Trademark Office

APPENDIX

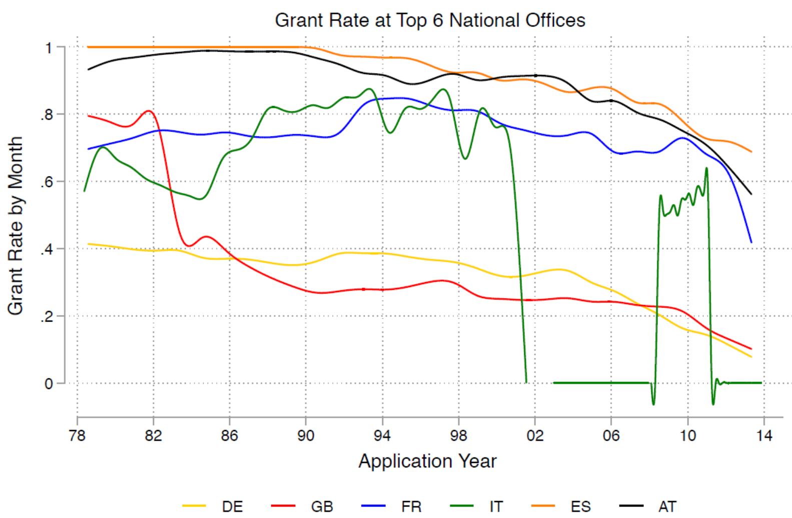
Appendix A. Data

The patent data used in this paper are drawn from PATSTAT's April 2016 version.

A.1 Grant Rates by Office

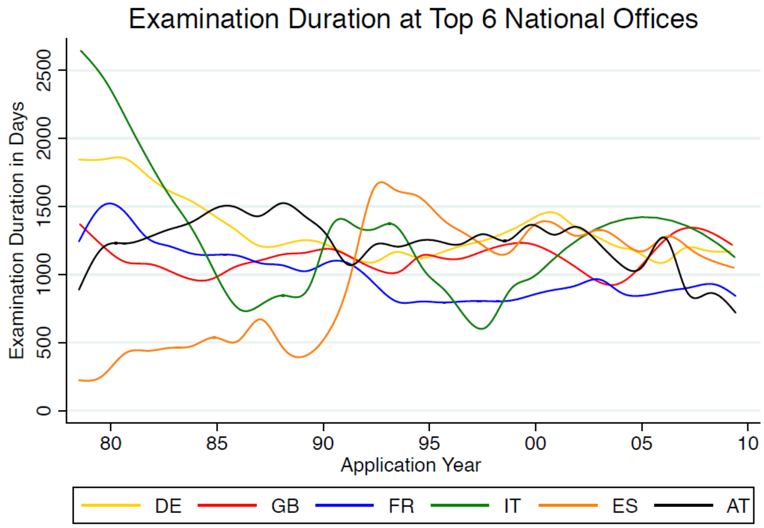
Here we provide the grant rates and examination durations broken down by national office.

Figure 12: Grant Rates at National Offices



Note Figure 12: Grant rates are calculated for each monthly cohort and each national office separately. Cohorts are defined by the month in which the patent application reached the national office. Data smoothed using a median cubic spline with 12 months per band.

Figure 13: Examination Durations at National Offices



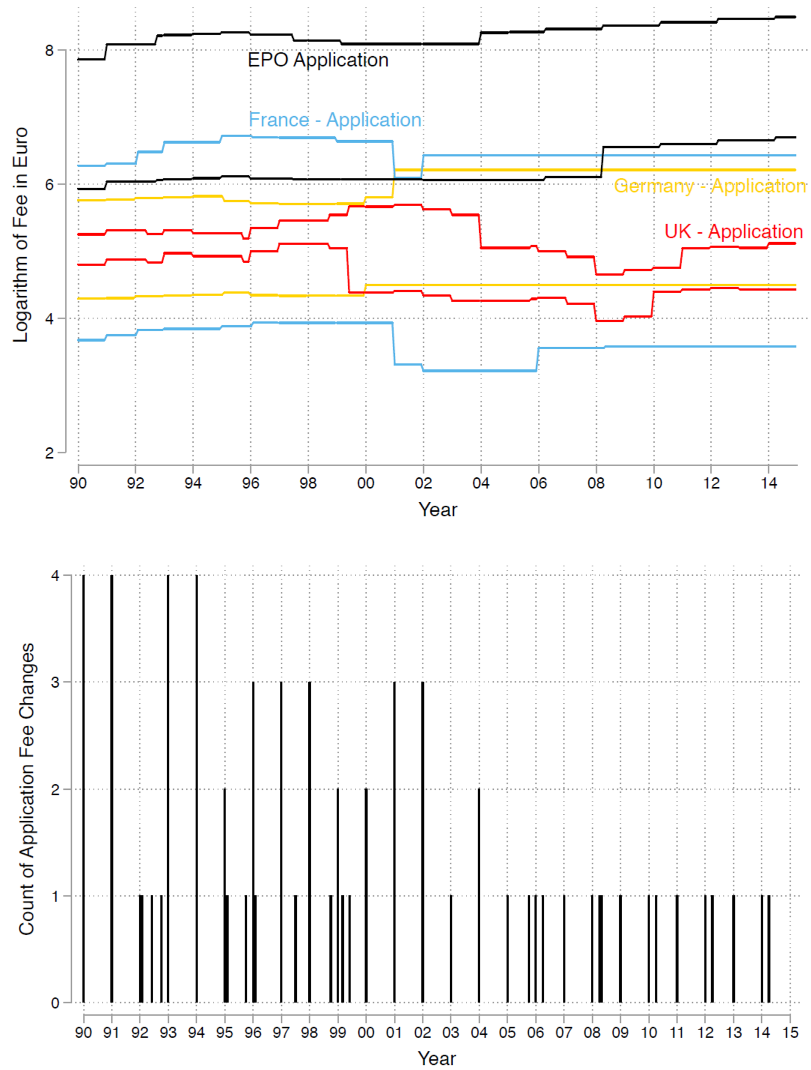
Note Figure 13: Durations are median examination durations within each monthly cohort. Cohorts are defined by the month in which the patent application reached the national office. Data smoothed using a median cubic spline with 12 months per band.

A.2 Fee Changes

In our analysis we use data on application fees and renewal fees from EPO, DPMA, INPI and UKIPO. As noted in the main text the fee schedules of these offices are adapted regularly. Here we provide evidence on the frequency of changes and on the coordination of changes to fees.

These figures document that over time the number of changes to fees has declined somewhat and that fee changes are increasingly less likely to occur at the same time. Overall we find there were 42 months with a fee change in 300 months, which is on average at least one change every 7 months.

Figure 14: Changes in Application and Renewal Fees at EPO, DPMA, INPI, UKIPO



Note Figure 14: The top graph plots the logarithm of the fee level for application fees and renewal fees at 5 years at the European Patent Office (EPO), the German patent office (DPMA), the French patent office (INPI) and the UK's patent office (UKIPO). The bottom graph plots the count of fee changes at these four offices by month between 1990 and 2015.

A.3 National Patent Applications Leading to EPO Applications

An important feature of the European Patent system is the possibility for applicants to apply in parallel to national offices and the EPO. This strategy of parallel patent applications can provide insurance against rejection by the EPO or one of the national offices. Firms adopting this approach face much higher costs as they must pay for two patents for the same invention in the same jurisdiction.

Initially we analyze applications at national offices and at the EPO separately. When constructing the national patent applications we drop all applications within a patent family that were filed at national offices at the same time as or after an application to EPO. This ensures that we do not treat applications to national offices that result from validations of patents granted by EPO as direct national applications.

Applications to national offices that predate an application to EPO based on the same invention are treated as separate national applications in our data. We provide descriptive statistics on these applications in this section.

Table 7 sets out all patent applications and grants in the national and EPO datasets. We find that the top ten national offices have granted 1,555,164 patents while EPO has granted 1,286,022 patents. Of these 239,762 patents are in families with patents granted both by a national office and by the EPO.

Table 7: Patents Granted by National Offices and EPO by Family

National grant	Granted by EPO No	Granted by EPO Yes	Granted by EPO .	Total
No	212,468	231,103	1,681,259	2,124,830
	10.00	10.88	79.12	100.00
	14.04	17.97	58.88	37.58
Yes	141,355	**239,762**	1,174,047	1,555,164
	10.12	12.16	77.71	100.00
	9.34	18.64	41.12	27.50
.	1,159,625	815,157	0	1,974,782
	61.67	38.33	0.00	100.00
	76.62	63.39	0.00	34.92
Total	1,513,448	1,286,022	2,855,306	5,654,776
	26.76	22.74	50.49	100.00
	100.00	100.00	100.00	100.00

Table 8 shows that the mean and median examination duration at most of these national offices is more than a year shorter than at the EPO. This suggests that the applicants are frequently seeking to obtain a national patent as quickly as possible, while delaying grant by EPO to learn more about their innovations.

Table 8: Difference in Examination Duration by National Offices

National Office	Mean	Median	Cases
AT	306	247	3549
BE	1267	1245	65
CH	211	233	2771
DE	380	460	56095
ES	173	-86.5	2374
FR	500	410	52812
GB	553	419	4245
IT	579	505	7189
NL	1087	995	4319
SE	886	903	2105
Total	465	445	135524

Note: The dimension of examination duration is in days.

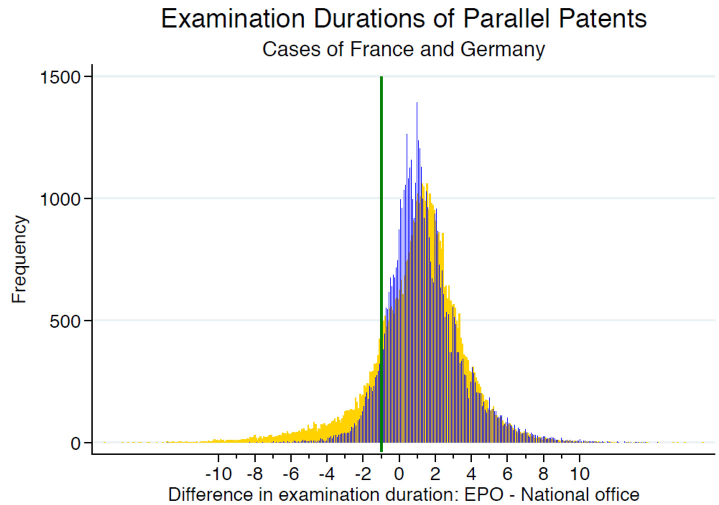
To further test this intuition we compare the number of countries in which patents are validated for patent families that contain a parallel national patent and EPO validation. What we find is that families with parallel validations are significantly larger: on average such families are validated in 14.9 countries, whilst those without a parallel patent are validated in 8.2 countries.

Figure 15 shows the distributions of the difference in examination durations at EPO and the national offices for patent families with parallel patents, originating in France and Germany. The green line in the graph separates families in which the EPO granted first (on the left) from those in which the national office granted first. Clearly the average family contains applications which were granted almost two years prior to EPO at the national office.

A.4 Merging Applicants Across Offices

PATSTAT provides separate identifiers for applicants at the national office and at EPO. Additionally, there are usually many applicant codes (person id) for each applicant at national offices and at EPO. The construction of patent portfolios within and across offices requires good matching procedures based on name, address, country and entity type.

Figure 15: Examination Durations



In Table 9 we focus on the composition of applications at EPO and on the grant rates for applicants from each country. As the technology areas represented in each country's portfolio differ we would caution against any strong interpretation of these numbers.

Table 9: Patents/Applicants at EPO by Applicant Origin (1978-2012)

	US	DE	GB	FR	IT	ES
Applications	815,005	551,498	126,774	207888	91,929	19,766
Granted patents	322,423	307,146	57,262	113,551	47,030	6,836
Grant rate	39.56	55.69	45.17	54.62	51.16	34.58
	JP	AT	SE	NL	CH	BE
Applications	501,004	30,870	64,957	96,083	109,815	29,535
Granted patents	255,089	16,187	31,737	43,650	56,063	13,463
Grant rate	50.92	52.44	48.86	45.43	51.05	45.58

Procedure for Linking Names across Offices

To link applicants' names across offices we standardized and aggregated portfolios within the EPO and the national data separately. Having completed this step we then linked portfolios across the two datasets.

Standardization and aggregation proceeded in four steps: first, we standardized all names, cleaning out punctuation marks and standardizing legal forms[20]; second we aggregated portfolios within the EPO data and the national data using a file derived from Derwent's encoding of patent applicants[21]; third we aggregated all remaining patents using standardized names. Finally, we then checked the largest remaining portfolios and assigned these to firm groups identified previously, where this was appropriate. The remaining patents were assigned to firms on the basis of firms' standardized names. Overall we have 521,564 separate firms in the data with 82,078 in the EPO data and 521,533 in the national office data.

Linking of portfolios across the two main datasets (EPO and national offices) proceeded in three steps: first, we appended the national data to the EPO data, second we linked the firm group identifiers from the national data to the EPO data for all those instances in which patents in the same patent family existed at EPO and national offices and we had either assigned the same Derwent code or the same standardized name to both patents. We then extended the national firm group identifiers to all EPO patents within the firm groups at EPO.

We checked the results of this procedure by inspecting the standardized names in the largest ten portfolios thus created. Next we manually checked the largest portfolios of patents within EPO that we had not assigned a national firm identifier and manually attached such identifiers on the basis of firms' names where appropriate.

[20] We used files originally created by Bronwyn Hall and Christian Helmers for this. We are grateful to them for sharing these files.

[21] We found 4,094 firm groups in the EPO data and 5,684 firm groups in the national office data. As the firm sets don't overlap entirely we have 5,905 separate Derwent codes in our dataset.

Finally we created firm identifiers based on standardized names for those firms in the EPO data that had not yet been assigned a firm identifier.

Overall there are 3,524,218 granted patents in the dataset we have constructed. Of these 2,079,016 were granted after 1989 and are within our estimation period. Within this period we identify 4,345 firm groups using the Derwent name file.

Appendix B. Overview of Patenting Process in the European Patent System

Figure 16: Patent Grant Procedure

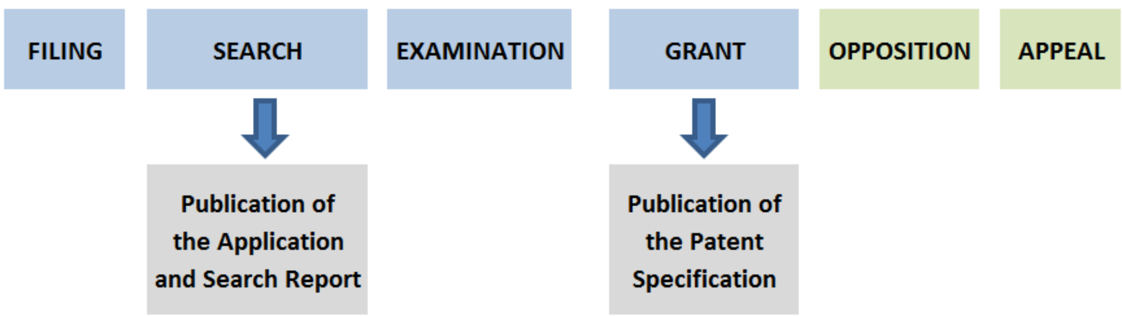


Figure 16 illustrates the main steps of the patent grant procedure in the EPS.

