THE MARKET VALUE OF TECHNOLOGICAL INNOVATION; EVIDENCE FROM EUROPEAN PATENTS

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January, 2015

ABSTRACT

This paper contributes to literature by giving more precise measures to technological innovation in order to estimate its economic value and assess its impact on the financial performance of companies in Europe. Focus is given to European patent system which is different from the American one. Financial and innovation data are collected during 1990-2012, for 599 companies belonging to 15 industries. According to market value approach, the relationship between market-to-book ratio and knowledge assets is proved to be positive and significant. Innovation is more valuable when it contributes to wider knowledge transfer, has larger geographical and technological scopes and radical character.

INTRODUCTION:

Innovation is considered as a key factor of economic development and one of the main engines of growth. The importance of its role has been emphasized in a complex context of successive technological revolutions and an unprecedented market liberalization that led to high competition between firms in all industries. It has become a strategic tool in the acquisition of a competitive advantage on the long run, for both large and small firms, M. Porter (1990). However, innovation is known as «full of uncertainties and with a high probability of failure», Holmstrom (1989). Its main characteristics are *riskiness* and the *uncertaint*y of its profitability as a *heavy investment*. In its early stage, investors are uncertain about the right value of the project, and whether the funds they raise will be totally employed in the perspective of fulfilling the innovation. Outsiders are faced to complicated and ambiguous mechanism divulgated only by insiders, especially the qualified ones (engineers, managers…), who are perfectly informed about the technical and financial requirements of the investment. Hall and Lerner (2009) explained that uncertainty is due partially to the temporal lag between investments in R&D activities, i.e. the innovation's input, and the obtaining of final output. As much as the lag is long, it is quite hard for investors to assess the failure or success's probability of such investment and to calculate reliable expected returns in information scarcity.

In addition to its high risk implication, one of the main issues related to innovation, in general, and technological one in specific, is the difficulty of its valuation. The ratio of knowledge assets to total assets continues to grow sharply and contributes to enhance the difference between market value and book value of listed companies. This phenomenon mirrors the importance of knowledge stocks in financial markets and their crucial role in assessing firms' values. Nevertheless, an obvious lack of precise measurement method of innovation is still observed in literature and practical context. The probability of measurement error is emphasized in Europe where accountancy standards are very specific for R&D expenses. Unlike American regulation where it is compulsory to disclose information about R&D expenses, European companies do not have the same obligation and have the choice to hide this information probably for strategic motivations, (Gambardella, 2014). The absence of common disclosure rule is the first source of difficulty in the assessment of knowledge assets in Europe. Looking at the output of innovation process, patents have been for long considered as the best proxy of company's capability to transform and combine R&D efforts into valuable and concrete output on markets. At this level of innovation process, the assessment of knowledge stock is still problematic for investors. Though the availability of patent data and its simple use, patents have been criticized for being a "noisy" measure of innovation, Griliches (1981). The sharp increase in patent applications in the United States Patents Trademark Office (USPTO) has contributed to the weakness of patents as instrument of innovation. Lower barriers to obtain a monopoly position for the use of one's invention were behind the deterioration of patents quality in the US but also in other jurisdictions. Patents grants are, consequently, not considered as efficient measure of the innovation quality. Besides, companies are faced to an important tradeoff between revealing the secrecy of their inventions when applying for patents and keeping the privacy of the information for insiders by renouncing to it. Though it guarantees the exclusive right of benefitting from the invention, patents carry the risk of litigation and imitations. This made firms often reluctant to apply for legal protection even for the most relevant inventions. In this context, it is more difficult for investors to make the difference between knowledge outputs with high economic value; the assessment on the basis of this proxy is still fuzzy. Consequently, it has been proved that limiting innovation to simple patent count is a biased measure since it does not mirror the right value of inventions.

The purpose of this paper is to find better measurement of the private value of innovation inside European companies. I make use of patents' attributes in order to assess the economic value of inventions and study its impact on financial performance. Forward citations (when patent A is cited by other applicants as prior art, see Variables Definition section) are the most commonly used quality measure in literature, Hall and al. (2007), as it is supposed that the most a patent is cited by other documents (patents, scientific papers…), the higher is its economic and technical value. Recent studies used complementary proxies of patents quality, such as the family size and the number of claims (all attributes are defined subsequently in specific sections). The novelty of this research is to gather, a complete set of qualitative measures provided by OECD patents database, July 2013. I resort to market value approach in order to valuate private value of innovation and verify the existence of its positive effect on financial performance. Literature refers to a second valuation method in addition to market value approach; innovation may be assessed through total factor productivity, (Mansfield 1968). Differences between both methodologies will be explained in subsequent sections. The use of market value approach implies the restriction on listed companies. I do focus my research on European context but keep a large range of industries, unlike most of previous studies. The relation between financial performance and technological innovation was has been specific to sectors; Hal and al.(2007) took the case of software sector, (Klock (1997), and Lung Ling (2006) of semi-conductors, Chemmanur (2001) pharmaceutical). The current paper takes technological innovation in its large sense; all companies with potential R&D activity are considered as innovative.