First, patent application is filed either at EPO or National Office. Second, when the formalities examination is carried out, a European or NPO Search report is drawn up[22]. From the date of publication, a European patent application confers provisional protection on the invention in the states designated in the application. Third, Patent Office examines whether the patent application and the invention meet the requirements of the European Patent Convention and if a patent can be granted. Fourth, when the examining division decides that a patent can be granted, it issues a decision to that effect. The decision to grant takes effect on the date of publication. Opposition and Appeal steps can follow the patent grant.

[22] Besides granting European patents, the EPO is also in charge of establishing search reports for national patent applications on behalf of the patent offices of France, Netherlands, Belgium, Luxembourg, Italy, Turkey, Greece, Cyprus, Malta, San Marino, Lithuania, Latvia and Monaco.

The granted European patent is a "bundle" of individual national patents. Once the mention of the grant is published, the patent has to be validated in each of the designated states within a specific time limit to retain its protective effect and be enforceable against infringers. In case the application was examined directly at the NPO, the granted patent is automatically protected in its jurisdiction.

Figure 17: Patenting Process in the European Patent System: the Timelines

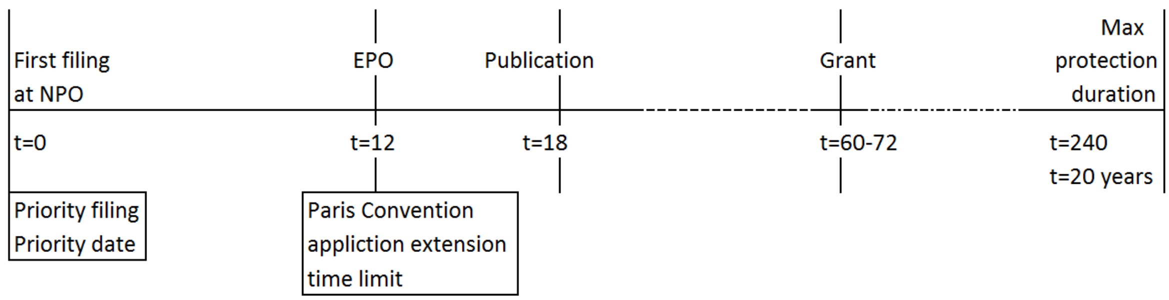
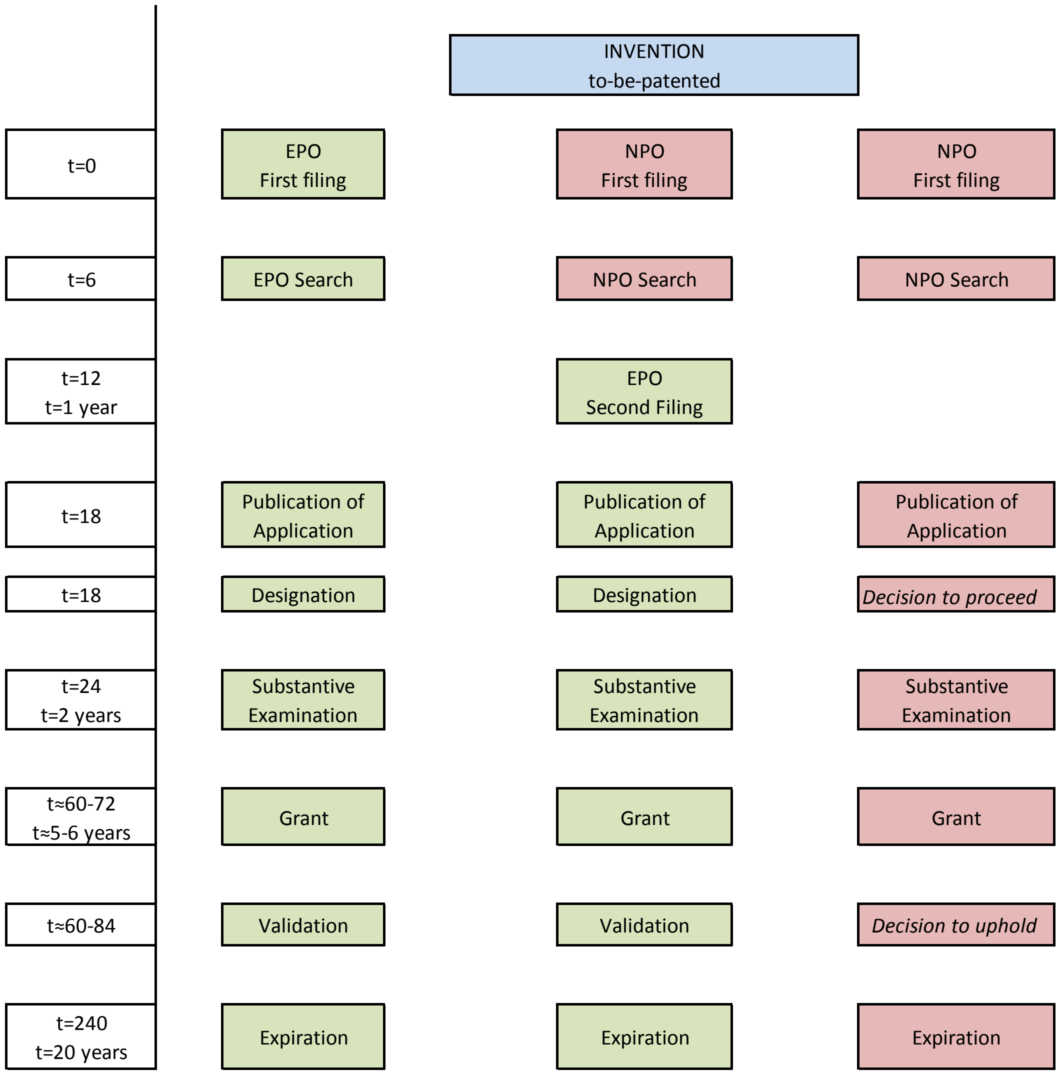


Figure 17 graphs the major timelines in the process of patenting. The timelines are provided in months. In the above figure patent application is first filed at the National Patent Office. The date of receipt of application is called ‘priority date’, and the first filing is called a ‘priority filing’. Since Paris Convention[23] of 1883, an applicant has 12 months to extend application abroad without risking loss of the patent on the grounds of lack of novelty. Hence, an applicant can make a second filing at the EPO. The application is published - normally together with the search report - 18 months after the date of filing or, if priority was claimed, the priority date. It takes a longer time to obtain the grant of the patent, normally 60 to 72 months, or 5 to 6 years, from the priority date, subject to quality of the application and complexity of the invention. Patent can be legally protected for the maximum period of 20 years from the filing date.

[23] The Paris Convention, adopted in 1883, applies to industrial property in the widest sense, including patents, trademarks, industrial designs, utility models, service marks, trade names, geographical indications and the repression of unfair competition. This international agreement was the first major step taken to help creators ensure that their intellectual works were protected in other countries. Paris Convention for the Protection of Industrial Property: http://www.wipo.int/treaties/en/ip/paris/

Figure 18: Patenting Process in the European Patent System: EPO and NPOs



Note Figure 18: t = time in months. The timelines in decision tree can vary depending on each individual application case and the Patent Office.

Applicants seeking protection in a number of EPC contracting states face a choice of filing direct with the EPO or filing with the National Patent Office. Figure 18 above illustrates the decision facing an applicant.

The European procedure does not supersede the national grant procedures. When seeking patent protection in one or more EPC contracting states applicants have a choice between following the national procedure in each state for which they want protection and taking the European route, which in a single procedure confers protection in all the contracting states that applicant designates.

Patent law in the contracting states has been extensively harmonized with the EPC in terms of patentability requirements. However, as grant procedures continue to be differently structured and are conducted in parallel by several offices, the national route generally leads to national rights with differing extents of protection.

As already indicated in the figures 16 and 17 above, the first step in patenting process is the filing of an application. During the first half a year, European or National Office Search report is drawn up, listing all the documents available to the Office that may be relevant to assessing novelty and inventive step. The search report is based on the patent claims but also takes into account the description and any drawings. It provides the initial opinion as to whether the claimed invention and the application meet the requirements of the European Patent Convention.

Companies which first filed at the National Office and wish to switch to EPO have 12 months to do so, as established in the Paris Convention (Paris Convention for the Protection of Industrial Property, 1883). This case is illustrated in the second column in figure 18.

The Publication of the patent application is normally made together with the search report in 18 months after the date of filing or, if priority was claimed, the priority date. Applicants then have 6 months to decide whether or not to pursue their application by requesting substantive examination. In case of seeking EPO patent, the applicant must pay the appropriate designation fees within the same time limit. Designation decision regards the choice of the states in which the patent protection ought to be enacted. This case is illustrated in the first column in figure 18. In case company is filing directly at the NPO, it only has to make a decision whether to proceed further to substantive examination. This is illustrated in the column 3 in figure 18.

There are no established time limits by which the patent has to be granted. It normally takes 5 to 6 years. Once the patent is granted by the EPO, company must decide in which designated states it seeks to validate its patent. It results in the “bundle” of national patents, called a ‘patent family’. However, in case of National Office route, the granted patent is automatically valid and legally protected in its national jurisdiction. The company however can decide if it wishes to upheld the granted patent and continue paying the renewal fees.

Patent maximum life cycle is 20 years from the filing date. Most patents are not protected for the maximum period. Legal protection must be renewed and the renewal fees must be paid annually, starting normally from the third year from the filing date.

CHAPTER 2

MARKET VALUE OF PATENTS AND TRADEMARKS

ABSTRACT

Aim of this analysis is to study whether the global financial crisis of 2008 had a significant effect on how stock markets value firms' investments in knowledge and branding as well as complementary investments in patents and trademarks. Building on data from European Intellectual Property Office (EUIPO) and European Patent Office (EPO) we construct a firm panel covering R&D, marketing and IP investments over the period 2005-2012. In addition, we estimate market value equations for the years 2005-2008 and 2009-2012. Empirical findings suggest that there are interesting differences in which investments contributed to market value before and after 2008. First, investments in R&D contribute far more significantly to the market value after the crisis than before. Second, it becomes apparent that after the crisis patent quality arises as a significant factor which increases value of the companies. At the same time patent quantity ceases to be an influencing factor in the market value equation after 2008.

KEYWORDS: Market Value, Tobin's Q, R&D, Patents, Patent Citations, Trademarks, Great Recession

JEL CODES: G32, E32, O32, O34

1. INTRODUCTION

Scholars have always sought to understand how firms extract value from intangible assets. The use of Intellectual Property (IP) has been recognized by industry and academics alike as an important means of appropriating value.

The purpose of this paper is to analyze how stock markets value knowledge assets of the firms in the context of recent economic recession.

The dynamic nature of the global economy has renewed interest in intangible capital and intellectual property as a source of growth for countries and businesses. The recent Great Recession of 2008 has generated uncertainty and resulted in severe restrictions of financial resources for many companies. Firms had to find new ways of allocating resources in a more efficient way. The question how this uncertainty and lack of funds affected innovation strategies in particular, remains little analyzed and deserves more attention to be fully answered.

J. Schumpeter (1942) famously argued that “recessions can provide a platform for innovation and economic growth by unleashing a process of *‘creative destruction’*, i.e. development of new technologies and ways of working”. From this perspective, recession may be seen as an opportunity for companies to exploit the turmoil in the market, overcome competitors, introduce novel products and reform their business models. On the other hand, crisis inevitably impedes the access to financial resources vital to companies’ survival, as well as reduces aggregate demand and consumption; hence the sales of businesses suffer.

The growing importance of intangible assets and the continuing globalization of the world economy up until the financial crisis of 2008 led to world-wide growth in the demand for patent and trade-mark rights. Simultaneously firms’ patenting strategies and their brand building strategies have become increasingly specific to the industry context: for instance firms in the ICT sector increasingly rely on amassing large patent portfolios and producers of consumer goods have extended their core brands to new markets, often creating complex systems of derivative brands.

The focus of this paper is to investigate how the global financial crisis of 2008 affected the interplay of investments in intangibles and investments in the associated IP rights. The level of uncertainty about the depth and duration of this crisis for the world economy was very significant and firms' responses could take two principal forms: i) reduce costs while maintaining their IP portfolios; ii) focus and invest in the most profitable opportunities, while dropping older, less profitable product lines. Either strategy is always prevalent anyway, but both could have become more important to firms during the crisis years.

The paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes data sources and provides the descriptive analysis of estimation sample. Section 4 sets out and explains the empirical model. Section 5 presents and discusses empirical findings. Section 6 concludes. An Appendix provides further analysis and documentation.

2. LITERATURE REVIEW

Most prior research on the market value of intangible assets is concerned with the impact of patent counts and R&D on the valuation of firms by stock markets. This type of methodology was originally introduced by Griliches (1981, 1984). The following decades saw an expansion in the empirical studies examining market value of companies in relation to intangible assets. It is well worth noting that most of the literature is focused on US firms and relies on patent data from United Stated Patents and Trademarks Office (USPTO). The most important studies in this vein were conducted by Griliches (1981, 1984, 1998), Pakes (1985), Jaffe (1986), Conolly and Hirschey (1988), Hall (1993; 2000), Hall et al. (2005), Hall and MacGarvie (2006). The market value of IP for European companies was analyzed by Blundell et al. (1999), Toivanen et al. (2002), Bloom and van Reenen (2002), Greenhalgh and Rogers (2006), Hall and Oriani (2006), Hall et al. (2007). Bosworth and Rogers (2001) conducted similar work for Australia.

Most of these studies relate the stock market value of firms to R&D and patents, as measures of knowledge capital. The typical finding of this work is that R&D has more explanatory power than patent counts in the market value equation. However, patents do contribute to the value of companies and enter the market value equation as a significant factor.

There are fewer empirical studies that incorporate patent citations as a measure of patent quality. Shane (1993) finds that patents weighted by citations have more predictive power that patent counts for a small sample of semiconductor firms. Austin (1993) finds that citation weighted patent counts did not have a significant impact in the biotechnology industry. Hall et al. (2005) were among the first researchers who conducted a large scale study to include a citation-weighted measure of patents in the market value regression. Their findings confirm that patent citations add information above and beyond Research and Development (R&D) and patent counts and help boost the market value of companies.