I obtain a sample of 599 firms belonging to 15 different industries and 18 European countries, and a total number of 78384 patents applied in the European Patent Office, EPO[1] between 1990 and 2012. Empirical investigation is based on unbalanced panel data. I find that R&D expenses to assets ratio is significantly related to financial performance of companies. Its impact on market to book ratio exceeds considerably all measures of innovation's output, i.e. patents and its qualitative attributes. Only patents to assets are considered as good proxy of innovation intensity while its productivity (patents to R&D) does not provide significant informational signal for investors. Qualitative measures based on forward/backward citations, technical and geographical scopes are proved correlated with market-to-book ratio, but still have a marginal impact compared to R&D to assets. Findings highlight the cumulative aspect of knowledge assets in European context since ratios of total attributes to assets have higher and more significant predictive power than average attributes per year. Another important finding is the importance of qualitative indexes provided by the latest work of OECD on patents, (July 2013). Results prove that comparing the value of patents with their equivalents via quality indicators is more significant for investors in assessing knowledge assets. Finally, I use claims attribute as instrumental variable for patents ratio in order to eliminate potential endogeneity problems caused by omitted variables or measurement error. The remainder of

[1] The European Patent Office offers inventors a uniform application procedure which enables them to seek patent protection in up to 40 European countries. Supervised by the Administrative Council, the Office is the executive arm of the European Patent Organisation, (http://www.epo.org/about-us/office.html).

the paper is organized as follow; the first section is devoted to literature review and hypothesis, followed by description of variables, data and summary statistics. A description of main results and instrumental variables regression are presented in the last section.

A- Hypotheses:

The goal of this research is to verify whether technological innovation does impact financial performance of companies, measured by the market-to-book ratio. One of the novelties of this paper is to come up with a complete set of qualitative proxies that would allow for better measurement of technological intensity. As it was mentioned in introduction, the main peculiarity is the interest given to European patent seen its specificities with regard to American equivalent. In this section, I present the expected results on the conclusion of my empirical investigation, in view of the European context and observation period.

Hypothesis 1: Technological innovation has a positive impact on financial performance. This effect is particularly significant when patents, main proxy of innovation, are granted by EPO. In view of important differences between European and American patents and seeing that most of previous works did focus on patents that stem from USPTO, I expect to find positive and significant relation between all innovation's measures throughout its process (input, output and qualitative measures).

Patenting process in EPO is considered to be more "rigorous" and with higher barriers for inventors before final grant, especially in terms of cost and the relevance of prior art. First, patenting fees in EPO depend on the geographic scope of the protection (i.e. the number of European countries where applicants would protect their invention). In a first step, inventors shall apply for patents in local jurisdictions before obtaining the European Patent Litigation Agreement. These fees may increase because of translation costs… Firms are, thus, faced to more important financial constraint with respect to USPTO which urges them to resort to European instance only when inventions are worthy a wider protection. Nonetheless, Hall et al. (2007) explain that EPO compensates higher costs in application stage by rigorous litigation system after grant date. Actually, applying in the EPO reduces later fees in case of litigations compared to USPTO because of strong protection rules in the geographical scope guaranteed by the European Patent Litigation Agreement (EPLA). A common "court" for European countries centralizes difference in grant lag strengthens the hypothesis that

European patents are more protected from plausible litigations. In most patent offices, applications are published within 18 months from priority date whilst in USPTO and until 2000, patents are not published until the grant date. The latter case is in favor of possible litigation during the grant lag especially that it may take up to 5 years. Litigations costs would be higher, in USPTO, since it is more difficult to distinguish the origin of the invention i.e., the first applicant for the same innovation. They last longer and contribute to the diminishment of patents economic value. It is important to state divergences in opposition procedure; it is possible that other opponents resort to the EPO in order to argument the grant of a given patent. Both parties; patent holder and opponent have the right to defend their position in front of the examiner who will decide on the basis of given arguments to whom grant the patent. While in the UPSTO, there is only a reexamination stage which differs from opposition procedure. Any other party can take the opponent position meanwhile only applicant can have the possibility to defend its arguments in front of examiner from the USPTO. Opposition procedure is, thus, another argument in favor of a rigorous European patent system; applicants must be able to present better arguments to defend their knowledge assets in front of other potential competitors.