It is well worth noting that most of the empirical research of the value of IP has been devoted to patents and to a lesser extent - to trademarks. Trademark rights were considered by Sandner and Block (2011), Bosworth and Rogers (2001) as well as Greenhalgh and Rogers (2006) and Thoma (2015). The lack of research on trademarks in the literature evaluating the economic value of intangible assets and in the field of industrial organization in general, was recognized and emphasized by Graham and Somaya (2006), Mendoca et al. (2004) and Sandner and Block (2011).

Comparing the patent and trademark application behavior of firms prior and after the crisis can in turn advance our understanding of the economic value of intangible assets. In order to provide conceptual framework we review the literature which focuses on economic recession impact on innovation.

Several economic studies publish research results with regard to innovation and Intellectual Property during the Great Recession. EUIPO and EPO (2016) suggest that “IPR-intensive industries have proved most resilient to the economic crisis”, as relative contribution of these industries to the EU economy slightly increased between the two periods 2008-2010 and 2011-2013. According to Paunov (2012), one in four firms stopped innovation projects due to the global crisis but innovation performance did not decrease. Her findings are based on firms’ innovation profiles in Latin American countries in 2008-2009. Sumedrea (2013) research confirms the importance of knowledge assets as profitability of companies in crisis time is found to be “linked to the financial capital through the value added intellectual capital coefficient". Corrado et al. (2016) shed light on the diffusion of intangible investment across Europe and the US over the years 2000-2013. Their estimates suggest intangible investment has been relatively resilient during the Great Recession in 2008-2009, while tangible investment fell massively. Based on Corrado, Hulten and Sichel (2005) methodology they find that intangible investments account for 40% of the capital deepening in the EU and 60% in the US. Cincera et al. (2011) investigate how corporate R&D evolves in the light of the contemporary economic crisis. Albeit company behavior varies, their findings suggest overall positive trend of firms investments in R&D. Some companies inevitably reduced their innovation activities. Companies which maintained the same levels of R&D or increased them were those that "thrive through the downturn and thus seek to gather the benefits in the upswing to come".

To date there is no research which looked at the market response to patent applications or grants in the context of recent Great Recession. This study contributes to the literature by providing novel empirical evidence on the value of R&D investments, patenting and trademarking activities in the context of the recent economic crisis of 2008.

3. DATA

This section discusses in detail the data used for the purposes of this project. We build a comprehensive dataset that brings together accounting, financial market, trademark and patent data. The first sub-section (2.1) clarifies the sources of the data and describes the way they were linked. The second sub-section (2.2) discusses the descriptive statistics.

3.1 DATA SOURCE AND SAMPLE

To perform our empirical study we brought together data from several sources. Data is combined with respect to: i) patents; ii) trademarks; iii) company-level financial data, such as enterprise value and R&D expenditure.

Company characteristics were collected from COR&DIP[24], Bureau van Dijk Amadeus and COMPUSTAT databases. Patent data was obtained from PATSTAT and trademark data was provided by the EUIPO.

We build a novel and rich database[25] linking these accounting and IP datasets via an elaborated matching process. Patents, patent citations and trademarks were consolidated at the corporate level in order to obtain company level IP portfolios.

We sought to obtain accounting and intellectual property data for the most significant R&D investors in the world. The European Commission and the Organization for Economic Co-operation and Development (OECD) provide the COR&DIP database which contains information about the R&D activity and inventive output (i.e. patents and trademarks) of the 2000 top corporate R&D performers worldwide. This data was the starting point of our dataset building process.

The COR&DIP database offers a set of comprehensive and highly useful data. Regarding the purpose of this research it also has several limitations. First, it only contains information for time period 2009-2012. Second, it lacks some information crucial for our empirical analysis, namely, enterprise value, total assets and brand related expenditure. We benefited from the good coverage of R&D expenditure information. Additional information to patent applications, such as grant dates, validation information and citations is also not provided by COR&DIP. In order to obtain additional information and expand the timespan of analysis we engaged in the process of matching the COR&DIP company sample with accounting data from Amadeus and COMPUSTAT. Patent data was linked using PATSTAT and trademark data was obtained from EUIPO.

Explications below outline in more detail the specific datasets with regard to patents, trademarks and financial information of the companies.

Patent data

Patent data was collected from PATSTAT[26] (April 2016 version). We extracted and observed patent application, grant, validation and renewal decisions and dates, as

[24] IP bundle of top corporate R&D investors, EC-JRC/OECD COR&DIP© database, v.0. 2015

[25] The detailed description of dataset building process is available in the Annex A.

well as the citations to applied and granted patents over the period 1978-2014. The payment dates of the validation and renewal fees have been used as indicators identifying the life cycle of each patent.

Trademark data

Trademark data was provided by EUIPO[27]. This data source collects information on the universe of European trademark applications, trademark renewals, cancellations, expirations and NICE classes[28] of the applications over the period 1996-2014.

Company level financial data

Company-level financial data is extracted from three data sources: COR&DIP, Bureau van Dijk Amadeus[29] and COMPUSTAT[30]. The main source of the company information is constituted by the EC-JRC (European Commission Joint Research Centre) and OECD (Organization for Economic Co-operation and Development) joint project "World Corporate Top R&D Investors: Innovation and IP bundles". The COR&DIP database provides a list of the top 2,000 corporate R&D performers worldwide. It contains information about the R&D activity and inventive output (i.e. patents and trademarks) of these 2000 companies[31]. The database also allocates each

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[26] PATSTAT contains bibliographical and legal status patent data extracted from the EPO (European Patent Office) databases and is provided as raw data or online.

[27] The European Union Intellectual Property Office (EUIPO), which was known as OHIM until 23 March 2016, is a decentralized agency of the European Union to offer IP rights protection to businesses and innovators across the European Union (EU) and beyond.

[28] The Nice Classification, established by the Nice Agreement (1957), is a system of classifying goods and services for the purpose of registering trademarks.

[29] Bureau van Dijk is a Moody's Analytics Company. Its dataset Amadeus contains information on around 21 million companies across Europe: https://amadeus.bvdinfo.com.

[30] Standard & Poor's COMPUSTAT is a database of financial, statistical and market information on active and inactive global companies throughout the world:
https://www.spglobal.com/marketintelligence/en/?product=compustat-research-insight

[31] The IP bundle of top corporate R&D investors database (EC-JRC/OECD COR&DIP) results out of the collaboration between the EC-JRC Institute for Prospective Technological Studies (IPTS) and the OECD Directorate for Science, Technology and Innovation (STI). Information about the R&D investors is taken

firm to an ICB (Industry Classification Benchmark) sector code, on the basis of its dominant activities. In addition COR&DIP lists Research and Development (R&D) investment, Net sales, Capital expenditure, Operating profits and Number of employees over the period 2009-2012.

Bureau van Dijk Amadeus database contains accounting data of the European firms. COMPUSTAT dataset provides with the accounting information of non-European companies, most of which are USA, Canadian and Japanese companies. We use the indicators of Enterprise value, Total Assets, Intangible Assets, R&D expenditure, Operating expenditure, Employment, Net Sales provided by Amadeus and COMPUSTAT for the period 2000-2014.

Constructing the dataset

A number of matching and data cleaning exercises were carried out in order to create the final dataset for the empirical analysis. The matching of five datasets proved to be a large scale and challenging task. A great deal of our efforts was devoted into ensuring the links are correct and the fullest set of information is retrieved.

COR&DIP dataset was a starting point of our analysis. We relied on information of the top 2000 R&D intensive companies[32]. This information contains company characteristics, their patent applications at the EPO as well as trademark applications made at the EUIPO during 2010-2012. A significant benefit of the COR&DIP dataset is that it contains harmonized company names for the corporate top 2000 R&D investors worldwide. It also links IP data to enterprise data using the names of the companies and of their subsidiaries (as of 2012) and matches those to applicant names provided in

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from the 2013 EU Industrial R&D Investment Scoreboard. Intellectual property (IP) – related information is taken from EPO's Worldwide Patent Statistical Database (PATSTAT, Autumn 2014) database for patents and from selected IP offices in the case of trademarks: 1) Patent applications filed at the five top IP offices (IP5) in the world, namely: EPO (European Patent Office), JPO (Japan Patent Office), KIPO (Korean Intellectual Property Office), SIPO (State Intellectual Property Office of the People's Republic of China), and USPTO (United States Patent and Trademark Office); 2) Trademark applications filed at the USPTO, OHIM (Office for Harmonization in the Internal Market) and IP AUS (IP Australia).

[32] Information about the R&D investors is taken from the 2013 EU Industrial R&D Investment Scoreboard.

patent and trademark documents[33]. COR&DIP dataset already provides with the information on patent and trademark portfolios for the top R&D investing firms for the period 2010-2012. However, in order to carry out our study a longer time period was required as the aim of this paper is to observe whether global financial crisis of 2008 had a significant effect on how markets value firms' investments in knowledge as well as investments in patents and trademarks.

We were able to complement the COR&DIP dataset substantially by linking in additional information from PATSTAT and EUIPO. Linking these data together yielded a total of 1.709 companies represented in 44 different countries. Final dataset for IP rights allows identifying EPO patent information over the period 1978-2015[34]. In addition, we collected the data for trademark application filings over the period 1996-2014[35]. Accounting information, including enterprise value of the company, R&D expenditure, total assets, marketing expenditure, turnover and employment is available for years 2000-2014. It is well worth recognizing that for a fraction of initial 2000 companies sample, i.e. the 291 companies were not matched with accounting and IP data due to limitations in accounting data availability and possible company name incoherence. It is also important to stress that company names are observed as provided by COR&DIP. Company names and their ownership situation is observed as in year 2013. The process of matching applicants to corporate entities is outlined in Appendix A.

In the course of constructing the estimation sample further data availability restrictions were imposed. First, only companies with data for R&D expenditure and operating expenditure available at least since 2003 were considered in the regressions. This restriction resulted in the sample of 578 firms. In addition, companies with missing enterprise value and other regression variables were eliminated from the estimations. Hence the final estimation sample comprises a total of 481 companies. They are

[33] The linking was carried out on a by-country basis using a series of algorithm contained in the Imalinker system (Idener Multi Algorithm Linker) developed by the OECD by IDENER, Seville, 2013 (Dernis et al., 2015).

[34] 1978 marks the establishment of European Patent Office.

[35] 1996 marks the beginning of European Union IP Office activity (then OHIM – Office for Harmonization in the Internal Market).

allocated in 10 different jurisdictions: Belgium, Canada, Switzerland, Curacao, Germany, France, Israel, Netherlands, Singapore and the United States of America. Most of these companies (357) originate from the USA. 108 firms are headquartered in Europe. With regard to geographical allocation our sample is unbalanced.

In the following sub-section we discuss in more detail the sample characteristics and engage in descriptive statistical analysis.

3.2 DESCRIPTIVE STATISTICS

This section provides descriptive analysis of the estimation sample. We focus on characteristics of 481 companies represented over 10 jurisdictions and 15 industry groups. Table 1 below shows the summary statistics for the estimation sample.

The estimation sample is composed of the companies that are ranked among the 2000 most R&D investing companies in the world. Hence the estimation sample of this study is biased in this sense. The results must be considered taking the sample qualities and bias into account. The average market value of companies in the regression sample is 13 billion euros. On average these firms spend 357 million euros per year on R&D, own around 391 patents and 70 trademarks. Over the period 2005-2012, these companies tend to apply for 92 patents at the EPO, and file 7 new trademark applications at the EUIPO on a yearly basis.

Descriptive statistics indicate that market value as well as various knowledge stocks[36]: R&D, patents, citations and trademarks, are highly skewed, with the means of these variables far exceeding the median.

Ratios of Tobin's Q[37], R&D/Assets, Citations/Patents or OPEX/Assets demonstrate more symmetric distribution as reflecting the systematic size effects. Patents/R&D ratios however are relatively highly skewed with standard deviation over 1.2. High variation in Patent counts to R&D ratio is expected. Even though patents are largely considered to be an indicator of R&D "success", patent counts are also extremely

[36] Detailed explications of all variables and their computations are provided is section 3.2.

[37] Tobin's Q is the ratio between Market Value and Total Assets of the company. Explication is provided is section 3.2.

noisy indicator of return on R&D investments (Hall et al., 2005). The usefulness of patent counts measure is diminished by large variance in the value of patents themselves. This study seeks to analyze whether patent citations, as a proxy for the patent quality, might convey additional information and serve as a significant factor in the market value regressions.

Table 1: Descriptive Statistics

Variables	Mean	Median	SD	Min	Max
Market value, mln EUR	13.000	2.337	31.682	-143	388.596
Total Assets, mln EUR	12.125	2.033	35.299	4	580.072
R&D, mln EUR	357	62	907	0	7.891
R&D stock, mln EUR	1.269	218	3.307	4	32.910
Operating expenditure, mln EUR	5.303	1.041	16.100	6	274.773
Operating expenditure stock, mln EUR	25.854	4.649	79.638	28	1.296.558
Patent applications	92	12	262	0	3.782
Patent applications stock	494	51	1.401	0	19.495
Patent portfolio	391	33	1.020	0	13.199
Citations to applications	111	11	378	0	9.493
Citations to applications stock	595	59	1.688	0	20.495
Citations to grants	38	3	111	0	1.848
Citations to grants stock	259	29	675	0	5.350
Trademark applications	7	1	15	0	206
Trademark portfolio	70	14	148	0	1.922
Regression variables	**Mean**	**Median**	**SD**	**Min**	**Max**
TQ	1,633	1,224	1,653	-0,380	38,925
R&D/Assets	0,216	0,126	0,289	0,002	3,695
Patent portfolio/R&D*1000	0,509	0,162	1,253	0,000	26,375
Patent applications/R&D*1000	0,615	0,240	1,265	0,000	19,804
Citations/Grants	1,305	0,583	3,180	0,000	65,690
Citations/Applications	1,354	0,929	1,455	0,000	15,263
Opex/Assets	2,775	2,271	2,063	0,168	20,934
Trademarks/Assets*1000	0,014	0,005	0,030	0,000	0,484
Observations			3.235		
Firms			481		

Note Table1: N = 3,235 observations for 481 firms. Values are provided for the estimation sample, taking into account period 2005-2012.

The mean value of Tobin's Q (TQ) is 1.6. This is a high value. In the equilibrium Tobin's Q is expected to be at unity, indicating parity between book value of the company and that of the stock market. TQs' positive deviation from unity suggests that the market values company above the value of its assets reported in the balance sheet. Knowledge assets are among the unrecorded factors that are expected to contribute to such positive market evaluation. As emphasized by Hall (2000), market value is a useful measure for innovation if we can rely on the fact that companies are bundles of assets, both tangible and intangible. Value of these assets is determined by the financial markets. In that sense, pricing of the companies are comparable to pricing of other goods in the market, and hedonic price models can be applied.