Supposing that European patents would have greater impact on the financial performance of companies stems from another significant difference between EPO and USPTO dealing with prior art. Applicants in USPTO have the obligation of listing in exhaustive manner all previous inventions that were more or less relevant to the patent while in the EPO applicants may cite only the most relevant documents to their inventions. The importance of this difference would interfere when assessing the quality of patents; a cited patent that has been granted by the EPO was particularly relevant to ulterior inventions while forward citations are not good proxy for patents quality in the American context. Besides, examiners in EPO are in charge of verifying the consistency of prior art and add, if it is necessary, citations that seem relevant for the invention. Consequently, part of the prior art are given by exogenous and objective parties which confers more credibility to citations relevance compared to USPTO context.

The main work that investigated the value of European patents goes back to Torrisi et al. (2007); authors made comparison between values of patents granted in the European Patent Office (EPO) and the UPSTO. They found that only patents filed in both jurisdictions are significantly related to Tobin's Q of companies. The quality of technological innovation was measured by a combination of forward citations, family size and the number of technical fields related to patents. However, these findings are based on common methodology of computing patents stocks and citations stocks which is not the case in the current paper.

Previous studies, centered mainly around on American and Japanese contexts, did not lead to unanimous findings when measuring the relation between financial performance and different proxies of innovation. Jaffe (1986) found that R&D expenses have weak and insignificant impact on financial performance while Bronwyn (1999) proved that investing in R&D activity is significantly valued by financial markets. When looking at specificities of European patents, Hall et al. (2007) found that R&D expenses are the most valuable measure of technological innovation by financial markets. None of the qualitative measures did surpass the explanatory power of innovation's input; authors speak about "horse race" phenomenon between patents, citations and R&D which are definitely the "winner".
Under the implicit hypothesis of market efficiency, I expect that market-to-book ratio would react positively to the various aspects of technological innovation especially given the characteristics of European patents, mentioned previously. The constant character of R&D expenses inside companies, unless a merger or acquisition event, can be a plausible explanation to a potential significant impact on financial performance. Seeing that I measure market value of companies at the filing date, the predictive power of future citations and all attributes acquired later can be weaker. The latter expectation is due to the necessity of distinguishing the future value of patents since the application year which is quite related to the degree of information asymmetry in the market between insiders and outsiders.

Hypothesis 2: Market-to-book ratio is particularly sensitive to qualitative measures of technological innovation such as patent scope, family size, the number of claims… Patents attributes provide richer information about the economic value of innovations. Their complementarity with classic proxies allows better measurement of performance ratio to innovation event.

Since most of attributes mirror the importance of patents from a technological, geographical and economic point of view, the impact of these variables is expected to be positive on the financial performance measured by market-to-book ratio. Detailed description of qualitative measures is presented in the next section devoted to variables description.

Several attributes rely on basic characteristics of patents mainly forward and backward citations and technological classes. Some of qualitative measures are, consequently, correlated because of their complementarity but not substitutable as they inform about different aspects of patents value. Qualitative indicators given by the latest OECD patents database, (July 2013), can be divided into two groups; the first set of measures provide information about each patent without comparing it to similar patents. For example, forward citations within 5 years do inform partially about the importance of patent A as a prior art but do not mirror whether the number of citations received is enough to speak about real knowledge spillover. The second one is a combination of three indicators; originality, generality and radicalness and allows better comparison of the value of each patent with its equivalents on the market. Further explanations are given in the next section (variable definitions) about the construction and the meaning of each indicator. Given the complete information they provide and the importance of establishing comparison between patents in order to assess their economic values, I expect that qualitative indicators have a positive and more significant effect on the market-to-book ratio compared to simple measures such as simple citations or claims count. Economic value of innovation becomes more precise when it takes into account the existence of similar knowledge assets.

Hypothesis 3: Technological innovation has stronger impact on financial performance in large European countries where R&D to GDP ratio is relatively considerable. The predictive power of innovation is also stronger in industries with low innovative intensity as I suppose that radical innovation stems mainly from such sectors.