Table 2: Descriptive Statistics, Pre-crisis and Post-crisis periods

	Pre-Crisis: 2005-2008			**Post-Crisis: 2009-2012**		
Variables	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
Market value, mln EUR	12.754	2.111	31.992	13.203	2.530	31.432
Total Assets, mln EUR	10.977	1.874	33.187	13.074	2.222	36.934
R&D, mln EUR	229	34	628	462	88	1.073
R&D stock, mln EUR	887	144	2.373	1.585	281	3.887
Operating expenditure, mln EUR	5.003	952	15.771	5.552	1.109	16.369
Operating expenditure stock, mln EUR	22.577	3.866	70.774	28.559	5.442	86.198
Patent applications	102	12	289	83	12	238
Patent applications stock	506	45	1.425	484	57	1.380
Patent portfolio	439	35	1.124	353	32	923
Citations to applications	119	12	341	105	10	407
Citations to applications stock	593	55	1.615	597	61	1.746
Citations to grants	47	5	126	30	2	97
Citations to grants stock	280	30	706	242	26	648
Trademark applications	6	1	15	7	1	16
Trademark portfolio	59	11	124	79	17	166
Regression Variables	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
TQ	1,703	1,239	1,901	1,575	1,206	1,414
R&D/Assets	0,144	0,089	0,175	0,276	0,172	0,345
Patent portfolio/R&D*1000	0,762	0,266	1,721	0,300	0,101	0,572
Patent applications/R&D*1000	0,865	0,344	1,709	0,408	0,188	0,645
Citations/Grants	1,252	0,561	3,008	1,349	0,603	3,316
Citations/Applications	1,404	0,924	1,654	1,313	0,934	1,265
Opex/Assets	2,570	2,110	1,932	2,945	2,444	2,151
Trademarks/Assets*1000	0,013	0,004	0,026	0,015	0,005	0,033
Observations		1.463			1.772	
Firms		445			477	

Note Table 2: Values are provided for the estimation sample. N=1463 observations during pre-crisis period, 2005-2008. N=1772 observations during post-crisis period, 2009-2012.

Further empirical analysis of this study seeks to disentangle the components contributing to the market value of a company by measuring the effects of R&D, patents, patent citations and trademarks to the Tobin's Q ratio.

Table 2 summarizes descriptive statistics of the main variables while splitting the time period into two parts[38]. The first time period encompasses pre-crisis years 2005-2008. The second time period encompasses post-crisis years 2009-2012.

The main difference that emerges between these two periods is the slight reduction in Tobin's Q ratio, falling from 1.7 to 1.57. It indicates that on average the book value of these companies increased at a faster pace compared to its value reflected in financial markets. Companies in the estimation sample heavily increase their R&D expenditure. R&D to Assets ratio also shifts from 0.14 to 0.27 between the two periods. At the same time, operating expenditure (OPEX) to Assets ratio increases only marginally.

Patents/R&D ratio exposed much less within-variation in the post-crisis period, reflected in the reduction of standard deviation and a smaller difference between mean and the median. The average patent portfolio of estimation sample reduced to 353 patents in 2008-2012 compared to 439 patents during 2005-2008. Accordingly, the mean of new patent applications filed on yearly basis reduced to 83 from 102. Mean of trademark applications increased up to 7 from 6, however.

Table 3 shows industry differences for selected variables. The sample comprises 15 industry groups as classified by ICB (Industry Classification Benchmark), on the basis of the super-sector. In total there are 19 super-sectors in the ICB taxonomy. The estimation sample is composed of the companies that represent quite a wide span of different industries. Most of the observations represent Technology industry group which is composed of Software and Computer services and Technology Hardware and Equipment. 140 companies of the estimation sample operate in this field. 114 firms represent Health Care industry, which is composed of Health Care Equipment & Services and Biotechnology & Pharmaceutical sectors. Third largest industry group of

[38] The t-tests were run in order to test whether the differences between pre-crisis and post-crisis periods are significant. They confirm significant difference between the means of the most of variables reported in Table 2. The t-test results are reported in Table 20 in the Appendix E.

the estimation sample is Industrial goods and services. Companies operating in the Aerospace & Defense, Electronic & Electrical Equipment and Industrial Engineering fall under this category. Tobin's Q differs quite significantly across the industry groups. The highest TQ value is observed in Health Care as well as Food & Drug Retailers (Retail super-sector). Companies in Financial Services also have a high Tobin's Q value. This is explained by considerably lower assets in comparison to the market value of the companies in this industry. Lowest values of Tobin's Q occur in the industry of Basic Resources, composed of Forestry & Paper, Industrial Metals & Mining and Mining sectors. Contrary to Financial Services, companies that operate in this industry tend to have relatively high value of total assets, which drives down the TQ ratio to market value. Same applies to Automobiles & Parts and Telecommunications industries.

Table 3: Industry characteristics

Industry name	**N**	**Perc.**	**Firms**	**TQ**	**R&D/ Assets**	**Patent portfolio/ R&D *1000**	**Citations/ Grants**	**Opex/ Assets**	**TM/ Assets *1000**
Technology	900	27,8%	140	1,61	0,28	0,27	0,84	2,88	0,010
Health Care	769	23,8%	114	2,54	0,35	0,45	2,88	2,04	0,021
Industrial Goods & Services	768	23,7%	111	1,26	0,12	0,60	0,79	2,98	0,010
Chemicals	277	8,6%	39	1,09	0,09	1,03	0,84	2,72	0,014
Automobiles & Parts	143	4,4%	21	0,70	0,19	0,41	0,85	4,60	0,004
Personal & Household Goods	135	4,2%	20	1,24	0,11	1,11	0,82	3,81	0,035
Oil & Gas	58	1,8%	8	1,20	0,03	0,28	0,72	2,73	0,002
Food & Beverage	51	1,6%	7	1,46	0,05	0,18	1,23	2,73	0,011
Construction & Materials	34	1,1%	6	0,64	0,04	0,13	0,46	2,04	0,003
Media	30	0,9%	4	2,16	0,17	1,09	0,83	2,35	0,014
Basic Resources	22	0,7%	3	0,61	0,02	0,42	0,38	2,67	0,000
Retail	16	0,5%	3	3,02	0,10	0,00	0,66	3,64	0,003
Utilities	15	0,5%	2	1,54	0,02	1,22	0,54	0,49	0,001
Telecommunications	10	0,3%	2	0,80	0,06	0,28	0,18	1,40	0,002
Financial Services	7	0,2%	1	3,36	0,44	1,76	0,41	2,54	0,376
Total	3.235	100,0%	481						
Mean				1,63	0,22	0,51	1,31	2,78	0,014

Note Table 3: N = 3,235 observations. Values are provided for all companies in the regression sample. Company data is provided as yearly averages, taking into account period 2005-2012.

Table 4 displays country differences for selected variables. Nearly 70% of companies in the estimation sample are headquartered in the USA. 108 are European companies. At this point it is important to stress that companies in our sample tend to operate on the multinational level in spite of their origin. Tobin's Q and other variables do not convey much information based on the geographical categorization alone.

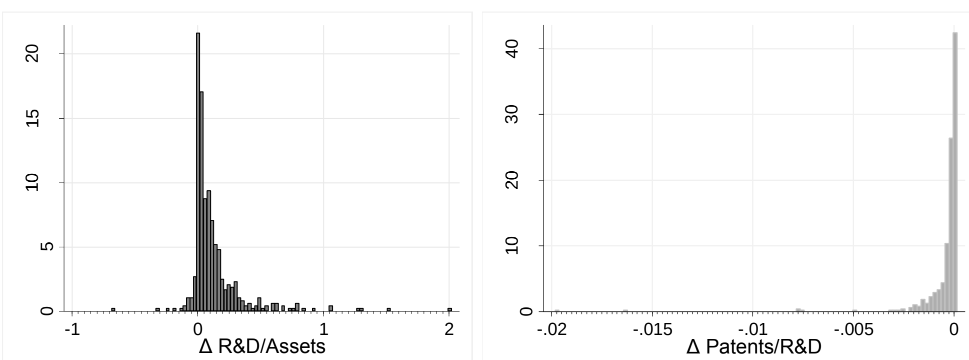
Table 4: Country characteristics

Country	N	Perc.	Firms	TQ	R&D/ Assets	Patent portfolio/ R&D *1000	Citations/ Grants	Opex/ Assets	TM/ Assets *1000
USA	2.351	72,7%	357	1,76	0,23	0,46	1,51	3,27	0,014
France	271	8,4%	36	0,93	0,13	0,52	0,71	1,22	0,006
Germany	246	7,6%	33	0,94	0,19	0,79	0,60	1,07	0,019
Switzerland	204	6,3%	29	2,06	0,25	0,66	0,78	1,59	0,011
Canada	62	1,9%	10	2,23	0,32	0,75	1,18	2,92	0,021
Nerherlands	46	1,4%	8	0,95	0,19	0,40	1,04	0,78	0,007
Israel	26	0,8%	4	0,94	0,18	0,22	1,32	2,47	0,054
Belgium	14	0,4%	2	0,69	0,12	1,03	0,54	0,50	0,005
Singapore	8	0,2%	1	0,57	0,37	0,20	0,27	9,97	0,000
Curaçao	7	0,2%	1	2,39	0,04	0,93	0,50	2,04	0,001
Total	3.235	100,0%	481						
Mean				1,63	0,22	0,51	1,31	2,78	0,014

Note Table 4: N = 3,235 observations. Values are provided for all companies in the regression sample. Company data is provided as yearly averages, taking into account period 2005-2012.

Figure 1 shows that companies are differently distributed regarding the post-crisis change in R&D to Assets ratio and that of Patents to R&D. Right skewed distribution of R&D/Assets ratio change between post-crisis and pre-crisis period shows that most of the companies tended to increase R&D to Assets in the post-crisis period. An opposite pattern is observed in the change of Patents to R&D ratio. Majority of companies decreased Patents/R&D ratio in the post-crisis. The change can be perceived as marginal, as nearly all sample falls under the range -0.005 and 0. Nevertheless, a clear pattern is observed.

Figure 1: Firm distribution



Note Figure 1: Distribution of 481 companies in the estimation sample is depicted. Left-hand side shows firm distribution by average post-crisis (2009-2012) and pre-crisis (2005-2008) difference in R&D stock/Assets ratio. Right-hand side graph shows firm distribution by average Patent portfolio/R&D stock ratio difference between post-crisis (2009-2012) and pre-crisis (2005-2008).

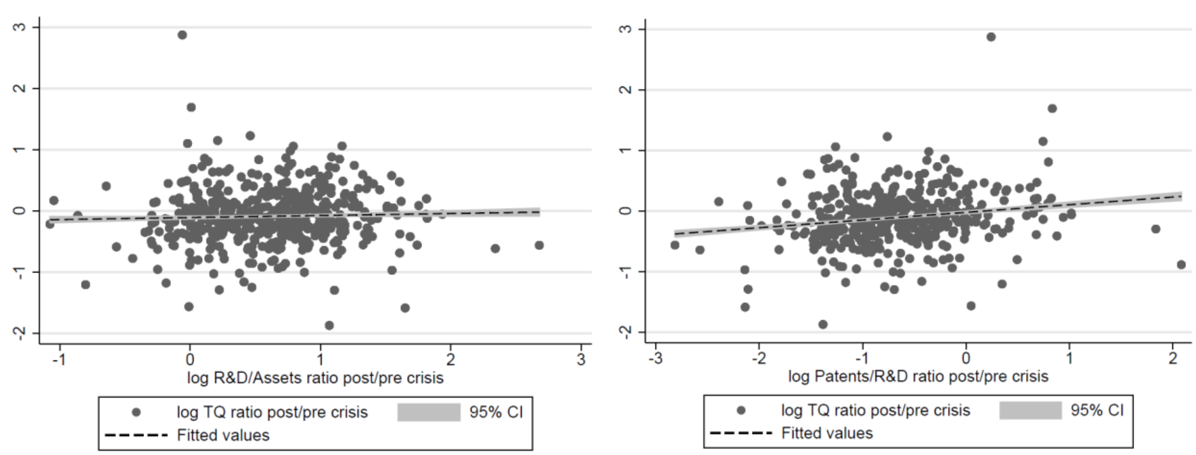
Table 5 groups companies according to their behavior after the crisis, during 2009-2012, compared to pre-crisis period over 2005-2012 As figure 2 also demonstrates, most of the companies increase their R&D to Assets ratio and decrease Patents to R&D ratio after 2008. This pattern of behavior applies to 379 companies out of total 481 in the sample.

Table 5: Firm allocation by change in the Post-crisis period

		Δ Patents/R&D		
		decrease after 2008	increase after 2008	**Total**
Δ R&D/ Assets	decrease after 2008	37	14	**51**
	increase after 2008	379	51	**430**
	Total	**416**	**65**	**481**

Note Table 5: Estimation sample of 481 firms is observed. We measure average differences between post-crisis (2009-2012) and pre-crisis (2005-2008) period for Patent portfolio/R&D stock and R&D stock/Assets.

Figure 2: Correlation: Tobin's Q, R&D/Assets and Patents/R&D



Note: Figure 2 takes into account 481 companies of the estimation sample. The left-hand side graph shows the relationship between post-crisis and pre-crisis ratio in Tobin's Q and in R&D stock/Assets ratio. The right-hand side graph shows the two-way relationship between post-crisis and pre-crisis ratio in Tobin's Q and in the Patent portfolio/R&D stock ratio.

It is interesting to observe whether change in R&D/Assets and Patents/R&D was associated with certain change in market value for these companies. Figure 2 illustrates the pre-crisis Tobin's Q relative to post crisis Tobin's Q relationship with the post crisis and pre-crisis ratios of these variables. A positive association is observed between the growth in R&D stock and growth in market value in the post-crisis period compared to pre-crisis period. It is sustained by the following regression analysis conducted in section 4. Patents/R&D ratio growth after the crisis is also positively and significantly related with Tobin's Q growth. The same relationship does not hold in the empirical model estimations when additional controlling variables are included.

The following section outlines the empirical model applied in estimating the market value equations. It also discusses the regression variables in the explicit manner.

4. EMPIRICAL MODEL

This section outlines the Market Value equation specification and discusses the empirical model.

4.1 FIRM LEVEL MARKET VALUE

Firm level analysis is conducted. The aim of this study is to assess how market value is affected by the investments in knowledge stock and investments in Intellectual Property (IP). We also aim to assess whether these effects differed in the period before the crisis, during 2005-2008, and after the crisis, during 2009-2012.

The majority of studies on innovation and performance use market valuation as an indicator of the expected value of future profits of the firm. There are two measures of a company's market value: market capitalization and enterprise value. The latter is a more precise measure. Market capitalization is calculated by multiplying current stock price and number of shares outstanding. While it provides information about company's size, its real share value and expected risk, it omits important factors in the overall valuation of a firm. Enterprise value takes into consideration the value of the debt obligations as well as cash and cash equivalents in addition to equity value. In general, enterprise value indicates real price that the company could be bought for in the current market.