I expect that countries like France, Germany and UK where technological intensity is quite strong compared to smaller economies inside the European Union would value more the R&D efforts inside companies. Financial markets are more sensitive to such strategies because of high competition and the importance of acquiring competitive advantage thanks to innovation. Besides, and seeing that the current research does not focus on specific industry, it is expected that in some sectors financial performance is more related to innovation. Previous studies have often focused on fields with high intensity of technological activities such as semi-conductors, biotechnology, software or pharmaceutical sector… The use of patent applications is more frequent and does not necessarily mirror the existence of radical innovation. The reaction to such strategies is, thus, less important because of the absence of real competitive advantage or value creation behind the frequent patent applications. Empirically speaking, it is expected that the impact of innovation's measures in these fields is not considerably significant. On the contrary, sectors with less frequent patenting activity may be at the root of innovation with higher economic value and consequently with strong and significant impact on the financial performance of companies. Control variables are used in order to detect country effect, the size of companies and industry effect.

B- Variable definitions:

The assessment of the technological intensity inside firms is one of the most challenging issues discussed in the literature of innovation and management. The classic measure relies on the duality between input and output of the innovative process, (Griliches 1986). Investing in Research and Development activities is considered to be as the first step necessary to the fulfillment of technological innovation, while the number of patent grants could be more informative about the success, (or failure) of this strategy. Earlier literature supposes that obtaining a legal protection to one's invention (or innovation) is a strong signal about firms' capability to transform the research effort into a valuable output. Despite the complementarily between the two variables, looking at the number of patents obtained by firms was proved to be a "noisy" proxy of technological innovation. Since the beginning of the 1990's, patent applications have increased dramatically in the United States Patent and Trademark Office (USPTO); they rose from nearly 60 000 applications in the mid-1980s to 120 000 applications in 1995, (Kortum and Lerner, 1998). The deep changes in management practices by enhancing the «applied activities of innovation», (Kortum and Lerner, 1998), and probably the easing of patent application procedure in the US are at the root of this important boost. However, the quantitative aspect was to the detriment of patent quality, especially in the USPTO, where only fewer patents have, henceforth, high economic value. In this context, previous papers showed that the distribution of patent count is highly skewed, (Harhoff et al. 1999), corroborating the existence of heterogeneity problem in simple patent count, as a measure of innovation. Settling for the number of patents obtained is quite silent about the purpose of seeking a legal protection; is it to keep the exclusive right of use or just a strategic decision to counter competitors? What kind of innovation does the patent protect; radical or incremental one[2]? Does patent count display the innovative capacity of firms, especially that some inventions do not meet the patentability conditions?

Despite the obvious biases created by the use of patent count, these documents remain one of the most powerful and concrete variables able to assess technological intensity inside firms. Therefore, it is more interesting to figure out significant information from patents' attributes and characteristics in order to define the economic value of technological innovation.

One of the novelties of this paper is to try to give a better measure to innovation in European countries. Unlike most of the previous literature in which researchers do focus on the American context, I follow Hall and al. (2007) methodology in exploring European patents which are considerably different, with a deeper look at its various attributes. As yet, the quality of patents has been assessed mainly and almost exclusively through forward citations in literature, Hall and al. (2005). In order to ameliorate the measure of patent quality, I resort to a larger set of attributes, detailed in this section. With the use these qualitative variables, I assume that the technological process is not achieved by obtaining a legal protection to one's inventions but is extended to the ex-post plausible valuations of patents.

The rich and informative content of patents documents could eliminate problems of heterogeneity caused by simple patent count, they mainly revolve around:

- The rights conferred by the patents
- The geographical scope of patent protection
- The technological fields to which is related the patent
- The possible renewals of the patent rights
- The importance of the patent to other inventors

[2] Radical Innovation: occurs when the invention is considerably different from existing ones. The value of the innovation is high and allows a long run competitive advantage.
Incremental Innovation: where added value is not significant, the invention is built around a combination of existing knowledge.

I- Patent Quality Measures:

- *Forward Citations*:

Like in the majority of scientific documents, applicants have to mention previous works that were useful to the fulfillment of their invention, which is quite similar to the «literature review» in scientific papers. The list of previous inventions constitutes the « prior art» of a patent and is part of its specifications. When a patent is cited, later, by other inventors, it mirrors its technological and economic importance. The more a patent receives citations after its publication date, the more it is considered as relevant and contributes to the knowledge spillover across firms but also within sectors, (Haffe and al.1993). Besides, the qualitative information given by citations mitigates the heterogeneity problem caused by the use of simple patent count, (Trajtenberg and al. 1990).