We posit a firm's market value equation in which market value (MV) is a function of total assets *(A)*, investments in R&D *(R)* and branding *(B)*, stocks of patents *(P)* and trademarks *(T)* as well as a random i.i.d. error term *(ϵ)*:

$$MV_t = (A_t, R_t, B_t, P_t, C_t\ T_t, \in_t) \tag{1}$$

Firm level market value equation was first introduced by Griliches (1981, 1984). This approach has been widely applied in econometric studies by Blundell et al. (1999), Hall et al. (2005, 2007), Gambardella et al. (2008), Thoma (2015) and others. The firm's market valuation is given by Tobin's Q equation. In its most general form the model takes form of the Cobb-Douglas function:

$$V_{it}(A, K) = q_t\ A_{it}^{\alpha}\ K_{it}^{\beta} \tag{2}$$

Typical Tobin's Q model starts with the assumption that company is composed of two types of assets. Tangible assets *(A)* and knowledge stock *(K)* contribute to the value of the company (V_{it}). A_{it} denotes the book value of companies' total assets at time t. K_{it} denotes the knowledge stock of the firm at a time t. q_t is the marginal Tobin's q. It can be interpreted as the average market valuation coefficient of firm's total assets, reflecting its differential risk and monopoly position.

Expression 2 can be understood as a model that is known in literature as a hedonic pricing model, where the good being priced is the firm and the characteristics of the good are its assets, both tangible and intangible (Hall and Oriani, 2006).

Typically, in market value estimation models, constant returns to scale are assumed. Therefore, $\alpha + \beta = 1$ in equation 2. In logarithms, equation 2 can be transformed as following:

$$\log V_{it} = \log q_t + \alpha \log A_{it} + \beta \log K_{it} \tag{3}$$

Given the constant returns to scale, equation 2 also takes the following form:

$$\log\frac{V_{it}}{A_{it}} = \log q_t + (\alpha - 1)\log A_{it} + \beta\log\frac{K_{it}}{A_{it}} \quad (4)$$

The dependent variable of the equation 4 represents Tobin's Q (TQ). Tobin's Q is the ratio of market value to the total assets reported by the firm. It also defines the replacement cost of the company (Hall et al., 2007). Under perfect competition TQ ratio is expected to be equal to unity. Tobin's Q deviation from unity is considered to be driven by unrecorded assets, such as knowledge assets or intellectual property, which positively contributes to companies' value premium. Firms with high level of intangible knowledge capital have a higher market value than one might expect in case only physical assets were taken into account (Bloom and van Reenen, 2002).

Various authors choose different measure to account for the knowledge assets. In general, most of the studies rely either on the R&D expenditure of the firm, or the counts of the patents or trademarks in order to approximate for the intangible assets. Our empirical model is described below. For the empirical analysis the equation 4 is rearranged in the following form:

$$\ln Q_{it} = \ln\frac{V_{it}}{A_{it}} =$$

$$\ln q_{it} + \beta_1 \ln A_{it} + \beta_2 \ln\frac{R_{it}}{A_{it}} + \beta_3 \ln\frac{PT_{it}}{R_{it}} + \beta_4 \ln\frac{C_{it}}{PT_{it}} + \beta_5 \ln\frac{B_{it}}{A_{it}} + +\beta_6 \ln\frac{TM_{it}}{A_{it}} + \delta_i + \tau_t + \varepsilon_{it} \quad (5)$$

The firm level market value equation 5 is estimated by ordinary least squares (OLS). It is regressed over the period 2005-2012, and additionally over the pre-crisis period of 2005-2008, and post-crisis period of 2009-2012. Firm specific time invariant effects (δ_i), time effects (τ_t) and a random stochastic term (ε_{it}) are taken into the account. In particular, firm valuation is regressed against several characteristics of firm's intangible assets including R&D investment, operating expenditures, as well as stocks of patents and trademarks. Measure of citations to patents is used as a proxy to capture the quality of the patents. The intercept *($\ln q_{it}$)* represents the average logarithm of Tobin's q for the sample firms. It captures the adjustment of the overall macro-economic effects in the stock market and can be interpreted as an estimate of the logarithmic average of Tobin's Q for the sample of firms during the relevant period (Hall, 2000). The meaning of the regression variables is described in more detail in the following sub-section.

4.2 COVARIATES

The meaning of the variables in the estimating equation 5 is described as follows.

Tobin's Q, (Q) or (V/A) – This is the dependent variable. Tobin's Q equals to the ratio of the firm's market value to its total assets. Market value of the company takes into consideration equity value of the company in addition to the value of the debt obligations as well as cash and cash equivalents. It is based on Bureau van Dijk and COMPUSTAT "Enterprise Value" measurement. Tobin's Q can be interpreted as a premium of companies' value which is generated by unrecorded assets. Our regression analysis seeks to disentangle components contributing to this premium.

Total assets (A) – annual book value of the total (tangible and intangible) assets of the company.

R&D stock (R) – the stock of past R&D investment. The stock is constructed as cumulative sum. We apply 15% annual depreciation rate[39] to the R&D stock.

$$\mathrm{RD}_{\mathrm{t}}^{\mathrm{stock}} = \mathrm{RD}_{\mathrm{t}}^{\mathrm{flow}} + (1-\delta)\mathrm{RD}_{\mathrm{t-1}}^{\mathrm{stock}} \tag{6}$$

Here $\delta = 15\%$ annual depreciation rate. It is usually assumed to be 15% (Hall et al., 2005; Thoma, 2015). In the model estimations R&D stock is scaled to total assets: (R/A).

Operating expenditure stock (B) – this is the stock of past operating expenditure (OPEX). We rely on the book value of the operating expenditure of the company as a

[39] 15% depreciation rate was suggested and first introduced by Hall B.

proxy indicator for the advertising expenditure. It is scaled to total assets in the regressions, similarly to R&D: (B/A).

$$B_t^{stock} = B_t^{flow} + (1 - \delta) B_{t-1}^{stock} \quad (7)$$

Here $\delta = 15\%$ annual depreciation rate. The stock is constructed as cumulative sum and declining balance formula is applied.

Patent Portfolio (PT) – this is the size of each firm's overall valid patent portfolio. In the model estimation we include patent portfolio ratio to R&D expenditure stock. Patents can be considered as the output of R&D (Hall et al., 2005; Thoma, 2015). Hence, patents/R&D ratio can interpreted as patent productivity. Notification in the estimation equation 5: (PT/R).

$$PT_t = PT_{t-1} + p_t - \bar{p}_t \quad (8)$$

Here PT_{t-1} is the past total stock of valid patents[40] (i.e. patents that are granted by the EPO and subsequently validated). p_t is the inflow of validated patents in the current year; $\bar{p}_t$ is the outflow of patents in the current year: patents that lapsed (i.e. validation fees or renewal fees were stopped being paid by companies), or patent exceeded its maximum lifetime of 20 years and fell in the public domain.

Patent Application Stock (APT) – the past stock of patent applications filed at the EPO at any time over the period 1978-2012. Application stock ratio to R&D expenditure stock is included in the regressions. Notification in the estimation equation 5: (PT/R).

$$APT_t^{stock} = APT_t^{flow} + (1 - \delta)\, APT_{t-1}^{stock} \quad (9)$$

Here $\delta = 15\%$ annual depreciation rate. Similarly to R&D and operating expenditure stock, patent applications are assumed to lose a fraction of their value every year. Such

[40] Number of validation jurisdictions is not accounted for. For instance, company is considered to own one valid patent irrespective if it is validated in only one or more than one country.

depreciation is dictated by the economic nature of patents. Due to technological progress, innovations protected by patents are prone to erode with the time.

Citations to Grants, (Cg) – the measure of the stock of forward citations to granted patents. Citations are counted at the EPO for 3 years after the grant date. We use data from EPO to construct these stocks. They provide a proxy for the technological importance of the firm's inventions in the past. The stock is constructed as cumulative sum and declining balance formula is applied.

$$\mathrm{Cg}_{\mathrm{t}}^{\mathrm{stock}} = \mathrm{Cg}_{\mathrm{t}}^{\mathrm{flow}} + (1-\delta)\mathrm{Cg}_{\mathrm{t}-1}^{\mathrm{stock}} \qquad (10)$$

Here $\delta = 15\%$ annual depreciation rate. In empirical model we use citations to granted patents stock scaled by the patent portfolio: (C/PT).

Citations to Applications, (C) – this is a measure of the stock of forward citations to applied patents. Citations are counted at the EPO for 3 years after the application publication date. It is also called a "broad citations" measure, while citations to granted patents represent "narrow citations" approach. We use data from EPO to construct these stocks. The stock is constructed as cumulative sum and 15% annual depreciation rate is applied. The ratio to patent application stock is used in the empirical estimation: (C/PT).

$$\mathrm{C}_{\mathrm{t}}^{\mathrm{stock}} = \mathrm{C}_{\mathrm{t}}^{\mathrm{flow}} + (1-\delta)\mathrm{C}_{\mathrm{t}-1}^{\mathrm{stock}} \qquad (11)$$

Here $\delta = 15\%$ annual depreciation rate. In empirical model we use citations to applications stock scaled by the patent application stock.

Trademark stock (TM) – the size of each firm's overall trademark application portfolio. We rely on the data from EUIPO to construct this measure.

$$\mathrm{TM}_{\mathrm{t}} = \mathrm{TM}_{\mathrm{t}-1} + \mathrm{tm}_{\mathrm{t}} - \overline{\mathrm{tm}}_{\mathrm{t}} \qquad (12)$$

Here TM_{t-1} is the past total stock of trademark filings tm_t; is the inflow of new trademark filings in the current year, or trademark renewals;[41] $\overline{tm}_t$ is the outflow of trademarks: trademarks that were cancelled or not renewed. Due to infinite lifecycle and an economic nature of brands, depreciation rate is not applied when computing the trademark stock. Indeed, the value of the brand might even increase with the time depending on firm's investment in the product development and their marketing strategy. In the empirical model estimations we rely on the trademark stock scaled to total assets: (TM/A).

Technology area fixed effects – Firms are classified using the ICB (Industry Classification Benchmark) taxonomy. It allows us to analyze differences across different business activities. The categorization is based on ICB system of 10 industries partitioned into 19 super-sectors which are further divided into 41 sectors, which then contains 114 sub-sectors.

Time fixed effects – these are annual time dummies. Using data on the date of patent application filing at the EPO and the date of trademark application filing at the EUIPO we construct dummies to capture time fixed effects.

The above described covariates are included in the estimation models reported in the next section. We build models that rely either on the patent portfolio or the stock of applied patents in addition to the stock of R&D expenditure as a proxy for the knowledge assets. Also, we include citations to granted patents or the citations to applied patents analyzing differences between impact of "narrow" and "broad" citations to the market value. Trademark stock and operating expenditure stock are employed as additional measurement of the knowledge assets. They are included in all model specifications. The following section discusses regression results.

[41] A European Union trade mark (EUTM) is valid for 10 years. It can be renewed indefinitely, for 10 years at a time

5. EMPIRICAL RESULTS

This section outlines and discusses empirical results. Building on the EC-JRC/OECD COR&DIP data as well as on PATSTAT and EUIPO data we construct a panel dataset of the largest R&D investors worldwide. Their knowledge assets and Intellectual Property portfolios are observed. Using this data we estimate market value equations in the spirit of Hall et al. (2005). Our models include both variables capturing knowledge investments and brand investments.

The dataset employed to estimate the market value equation has the structure of an unbalanced panel. It comprises 3,235 observations on 481 companies for the years 2005 through 2012.

"Horse Race" regressions

As a first-cut estimation, a number of "horse-race" regressions were conducted. The aim of these regressions was two-fold. First, we sought to analyze stand-alone explanatory power of potential covariates to be included in the main model. Second, it allows better comparing the results of our analysis with those to previous studies.

"Horse Race" regressions are conducted as step-by-step estimations, looking into explanatory power each variable individually has on the dependent variable.

Tables 13 and 16 show the "Horse Race" regression results for the whole period, 2005-2012. Tables 14 and 17 report "Horse Race" regression results for the pre-crisis period, for the years 2005-2008 Tables 15 and 18 report "Horse Race" regression results for the post-crisis period, for the years 2009-2012.

The first set of models reported in tables 13-16 estimate individual effect of each regressor on the Tobin's Q. The second set of models reported in tables 17-18 estimate individual effect in addition to total assets. Two types of models were considered to achieve comparability with previous studies and control the robustness of our results.

Market value is more tightly associated with the R&D stocks than with patents. R&D and patent citations emerge as the only relevant factors enhancing the market value.

When controlling for the total assets, we find that R&D fit deteriorates rather sharply in the pre-crisis period. In the post-crisis period the only two relevant factors contributing to market value are R&D stock and citations to granted patents. Trademarks and patent counts are only significant in the pre-crisis period. These outcomes are sustained by the results obtained in the full model specifications.

Estimation of main model: 2005-2012

Table 6 sets out the main estimation model results for the period 2005-2012. We investigate whether it is patent applications or patent grants that affect market value in this period. Also we address the question whether citations to patent applications or citations to granted patents are more important for investors. In addition, R&D expenditure to assets ratio is included as a proxy for the knowledge assets. Operating expenditure to assets ratio is employed as a measurement for branding activities.

The results indicate that market value is largely driven by R&D investments. This is by far the most significant and robust result across different model specifications. This result is consistent with the findings in earlier studies conducted by Hall (2000), Blundell et al. (2002), Toivanen et al. (2002), Hall and Oriani (2006), Hall et al. (2005) and Greenhalgh and Rogers (2006).

Neither patent portfolio size nor patent application counts have meaningful explanatory power in model specifications of market value equation reported in table 6.

An important issue that must be taken into consideration when interpreting these results is that we observe EPO patent applications and grants. Even though companies in the estimation sample originate mainly from the USA, and most of the companies operate in global markets. It is well worth recognizing that different results could be obtained if the equivalent USA patent measures were included in the estimations. Some previous studies reported the interdependence between EPO and US patents in market value equations. For instance, Hall et al. (2007) find that "financial markets place a positive value on EPO patented inventions owned by European firms only when patent protection is also acquired in the United States". They report that patents taken out in only one jurisdiction have "little if any association with firm market value", while patents taken out in both EPO and USPTO are more valuable.