However, the use of cites as a quality indicator for European patents is obviously different from the American context. Applicants have an exhaustiveness obligation in the USPTO when writing the prior art; they have to mention all the previous documents technically related to their work. While *examiners*, in the EPO, should select *only the most relevant* patent and non-patent literature in the Search Report, (Harhoff and al. 2006). «According to EPO philosophy a good search report contains all relevant information within a minimum number of citations», (Michel and Bettels, 2001). Though cites number could be much higher in American patents, I suppose that European citations are better quality indicator; a patent is cited only if it is particularly relevant to other inventions. There is obviously a tradeoff between exhaustive information and better quality signal when selecting data about American or European patents. However, the qualitative role of citations is in support of the European documents where there are higher barriers to be cited. Besides, Hall and al. (2005) highlight the role of examiners in controlling for citations and consider that they are more objective than applicants, making European citation process more consistent again.

OECD citation database (July 2013), is constructed on the basis of EPO patents and take into account:

- Patent Equivalents: documents protecting the same invention in other patent offices, (Harhoff et al. 2003) resort to patent equivalents in order to make comparable

European and American citations; the lag in citations number is mitigated thanks to the equivalents.

- Self-citations: when a company cites its previous inventions, it mirrors the continuity in its innovation process and its capability to create internal knowledge spillover.

On the basis of the OECD patents database, I look at the citations count within 5 years after the publication date. Seeing that the majority of firms can file more than one patent during one year, I use the total number of cites received for all the patents filed in year *t*, by the same company. Let $C_{(i,t)}$ be « the number of citations received by patent application *i* published in year *Pi* within *T* years, $C_{(i,t)} = \sum_{t=Pi}^{Pi+T} \sum C_{j,i}$; $T \leq 5$ years, where $C_{i,j}$ is a dummy variable that takes the value 1 if the patent j cites i and 0 otherwise, (OECD, Citations Database July 2013). Cites indicator given by the OECD takes into account the self-citation, i.e. all the citations made by a firm to its previous patents.

$C_{(t)} = \sum C_{(i,t)}$, is the total number of cites received by patents applied at year *t* by the same company.

- *Backward Citations:*

Also called prior art is the set of knowledge on which is based the invention. It includes previous patents documents as well as all kinds of scientific investigations considered as non patent literature by examiners. Applicants in the EPO should mention the most relevant elements that were useful to the construction of the invention; the list is then checked by examiners who classify backward citations according to the degree of their relevance. This attribute is fundamental in the assessment of the economic value of patents. Besides, it is the used in the construction of more complex qualitative indexes such as radicalness, which measures the novelty of each invention protected by patent system. Prior art is also a good proxy of the knowledge transfer between companies, or within the same firm if it contains self-citations, but also cross sectors. The relation between backward cites and patent value is, thus, still fuzzy; some consider that a wider transfer knowledge is behind a higher quality of the invention, (Harhoff et al., 2003), whereas (Lanjouw and Schankerman, 2001) prove that more backward citations mirror the incremental nature of the invention. The negative impact of prior art in the second case is explained by the importance of radical innovation in the value creation inside companies; when patents reflect the simple recombination of existing knowledge, it is supposed that there is no significant value creation by innovation. It is important to highlight one of the main differences between the current study and the literature which is built according to the American context. Divergences in patenting procedure between the EPO and USPTO may be at the root of significant contradictory results. The predominant character of relevancy in EPO versus exhaustivity in US can make backward citations positively related to patents value.

- *Family Size:*

In the European Patent Office (EPO), and according to the Paris Convention for the Protection of Industrial Property[3], inventors have the right to file other applications in other jurisdictions related to the same patent, during the next 12 months from the first application date. The family size is, thus, presented by « the number of the patent offices in which an invention has been protected», (*OECD Science, Technology and Industry Working Papers,* 2013*)*. The attribute of family size shows the geographical scope of inventions (or innovations).

To be coherent with the previous literature (Harhoff et al.,2003), I suppose that companies are more likely to pay higher fees to protect valuable inventions in more than one jurisdiction.

- *Claims:*

This variable enumerates the boundary of property rights in the patent, (Lanjouw and Schankerman, 2002). All patents must contain at least one claim in which applicants have to «define the matter for which protection is sought», EPO, Article 84. A high claims number implies higher fees to obtain a legal protection, (OECD 2009) as the structure of patents is defined through claims. The breadth of property rights is significantly correlated to patents market value, (Tong and Davidson), but also to later litigations, (Lanjouw and Schankerman, 2001a).