Table 6: Market Value as a Function of R&D, Patents, Citations and Trade-marks, 2005-2012, OLS, dependent variable: Tobin's Q

	M1	M2	M3	M4
Variables (dependent variable: ln Tobin's Q)	**Grants/ Narrow Citations**	**Grants/ Broad Citations**	**Applications/ Narrow Citations**	**Applications/ Broad Citations**
ln R&D/Assets	1.272***	1.303***	1.274***	1.297***
	(0.307)	(0.307)	(0.308)	(0.308)
ln Patent portfolio/R&D	0.124	0.127		
	(0.123)	(0.128)		
ln Patent applications/R&D			0.153	0.186
			(0.139)	(0.144)
ln Citations/Grants	0.0660*		0.0618*	
	(0.0292)		(0.0305)	
ln Citations/Applications		0.0593		0.0523
		(0.0456)		(0.0459)
ln Opex/Assets	-2.171***	-2.226***	-2.170***	-2.225***
	(0.436)	(0.439)	(0.435)	(0.437)
ln Trademarks/Assets	0.373*	0.385*	0.370*	0.376*
	(0.159)	(0.159)	(0.160)	(0.160)
ln Assets	-0.0840***	-0.0854***	-0.0843***	-0.0867***
	(0.0129)	(0.0131)	(0.0126)	(0.0127)
Constant	3.003***	3.053***	2.991***	3.055***
	(0.505)	(0.513)	(0.500)	(0.506)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235
R2	0.386	0.382	0.386	0.382
Log-likelihood	-1144.9	-1155.7	-1144.3	-1153.8

Note Table 6: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors clustered at the company level (481 clusters).

Interestingly, citations to patents granted by the EPO are perceived as a significant factor by financial markets and contribute positively to the market value of the companies. Conversely, the same does not hold when citations to patent applications are considered. They do not have explanatory power in the market value equations. Financial markets tend to recognize the quality of de-facto approved and owned patents instead of attributing enough importance to citations of only potentially economically valuable inventions.

The results reported in table 6 also indicate that both knowledge assets and trademarks are economically valued by the stock market. Both measures of investments in R&D and trademark portfolio size were positively associated with Tobin's Q when estimating period of eight years, 2005 through 2012. The contribution of trademarks to firms' market values was robust at 5% level.

Estimation of main model: Pre-crisis (2005-2008) and Post-crisis (2009-2012)

Table 7: Market Value as a Function of R&D, Patent Portfolios, Citations and Trademarks: Split samples, OLS, dependent variable: Tobin's Q

	M1 - pre	**M2 - pre**	**M1 - post**	**M2 - post**
Variables (dependent variable: ln Tobin's Q)	**Pre-crisis 2005-2008**		**Post-crisis 2009-2012**	
	Grants/ Narrow Citations	**Grants/ Broad Citations**	**Grants/ Narrow Citations**	**Grants/ Broad Citations**
ln R&D/Assets	0.719+	0.757*	1.873***	1.901***
	(0.368)	(0.369)	(0.339)	(0.339)
ln Patent portfolio/R&D	0.333*	0.358*	-0.114	-0.128
	(0.136)	(0.139)	(0.131)	(0.139)
ln Citations/Grants	0.0658+		0.0624*	
	(0.0370)		(0.0308)	
ln Citations/Applications		0.0382		0.0723
		(0.0490)		(0.0565)
ln Opex/Assets	-1.368**	-1.454**	-2.899***	-2.939***
	(0.509)	(0.512)	(0.451)	(0.455)
ln Trademarks/Assets	0.467*	0.486**	0.297+	0.304+
	(0.185)	(0.185)	(0.160)	(0.160)
ln Assets	-0.0854***	-0.0887***	-0.0782***	-0.0782***
	(0.0144)	(0.0146)	(0.0139)	(0.0140)
Constant	2.506***	2.618***	3.196***	3.204***
	(0.588)	(0.595)	(0.556)	(0.566)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	1463	1463	1772	1772
R2	0.395	0.392	0.409	0.405
Log-likelihood	-590.4	-594.8	-497.8	-503.9

Note Table 7: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies (pre-crisis and post-crisis), and 10 country dummies. Standard errors clustered at the company level: 445 clusters for the pre-crisis period and 477 clusters for the post-crisis period.

Table 8: Market Value as a Function of R&D, Patent Applications, Citations and Trademarks: Split samples, OLS, dependent variable: Tobin's Q

	M3 - pre	M4 - pre	M3 - post	M4 - post
Variables (dependent variable: ln Tobin's Q)	**Pre-crisis 2005-2008**		**Post-crisis 2009-2012**	
	Applications/ Narrow Citations	**Aplications/ Broad Citations**	**Applications/ Narrow Citations**	**Aplications/ Broad Citations**
ln R&D/Assets	0.725*	0.758*	1.863***	1.882***
	(0.369)	(0.369)	(0.342)	(0.342)
ln Patent applications/R&D	0.350*	0.392**	-0.120	-0.0887
	(0.150)	(0.151)	(0.154)	(0.165)
ln Citations/Grants	0.0596		0.0656*	
	(0.0384)		(0.0318)	
ln Citations/Applications		0.0312		0.0703
		(0.0493)		(0.0586)
ln Opex/Assets	-1.359**	-1.441**	-2.902***	-2.947***
	(0.507)	(0.508)	(0.451)	(0.455)
ln Trademarks/Assets	0.470*	0.484**	0.297+	0.298+
	(0.185)	(0.185)	(0.162)	(0.161)
ln Assets	-0.0846***	-0.0882***	-0.0789***	-0.0806***
	(0.0142)	(0.0143)	(0.0136)	(0.0137)
Constant	2.469***	2.581***	3.225***	3.264***
	(0.580)	(0.585)	(0.553)	(0.562)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	1463	1463	1772	1772
R2	0.395	0.392	0.409	0.405
Log-likelihood	-590.7	-594.3	-498.0	-504.9

Note Table 8: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies (pre-crisis and post-crisis), and 10 country dummies. Standard errors clustered at the company level: 445 clusters for the pre-crisis period and 477 clusters for the post-crisis period.

Tables 7 and 8 provide split-sample estimation results. The time period is divided into Pre-crisis years 2005-2008, and Post-crisis years 2009-2012, inclusive[42].

[42] Additionally, regression with pre- and post-crisis dummy interaction terms was done. The results are reported in Table 19 in the Appendix E. The split-sample regression results were confirmed: patent counts are only significant in the pre-crisis period; in the post-crisis period patent quality measured by citations to granted patents become relevant to the stock market valuation. Interacting covariate R&D and Total Assets ratio suggests more outspoken effect of R&D spending on the market value than the split-sample

This type of analyses is carried out in order to compare the model estimations between these two periods. Given the shock induced in financial markets by the Great Recession, it is relevant to analyze the market response to valuation of knowledge assets for each period separately. The exact timing of the crisis is rather ambiguous[43] and different time periods are considered. Since this study analyzes stock market valuation of companies, we consider the crisis duration definition that of financial markets. Financial conditions deteriorated sharply in September 2008[44]. The stress of interbank lending began to ameliorate during the fall and winter of 2008, but remained elevated until summer of 2009. Lending started rebound with a slow recovery at the end of 2009 (Chodorow-Reich, 2014). The financial crisis, considering the turmoil in interbank lending and major macroeconomic recession, is defined to last from October 2008 until June 2009[45].

Well recognizing that various repercussions of the recession have been evident for many years after 2008, we divide the estimation period into two groups: 2005-2008 and 2009-2012 as pre-crisis and post-crisis accordingly. The first period of time is considered from 2005 in order to account for more precise measures of R&D stock. R&D expenditure is by far the most truncated variable in our dataset. Broader timespan of the estimation period comes at the cost of the number of the firms to be included in the sample. Therefore, 2005 as the starting year of the analysis was chosen as an optimal solution. The final year in the estimation period is 2012 due to IP data availability. Reliable measures of patent and trademark statistics are collected until this year. Even though trademark and patent application counts might have been available

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regression. Nevertheless, both estimations suggest that R&D gains more importance and has stronger positive effect on companies' market value in the post-crisis period of 2009-2012, than in the pre-crisis period of 2005-2008.

[43] The first signs of the possibility of problems at major financial institutions came in June 2007, with the rescue by the investment bank Bear Stearns of a subsidiary hedge fund (Chodorow-Reich, 2014). Financial conditions deteriorated sharply in September

[44] On September 15 Lehman Brothers filed for bankruptcy.

[45] The choice of June 2009 as terminal month reflects both the timing of the US recession, which ended that month, and the timing of the return to normalcy in the interbank lending market.

until 2014, patent grant statistics are truncated due to long patent application examination periods at the EPO.

Market value is estimated based on equation 5 reported in the section 3.1. Patent portfolio is used in Table 7, while patent application stocks are used in Table 8.

The result that emerges as robust and holds in all model specifications is that R&D stock to Assets ratio and Operating expenses to Assets ratios have much larger coefficients in the years after the financial crisis than in the years before. More work will be required to analyze this result, but it may point to a premium for efforts to escape the drag of the crisis by investing in new opportunities.

Throughout all model specifications reported in Tables 7 and 8, we observe that in the pre-crisis period R&D stock coefficient is around 0.7. In the post-crisis period however, R&D stock effect increased substantially, reaching 1.8, and is highly robust at 0.1% level.

The opposite is observed when estimating patent portfolio to R&D ratio or patent application stock to R&D ratio. In the pre-crisis period patent productivity shows rather large effect on firm's market value with coefficient of 0.3. In the post-crisis period however this effect is no longer significant.

In general, patents vary enormously in terms of underlying value. Patent counts alone might not be sufficient indicator to be regarded by the stock markets. The purpose of including the patent counts weighted by citations in the empirical analysis was to obtain the indicator of the value of innovations patented by firms. Many of the previous econometric studies, e.g. by Bloom and van Reenen (2002), Hall et al. (2005), Thoma (2015), found that patent stock enhances Tobin's Q. Nevertheless, several recent studies, e.g. Sandner and Block (2011) found that patent stock was not contributing significantly to the market value and rather patent quality measures or trademark stocks emerged as robust market value enhancers. As indicated by Trajtenberg (1990), "the use of patents in economic research has been seriously hindered by the fact that patents vary enormously in their importance or value, and hence, simple patent counts cannot be informative about innovative output." In his article Trajtenberg (1990) shows that particular innovation (Computed Tomography scanners) is closely associated with citation-based patent indices and independent measures of the social value of innovations in that field. Thoma (2015) provides evidence that when index of patent family value distribution is taken into account, the return of the value of weighted patents are of comparable scale to that of R&D investment, confirming the view that financial markets are capable to discriminate the value heterogeneity of firm's patent assets (Hall et al., 2005; Lanjouw and Schankerman, 2004; Thoma, 2015).

We consider patent citations measure to account for the quality of patents. Results suggest that citations to granted patents obtain more significance in the post-crisis years, as significance level increases from marginal 10% level up to 5% level. Citations to applied patents were not observed as a relevant element neither in pre-crisis nor in post-crisis period however.

Trademarks arise in the estimation equation as a separate variable. Trademark stock is a positive and significant factor in the pre-crisis period of 2005-2008 throughout all model specifications. However, we find that in the post-crisis period, the effect of trademark stock on the value of companies erodes. The coefficient is still positive, but reduces nearly by half. The effect of trademarks also loses its significance in the post-crisis period as compared to pre-crisis period. These results must be taken with a pinch of salt. Similarly as patents, we only observe European trademarks in this study. Measures of US or other trademarks in case they were additionally included in the analysis might provide different results. However, we believe that the European trademark portfolios serve as a good proxy for companies overall trademarking activity. The pattern that emerges comparing pre-crisis and post-crisis periods holds for both patents and trademarks. It suggests that the mere counts of these IP rights are no longer a sufficient factor to enhance the firm's value.

The main shortcomings of the estimation stem from unobserved heterogeneity and sample selection bias. Our company sample represents large and mostly multinational enterprises that are among the top 2000 R&D investors in the world. Average market value of these companies is 13 billion euros and average annual R&D budget is around 357 million euros. Nevertheless, it is worth mentioning that this type of empirical analysis is possible only for publicly listed companies for which the market capitalization and market value data is accessible.

Also, one may worry that findings are affected to some extent by unobserved heterogeneity. Variables such as R&D expenditure, patent and trademark portfolios might be correlated with unobserved company characteristics. Among those, managerial quality and firm strategy toward Intellectual Property must be named as important yet unobserved company features. Companies behave differently and react in different manner in the time of crisis. In this paper we seek to explore whether economic recession has caused markets to value the investments in knowledge capital more or less comparing two periods, pre-crisis and post-crisis. When faced with sudden and severe financing restrictions companies have made decisions based on their internal policies. The element of turmoil together with the time shortage has caused the lack of coordination between the rivals. Based on this assumption we believe that the company behavior during the financial crisis was impacted largely by the management quality and only subsequently by the actions of their rivals.

The next section summarizes findings of this study and provides concluding remarks.

6. CONCLUSIONS

Innovation and productivity are the topics that fascinate economists since the very beginning of the study of economics. Nearly half a century ago the insight was made that economic growth could not be explained on the basis of the traditional factors of production of land, labor and capital alone. Rather a large residual factor in growth was attributed to improvements in productivity consequent on technological progress or innovation (Solow, 1957). During the 1980s and 1990s economists' interest in the possible role of knowledge (technology) for growth and development increased. On the theoretical front an important development was the emergence of new growth theory (e.g. Romer, 1990) according to which endogenous knowledge accumulation accounts for differences in economic development across the countries.

The macroeconomic rationale is well applied in microeconomic setting when analyzing company level market value premium. Intangible assets such as knowledge stock and intellectual property are recognized as significant factors that enhance the value of the companies.

Most of the prior literature considered R&D expenditure and patents as factors in the market value equation. Patent citations as a measure for the patent quality were studied by Hall et al. (2005), who were among the first researchers to incorporate citations in Tobin's Q model and to our knowledge have conducted the largest-scale study. With the exception of the studies by Greenhalgh and Rogers (2006), Sandner and Block (2011), Block et al. (2014) and Thoma (2015), previous studies rarely consider marketing activities and brands in the market value equations alongside with R&D and patents. There is a lack in debate and empirical evidence regarding the value that trademarks or branding expenditure generates for the companies, and the way it is perceived by financial markets.

This main novel contribution of this study is empirical analysis of the market value equation in the context of recent Great Recession. The rich and novel dataset that we built for this analysis collects information on both patent and trademark stocks, alongside with patent citations. R&D and operating expenditure accounts for the knowledge assets and branding expenditure. This study is also among the few studies which incorporate patent citations in the model estimation and attempts to analyze how trademark portfolios affect the Tobin's Q.

Our findings are in line with those of the previous studies suggesting that market value is largely driven by R&D investments. This result is the most robust one across different model specifications through periods 2005-2012, 2005-2008 and 2009-2012.

An interesting pattern was discovered when analyzing patent counts and patent citations' impact on the market value of the companies during pre-crisis and post-crisis periods. It becomes apparent that in the pre-crisis period patent portfolio size as well as patent application stock were perceived as significant factors by financial markets. They contributed to the enhancement of the market value premium of the companies. Citations to patents was not relevant factor in the pre-crisis period.

Conversely, in the post-crisis period an opposite holds. We observe the deteriorated significance in patent counts and emerged significance of the citations to granted patents. These results indicate that financial markets value the quality of innovation rather than mere patent counts in the post-crisis period.

A similar pattern is found when comparing the effect of trademark stock. In the pre-crisis period companies owning more European trademarks are valued above their reported assets and generate premium to the firm's price in financial markets. No significance is attributed to the trademark stock when estimating market value equations for the post-crisis period during 2009-2012. It allows us to speculate on the possibility that a trademark quality measure might be regarded as an important factor and reflect positive influence toward market value

Overall, the main findings points to conclusion that in the post-crisis period two factors emerges as significant market value enhancers. The first is the knowledge stock approximated by R&D expenditure stock. The second is the quality of innovation generated by R&D, approximated by the patent citations.

More work will be required to analyze this result, but it may suggest the efforts to escape the drag of the crisis by investing in new opportunities. On the other hand, financial markets may have shifted their attention to the innovation behind the legal IP rights. Patent counts that serve as strategic instruments and comprise patent thickets might not be deemed as relevant for the firm's value premium but rather the cutting-edge technology that has a true potential in generating demand for companies products. By the same logic, the value of the brand might become the factor discriminated by the financial markets.

These findings shed the light on change in perception of the stock markets toward innovation in the context of the Great Recession. They also suggest that the companies' willingness to invest in scientific capabilities might have been increased in the aftermath of the economic crisis.

Our empirical analysis complements previous studies which analyze the trends of corporate research. For instance, Arora et al. (2015) provide evidence that over the long run of 1980-2007 publicly traded American companies diminished their investment in research significantly. At the same time, patenting activity by firms has increased. This shows that the pattern of corporate innovation strategy was sustained over the long period of time before the economic crisis of 2008.

The significant boost in market value premium generated by firms' investment in science, points to the possible shift in corporate research strategies. The results of our analysis clearly indicate both the importance placed to R&D investments by both stock markets and companies. In the post-crisis period the importance of patent stocks is diminished however. Hence we may observe the development of the novel trend of higher valuation of the firm's scientific capabilities rather than patents themselves. One caveat of our analysis is the brevity of the time period observed. It is also possible that an increase in R&D will result in larger patent portfolios generated over longer period of time. The change in market valuation of the knowledge assets might prove to be either the new long-term pattern, or the short-term turmoil caused by the crisis. These questions provide the base for future research possibilities.

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LIST OF ABBREVIATIONS

EC-JRC – European Commission Joint Research Centre

EU – European Union

EPO – European Patent Office

EUIPO – European Intellectual Property Office

ICB – Industry Classification Benchmark

IP – Intellectual Property

IPR – Intellectual Property Right(s)

IPTS – Institute for Prospective Technological Studies

NICE – Nice Agreement Concerning the International Classification of Goods and Services for the Purposes of the Registration of Marks

OECD – Organization for Economic Co-operation and Development

OPEX – Operational Expenditure

PATSTAT – EPO Worldwide Patent Statistical Database

R&D – Research and Development

TQ – Tobin's Q

APPENDIX

APPENDIX A. BUILDING PROCESS OF THE ESTIMATION SAMPLE DATASET

The matching of EC-JRC/OECD COR&DIP data as well as of PATSTAT and EUIPO datasets could be broadly divided into several steps:

a. COR&DIP Matching with PATSTAT

The aim of this exercise was to find all the patents that were filed at the EPO at any time during 1978-2015 and belonged to the top 2000 global R&D investing firms as identified by COR&DIP.
The matching was carried out as following algorithm:

i. Link COR&DIP and PATSTAT based on the unique EPO patent application identifier.
ii. Identify the same group of companies, and assign these companies with patent applications filed during 1978-2015.

b. COR&DIP matching with EUIPO

The aim of this exercise was to find all the trademark applications that were filed at the EUIPO at any time during 1996-2014 and belonged to the top 2000 global R&D investing firms as identified by COR&DIP. The matching was carried out as following algorithm:

i. Link COR&DIP and EUIPO based on unique trademark number common for both databases.

ii. Identify the same group of companies and assign patent applications filed during 1996-2014.

c. Link PATSTAT and EUIPO data for top 2000 R&D investing companies together based on unique company identifier provided by COR&DIP.

d. Link joint patent and trademark dataset with Bureau van Dijk Amadeus dataset.

The aim of this exercise was to retrieve financial data for the European companies. The link was carried out on the basis on firm name. In this case we could not rely on a unique numerical identifier as in case of matching with PATSTAT and EUIPO. The matching was carried out as following algorithm:

i. In order to simplify the task of manual matching of firm names, we identified the first word in the name of each company.
ii. The matching was performed on the basis of the first word in each firm's name and its geographical location – country code.
iii. We carried out manual control of each match and identified true and false matches.
iv. In case of multiple matches we identified the correct link.
v. In case of false positive or false negative matches, additional name search was carried out in the database of Amadeus.

e. Link joint patent and trademark dataset with COMPUSTAT dataset.

The aim of this exercise was to retrieve financial data for the non-European companies. In the same manner as in matching with Amadeus data, the link was carried out on the basis on firm name and following the same algorithm as indicated in above section d.

APPENDIX B. SUMMARY OF PRIOR ART

Table 9: Empirical studies of the market value and innovation

Paper	R&D	Patents	Citations	TM	Sample	Geographical coverage	Time period
Griliches (1984)	YES	YES	NO	NO	1.091	USA	1968-1974
Megna and Klock (1993)	YES	USPTO	NO	NO	11	USA	1977-1990
Hall (1998)	YES	YES	NO	NO	5.000	USA	1976-1995
Blundell et al. (1999)	NO	USPTO	NO	NO	340	UK	1972-1982
Bloom and Van Reenen (2002)	NO	USPTO	YES	NO	404	UK	1968-1996
Toivanen et al. (2002)	YES	NO	NO	NO	1.519	UK	1988-1995
Hall, Jaffee and Trajtenberg (2005)	YES	USPTO	YES	NO	1.982	USA	1979-1988
Greenhalgh and Rogers (2006)	YES	UK, EPO	NO	EUIPO	3.227	UK	1989-2002
Hall and Oriani (2006)	YES	NO	NO	NO	2.156	US, UK, FR, IT, DE	1989-1998
Hall, Thoma and Torrisi (2007)	YES	USPTO, EPO	YES	NO	7.168	Europe (21)	1991-2002
Sandner and Block (2011)	YES	EPO	YES	EUIPO	1.216	EU	1996-2002
Thoma (2015)	YES	USPTO, EPO	NO	USPTO	4.780	USA, Europe	1991-2005
Our study	YES	EPO	YES	EUIPO	481	BE, CA, CH, CW, DE, FR, IL, NL, SG, US	2005-2012

APPENDIX C. ESTIMATION SAMPLE CHARACTERISTICS

Table 10: Estimation Sample Characteristics: Correlation of Variables, 2005-2012

	ln Tobin's Q	ln Assets	ln R&D/Assets	ln Patent portfolio/ R&D	ln Patent applications/ R&D	ln Citations/ Grants	ln Citations/ Applications	ln Opex/ Assets	ln Trademarks/ Assets
ln Tobin's Q	1								
ln Assets	-0.3105* 0.0000	1							
ln R&D/Assets	0.1981* 0.0000	-0.2992* 0.0000	1						
ln Patent portfolio/R&D	-0.1431* 0.0000	0.5367* 0.0000	-0.1204* 0.0000	1					
ln Patent applications/R&D	-0.1057* 0.0000	0.5228* 0.0000	-0.0755* 0.0000	0.9496* 0.0000	1				
ln Citations/Grants	0.2005* 0.0000	-0.0578* 0.0010	0.1153* 0.0000	0.0905* 0.0000	0.1892* 0.0000	1			
ln Citations/Applications	0.2002* 0.0000	-0.0286 0.1034	0.0928* 0.0000	0.1668* 0.0000	0.2241* 0.0000	0.6117* 0.0000	1		
ln Opex/Assets	-0.0212 0.2282	-0.3474* 0.0000	0.2524* 0.0000	-0.2314* 0.0000	-0.2222* 0.0000	-0.0811* 0.0000	-0.1209* 0.0000	1	
ln Trademarks/Assets	-0.0711* 0.0001	0.5925* 0.0000	-0.1052* 0.0000	0.4600* 0.0000	0.4635* 0.0000	0.0481* 0.0062	0.0836* 0.0000	-0.1390* 0.0000	1

Note Table 10: Significance level of each correlation coefficient in parentheses; * p<0.05; correlation of variables in the estimation sample which contains 3,235 observations and 481 companies. Observation period: 2005-2012.

Table 11: Estimation Sample Characteristics: Correlation of Variables, 2005-2008

	ln Tobin's Q	ln Assets	ln R&D/Assets	ln Patent portfolio/ R&D	ln Patent applications/ R&D	ln Citations/ Grants	ln Citations/ Applications	ln Opex/ Assets	ln Trademarks/ Assets
ln Tobin's Q	1								
ln Assets	-0.2730*	1							
	0.0000								
ln R&D/Assets	0.1294*	-0.1993*	1						
	0.0000	0.0000							
ln Patent portfolio/R&D	-0.0651*	0.5382*	-0.0005	1					
	0.0127	0.0000	0.9849						
ln Patent applications/R&D	-0.0312	0.5110*	0.0200	0.9633*	1				
	0.2332	0.0000	0.4455	0.0000					
ln Citations/Grants	0.2037*	-0.0806*	0.1208*	0.1311*	0.2028*	1			
	0.0000	0.0020	0.0000	0.0000	0.0000				
ln Citations/Applications	0.2009*	-0.0404	0.0975*	0.1788*	0.2351*	0.7241*	1		
	0.0000	0.1220	0.0002	0.0000	0.0000	0.0000			
ln Opex/Assets	-0.0189	-0.3005*	0.1864*	-0.1949*	-0.1811*	-0.0705*	-0.1133*	1	
	0.4691	0.0000	0.0000	0.0000	0.0000	0.0070	0.0000		
ln Trademarks/Assets	-0.0247	0.5943*	-0.0439	0.4705*	0.4648*	0.0623*	0.0858*	-0.1101*	1
	0.3450	0.0000	0.0933	0.0000	0.0000	0.0172	0.0010	0.0000	

Note Table 11: Significance level of each correlation coefficient in parentheses; * p<0.05; correlation of variables in the estimation sample which contains 1,463 observations and 445 companies. Observation period: 2005-2008.

Table 12: Estimation Sample Characteristics: Correlation of Variables, 2009-2012

	ln Tobin's Q	ln Assets	ln R&D/Assets	ln Patent portfolio/ R&D	ln Patent applications/ R&D	ln Citations/ Grants	ln Citations/ Applications	ln Opex/ Assets	ln Trademarks/ Assets
ln Tobin's Q	1								
ln Assets	-0.3449*	1							
	0.0000								
ln R&D/Assets	0.2977*	-0.4364*	1						
	0.0000	0.0000							
ln Patent portfolio/R&D	-0.2248*	0.5480*	-0.1761*	1					
	0.0000	0.0000	0.0000						
ln Patent applications/R&D	-0.1854*	0.5389*	-0.1597*	0.9425*	1				
	0.0000	0.0000	0.0000	0.0000					
ln Citations/Grants	0.2006*	-0.0424	0.1083*	0.0629*	0.1803*	1			
	0.0000	0.0745	0.0000	0.0081	0.0000				
ln Citations/Applications	0.2002*	-0.0177	0.0957*	0.1578*	0.2120*	0.5179*	1		
	0.0000	0.4576	0.0001	0.0000	0.0000	0.0000			
ln Opex/Assets	-0.0193	-0.3984*	0.2736*	-0.2508*	-0.2615*	-0.0949*	-0.1325	1	
	0.4158	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000		
ln Trademarks/Assets	-0.1112*	0.5894*	-0.2063*	0.4687*	0.4693*	0.0349	0.0818*	-0.1773*	1
	0.0000	0.0000	0.0000	0.0000	0.0000	0.1423	0.0006	0.0000	

Note Table 12: Significance level of each correlation coefficient in parentheses; * p<0.05; correlation of variables in the estimation sample which contains 1,772 observations and 477 companies. Observation period: 2009-2012.

APPENDIX D. "HORSE RACE" REGRESSIONS

Table 13: "Horse Race" Regressions of R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
ln Assets	-0.0475***									
	(0.00937)									
ln R&D/Assets		0.963**								
		(0.292)								
ln Patent portfolio/R&D			-0.139							
			(0.113)							
ln Patent portfolio/Assets				-0.125						
				(0.132)						
ln Patent applications/R&D					-0.0982					
					(0.125)					
ln Patent applications/Assets						-0.0537				
						(0.145)				
ln Citations/Grants							0.0883**			
							(0.0322)			
ln Citations/Applications								0.0880+		
								(0.0478)		
ln Opex/Assets									-0.386	
									(0.399)	
ln Trademarks/Assets										-0.170
										(0.132)
Constant	1.481***	-0.100	0.822***	0.816***	0.819***	0.804***	0.720***	0.714***	1.197**	0.811***
	(0.140)	(0.271)	(0.0417)	(0.0428)	(0.0501)	(0.0519)	(0.0406)	(0.0505)	(0.424)	(0.0358)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235	3235	3235	3235	3235	3235	3235
R2	0.339	0.322	0.312	0.311	0.311	0.310	0.320	0.313	0.311	0.312
Log-likelihood	-1263.7	-1305.7	-1329.1	-1330.9	-1331.7	-1333.1	-1308.7	-1324.9	-1330.7	-1329.0

Note Table 13: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors are clustered at the company level (481 clusters).

Table 14: "Horse Race" Regressions of R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2008: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**
ln Assets	-0.0379***									
	(0.0106)									
ln R&D/Assets		0.559+								
		(0.339)								
ln Patent portfolio/R&D			0.0950							
			(0.127)							
ln Patent portfolio/Assets				0.136						
				(0.150)						
ln Patent applications/R&D					0.128					
					(0.136)					
ln Patent applications/Assets						0.188				
						(0.160)				
ln Citations/Grants							0.103**			
							(0.0392)			
ln Citations/Applications								0.0830		
								(0.0551)		
ln Opex/Assets									-0.184	
									(0.462)	
ln Trademarks/Assets										0.0172
										(0.150)
Constant	1.201***	0.173	0.634***	0.628***	0.621***	0.610***	0.583***	0.588***	0.855+	0.658***
	(0.153)	(0.295)	(0.0478)	(0.0482)	(0.0530)	(0.0535)	(0.0475)	(0.0599)	(0.493)	(0.0399)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1463	1463	1463	1463	1463	1463	1463	1463	1463	1463
R2	0.358	0.345	0.342	0.343	0.343	0.344	0.353	0.345	0.342	0.342
Log-likelihood	-634.4	-648.5	-651.6	-651.1	-651.0	-650.2	-639.5	-648.5	-652.3	-652.5

Note Table 14: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (445 clusters).

Table 15: "Horse Race" Regressions of R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2009-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**
ln Assets	-0.0548***									
	(0.00995)									
ln R&D/Assets		1.400***								
		(0.355)								
ln Patent portfolio/R&D			-0.370**							
			(0.118)							
ln Patent portfolio/Assets				-0.360**						
				(0.135)						
ln Patent applications/R&D					-0.358**					
					(0.136)					
ln Patent applications/Assets						-0.309*				
						(0.155)				
ln Citations/Grants							0.0785*			
							(0.0363)			
ln Citations/Applications								0.0894+		
								(0.0538)		
ln Opex/Assets									-0.537	
									(0.432)	
ln Trademarks/Assets										-0.324*
										(0.138)
Constant	1.575***	-0.519	0.866***	0.858***	0.889***	0.867***	0.719***	0.706***	1.352**	0.822***
	(0.148)	(0.333)	(0.0431)	(0.0442)	(0.0536)	(0.0554)	(0.0423)	(0.0534)	(0.462)	(0.0359)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1772	1772	1772	1772	1772	1772	1772	1772	1772	1772
R2	0.337	0.319	0.307	0.304	0.303	0.299	0.303	0.297	0.296	0.301
Log-likelihood	-599.9	-624.0	-639.2	-643.8	-644.3	-649.4	-644.0	-652.4	-653.1	-646.7

Note Table 15: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (477 clusters).

Table 16: "Horse Race" Regressions of Total Assets, R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	M1	M2	M3	M4	M5	M6	M7	M8
ln Assets	-0.0475***	-0.0432***	-0.0583***	-0.0602***	-0.0479***	-0.0488***	-0.0610***	-0.0642***
	(0.00937)	(0.00928)	(0.0114)	(0.0110)	(0.00902)	(0.00923)	(0.00975)	(0.0117)
ln R&D/Assets		0.687*						
		(0.282)						
ln Patent portfolio/R&D			0.226+					
			(0.132)					
ln Patent applications/R&D				0.306*				
				(0.142)				
ln Citations/Grants					0.0903**			
					(0.0283)			
ln Citations/Applications						0.104*		
						(0.0461)		
ln Opex/Assets							-1.341***	
							(0.404)	
ln Trademarks/Assets								0.378*
								(0.161)
Constant	1.481***	0.784**	1.585***	1.574***	1.417***	1.412***	3.094***	1.676***
	(0.140)	(0.301)	(0.154)	(0.145)	(0.136)	(0.139)	(0.493)	(0.165)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235	3235	3235	3235	3235
R2	0.339	0.345	0.342	0.344	0.350	0.344	0.351	0.345
Log-likelihood	-1263.7	-1249.6	-1255.1	-1250.5	-1236.5	-1251.2	-1232.7	-1249.1

Note Table 16: Robust standard errors in parentheses; + $p<0.10$ * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors are clustered at the company level (481 clusters).

Table 17: "Horse Race" Regressions of Total Assets, R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2008: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
ln Assets	-0.0379***	-0.0368***	-0.0601***	-0.0599***	-0.0379***	-0.0395***	-0.0444***	-0.0631***
	(0.0106)	(0.0106)	(0.0118)	(0.0114)	(0.0102)	(0.0105)	(0.0110)	(0.0129)
ln R&D/Assets		0.476						
		(0.330)						
ln Patent portfolio/R&D			0.446**					
			(0.138)					
ln Patent applications/R&D				0.489***				
				(0.147)				
ln Citations/Grants					0.103**			
					(0.0369)			
ln Citations/Applications						0.0964+		
						(0.0523)		
ln Opex/Assets							-0.775+	
							(0.466)	
ln Trademarks/Assets								0.556**
								(0.182)
Constant	1.201***	0.770*	1.393***	1.363***	1.123***	1.139***	2.114***	1.498***
	(0.153)	(0.332)	(0.157)	(0.152)	(0.150)	(0.154)	(0.559)	(0.178)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1463	1463	1463	1463	1463	1463	1463	1463
R2	0.358	0.360	0.371	0.372	0.369	0.363	0.362	0.369
Log-likelihood	-634.4	-631.4	-618.9	-617.6	-621.1	-628.9	-630.1	-621.5

Note Table 17: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (445 clusters).

Table 18: "Horse Race" Regressions of Total Assets, R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2009-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
ln Assets	-0.0548***	-0.0463***	-0.0546***	-0.0577***	-0.0554***	-0.0557***	-0.0758***	-0.0646***
	(0.00995)	(0.00954)	(0.0129)	(0.0125)	(0.00966)	(0.00991)	(0.0104)	(0.0126)
ln R&D/Assets		0.918**						
		(0.339)						
ln Patent portfolio/R&D			-0.00555					
			(0.148)					
ln Patent applications/R&D				0.0740				
				(0.165)				
ln Citations/Grants					0.0820**			
					(0.0314)			
ln Citations/Applications						0.106+		
						(0.0555)		
ln Opex/Assets							-1.864***	
							(0.433)	
ln Trademarks/Assets								0.225
								(0.166)
Constant	1.575***	0.599+	1.573***	1.595***	1.518***	1.499***	3.860***	1.688***
	(0.148)	(0.352)	(0.170)	(0.159)	(0.143)	(0.146)	(0.533)	(0.176)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1772	1772	1772	1772	1772	1772	1772	1772
R2	0.337	0.347	0.337	0.337	0.348	0.342	0.363	0.340
Log-likelihood	-599.9	-586.6	-599.9	-599.5	-585.3	-593.7	-564.3	-596.7

Note Table 18: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (477 clusters).

APPENDIX E. ADDITIONAL EMPIRICAL ANALYSIS

Table 19: Market Value as a Function of R&D, Patents, Citations and Trade-marks, OLS, dependent variable: Tobin's Q

Variables (dependent variable: ln Tobin's Q)	M1	M2	M3	M4
	Grants/ Narrow citations	Grants/ Broad citations	Applications/ Narrow citations	Applications/ Broad citations
ln Assets - pre	-0.0918***	-0.0944***	-0.0915***	-0.0945***
	(0.0137)	(0.0139)	(0.0135)	(0.0135)
ln Assets - post	-0.0773***	-0.0775***	-0.0773***	-0.0790***
	(0.0138)	(0.0139)	(0.0135)	(0.0136)
ln R&D/Assets - pre	1.111**	1.139***	1.113**	1.136***
	(0.342)	(0.342)	(0.342)	(0.342)
ln R&D/Assets - post	1.379***	1.410***	1.387***	1.409***
	(0.313)	(0.313)	(0.316)	(0.315)
ln Patent portfolio/R&D - pre	0.315*	0.330*		
	(0.132)	(0.135)		
ln Patent portfolio/R&D - post	-0.0671	-0.0784		
	(0.133)	(0.140)		
ln Patent applications/R&D - pre			0.348*	0.381**
			(0.145)	(0.147)
ln Patent applications/R&D - post			-0.0844	-0.0517
			(0.155)	(0.165)
ln Citations/Grants - pre	0.0596+		0.0529	
	(0.0357)		(0.0372)	
ln Citations/Grants - post	0.0666*		0.0690*	
	(0.0304)		(0.0313)	
ln Citations/Applications - pre		0.0418		0.0326
		(0.0463)		(0.0466)
ln Citations/Applications - post		0.0779		0.0770
		(0.0560)		(0.0577)

ln Opex/Assets - pre	-1.991***	-2.045***	-1.994***	-2.051***
	(0.454)	(0.456)	(0.453)	(0.454)
ln Opex/Assets - post	-2.343***	-2.390***	-2.344***	-2.390***
	(0.453)	(0.456)	(0.453)	(0.455)
ln Trademarks/Assets - pre	0.466*	0.486**	0.466*	0.481**
	(0.181)	(0.181)	(0.181)	(0.181)
ln Trademarks/Assets - post	0.313+	0.319*	0.314+	0.312+
	(0.161)	(0.160)	(0.162)	(0.162)
Constant	3.049***	3.061***	3.049***	3.082***
	(0.537)	(0.546)	(0.533)	(0.541)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235
R2	0.390	0.386	0.390	0.387
Log-likelihood	-1133.1	-1142.9	-1132.9	-1142.3

Note Table 19: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors clustered at the company level (481 clusters). Covariate names with "-pre" specification indicates the interaction with pre-crisis dummy: the period 2005-2008. Covariate names with "-post" specification indicates the interaction with post-crisis dummy: the period 2009-2012.

Table 20: Descriptive Statistics, Pre-crisis and Post-crisis periods, t-test statistics

Variables	Pre-Crisis 2005-2008 Mean	Post-Crisis 2009-2012 Mean	Diff. in means	t-test	Ha: diff < 0 Pr(T < t)	Ha: diff != 0 Pr(|T| > |t|)	Ha: diff > 0 Pr(T > t)
Market value, mln EUR	12.754	13.203	448	0,4006	0,6556	0,6887	0,3444
Total Assets, mln EUR	10.977	13.074	2.097	1,6824	0,9537	0,0926	0,0463
R&D, mln EUR	229	462	232	7,2999	1,0000	0,0000	0,0000
R&D stock, mln EUR	887	1.585	698	6,0035	1,0000	0,0000	0,0000
Operating expenditure, mln EUR	5.003	5.552	550	0,9647	0,8326	0,3348	0,1674
Operating expenditure stock, mln EUR	22.577	28.559	5.982	2,1277	0,9833	0,0334	0,0167
Patent applications	102	83	-19	-1,9994	0,0228	0,0456	0,9772
Patent applications stock	506	484	-22	-0,4403	0,3299	0,6597	0,6701
Patent portfolio	439	353	-86	-2,3925	0,0084	0,0168	0,9916
Citations to applications	119	105	-14	-1,0189	0,1542	0,3083	0,8458
Citations to applications stock	593	597	4	0,0719	0,5287	0,9427	0,4713
Citations to grants	47	30	-17	-4,3633	0,0000	0,0000	1,0000
Citations to grants stock	280	242	-38	-1,5865	0,0564	0,1127	0,9436
Trademark applications	6	7	1	1,5623	0,9408	0,1183	0,0592
Trademark portfolio	59	79	20	3,7045	0,9999	0,0002	0,0001
Regression Variables	**Mean**	**Mean**					
TQ	1,703	1,575	-0,128	-2,1915	0,0142	0,0285	0,9858
R&D/Assets	0,144	0,276	0,132	13,3207	1,0000	0,0000	0,0000
Patent portfolio/R&D*1000	0,762	0,300	-0,462	-10,6156	0,0000	0,0000	1,0000
Patent applications/R&D*1000	0,865	0,408	-0,458	-10,4151	0,0000	0,0000	1,0000
Citations/Grants	1,252	1,349	0,098	0,8682	0,8073	0,3853	0,1927
Citations/Applications	1,404	1,313	-0,092	-1,7831	0,0373	0,0747	0,9627
Opex/Assets	2,570	2,945	0,374	5,1566	1,0000	0,0000	0,0000
Trademarks/Assets*1000	0,013	0,015	0,002	2,3630	0,9909	0,0182	0,0091
Observations	1.463	1.772					
Firms	445	477					

Note Table 20: t-test statistics of the variables reported in Table 2. Two-sample t test with equal variances; diff = mean(postcrisis) - mean(precrisis); Ho: diff = 0; degrees of freedom = 3233.

CONCLUSION

This PhD thesis is composed of two chapters which stand as independent pieces of research with distinct research questions, methodology and estimation datasets. They are however unified by the topic of Intellectual Property Economics. Both chapters also relate to the Intellectual Property Rights in Europe.

European System of Intellectual Property registry is highly complex. It involves multiple international players. Both patents and trademarks, which are the main two IP rights and the subject of analysis of this PhD thesis, can be registered at the national level or at the regional – European – level.

The first chapter of this thesis analyses what drives companies' decisions to choose either national patent protection route, or opt for legal patent protection offered by the EPO. From strategic point of view, the choice available in Europe poses not only a challenge but also an opportunity to benefit from such system. We seek to observe and analyze the factors influencing firm's strategic decisions to file their patents at the EPO, or nationally. In addition, we estimate whether these factors influence the number of states in which patents are held valid.

Empirical analysis suggests that firms react to fee changes of National Patent Offices, grant rates and examination durations when choosing where to file a patent application. The higher grant rate at EPO increases the applicants' propensity to file at EPO instead of National Offices. Conversely, the longer lasting patent examination at EPO, reduce the applicants inclination to file there. Also, the higher patenting fees and National Office proved to have effect on applicants, encouraging their propensity to file at EPO. Companies respond also to their rival's behavior. When their competitors have higher share of their patent portfolio protected via EPO, firms tend to mimic their behavior by filing more often at the EPO, and they validate the patents more broadly. Entrant firms are more likely to seek protection at the National Offices. These firms also have smaller patent families. Patent Citations are employed as a measure of the patent quality. We find that firms which patents are more cited at EPO or USPTO have higher likelihood to patent at the EPO. These firms also validate their granted patents in more jurisdictions.

The second chapter of this thesis analyses the market value of Intellectual Property and Intangible Assets in the context of recent Great Recession. We observe sub-set of the top R&D investing companies in the world and their ownership of European patents and trademarks as well as their investments in R&D. The aim of empirical analysis is to identify whether any meaningful differences emerge in the way that financial markets value the above mentioned IP rights and R&D investments prior to the Great Recession, over the period of 2005-2008, and in the period following the Recession, over 2009-2012. The main findings allow concluding that in the post-crisis period two factors emerge as significant market value enhancers. The first is the knowledge stock approximated by R&D investments. The second is the quality of innovation generated by R&D, approximated by the patent citations.

Overall, findings of the two chapters relate to different research questions. On the other hand, when presented together, our analysis directs to consideration for the joint future research opportunities. Firm’s Intellectual Property portfolios consist of several components, such as registered IP rights: patents trademarks and designs, as well as non-registered trade-secrets or copyright. This fact logically calls for a more in-depth research considering the interrelations between various IP rights.

It is well worth recognizing that companies patenting and branding strategies can be related to one other. Earlier work has largely ignored the relationships between different types of IP rights. As noted by Graham and Somaya (2006), the prevailing implicit assumption viewed the different types of intellectual property rights as substitutes rather than as complements. They also suggest that different types of IP rights may act as complements due to market-driven factors and economies of scope.

Especially in the context of market turmoil such as Great Recession, the relationship between IP rights and their strategies become even more acute for the companies. Hence the future research could analyze the patenting strategies alongside with the branding strategies among the influencing factors. Also, future work could analyze the effect of Recession on firm’s propensity to protect their IP rights at National Offices or at the European level.