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[3] The convention was signed on 20 March 1883, in Paris in order to guarantee to inventors the right of application in the contracting states. « Under the provisions on **national treatment**, the Convention provides that, as regards the protection of industrial property, each Contracting State must grant the **same** protection to nationals of other Contracting States that it grants to its own nationals. Nationals of non-Contracting States are also entitled to national treatment under the Convention if they are domiciled or have a real and effective industrial or commercial establishment in a Contracting State. », *World Intellectual Property Organization*.

- *Patent Scope:*

They mirror the technological value of patents. An invention could have higher economic value if it is related simultaneously to diverse technological sectors. The usefulness of an invention in more than one area is an indicator of the sectorial interdependence and the knowledge transfer across fields. In the OECD database, researchers follow Lerner (1994) methodology in defining the scope index. They look at the number of 4-Digit subclasses given by the International Patent Classification[4] (IPC) of the invention.

$Scope_p = n_p$; $n \in \{IPC_1^4, \ldots, IPC_i^4, IPC_j^4, IPC_n^4\}$; where $IPC_i^4 \neq IPC_j^4$ and n_p is the number of distinct 4-Digit subclasses listed in the patent p, (*OECD Science, Technology and Industry Working Papers,* 2013).

- *Renewals:*

«The OECD patent renewal indicator corresponds to the simple count of years during which a granted patent has been kept alive, i.e. the latest year in which it has been renewed or until it has lapsed or has been withdrawn. Years are counted starting from the year in which a patent has been applied. », (*OECD Science, Technology and Industry Working Papers,* 2013). (Pakes and Schankerman, 1984) put the emphasis on the role of renewals as determinant of patent private value and prove that patent applicants make higher profits through optimizing renewal decisions. Companies are ready to pay renewal fees as long as patents have economic and technological value in the market. The most valuable patents would have higher number of renewals and last longer despite the appearance of new inventions. Therefore, I expect positive correlation between renewal attribute and the quality of patents, significantly evaluated by financial markets.

- *Radicalness Indexes:*

One of the novelties of the OECD patents database is the construction of complex indexes including one or more of the previous qualitative measures of technological innovation. Radicalness index is organized on the basis of IPC technology classes that a

[4] The International Patent Classification (IPC), established by the Strasbourg Agreement 1971, provides for a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain.

patent is related to through citations. The first intuition to the construction of such qualitative measure follows Shane (2001) definition « radicalness of a patent is measured as a time invariant count of the number of IPC technology classes in which the patents cited by the given patent are, but in which the patent itself is not classified». The idea is to explore the breadth of technological sectors covered by the patent, but to which the patent itself does not belong. Let us consider a patent A, radicalness index is computed on the basis of its prior art, precisely the technological classes of backward citations.

Radicalness index (A) = $\sum \frac{CTj}{np}$; IPCj ≠ IPC(A), where CTj denotes the IPC classes of the backward citations to which patent A does not belong, n is the total number of technology classes. The use of this indicator is meant to mirror the radical nature of the invention regarding its prior art from other classes, but does disclose information about the novelty of inventions among more recent patents belonging to the same class. Higher radicalness score also show the knowledge transfer across IPC classes and is expected to be positively correlated with patents economic and technological value.

- *Generality Index:*

This indicator is calculated on the basis of forward citations and is used to assess the range of later inventions that have benefitted from it. The wider the range of IPC classes belonging to citing patents, the more important is the economic and technological value of the patent. Citations used in all indexes are made behalf on EPO patents, the OECD allows for better comparison with previous literature by including the equivalents and all categories of citations made within 5 years. Let us consider a focal patent A and Y_i are patents citing A, where i=1,…, N (with N is the total number of its forward citations).

βij is the ratio defined as follow: βij=$\frac{Tij(n)}{Ti(n)}$

« Ti(n) is the total number of IPC *n*-digit classes in *Yi*

Tij(n) is the total number of of IPC *n*-digit classes in the *jth* IPC4 digit class in *yi* and

j=1… Mi is the cardinal of all IPC4-digit classes in *yi* », (OECD Technology and Industry working papers 2012/2013).

Generality Index= 1- $\sum_{j=1}^{M}(\frac{1}{N}\sum_{i=1}^{N}\beta ij)^2$

- *Originality index:*

The originality of patents is defined as the breadth of technology classes on which relies the invention, (Squicciarini and al., 2013). Since it is based on backward citations, originality index mirrors the knowledge transfer across sectors. The technique of constructing originality index is quite similar to generality index; the main difference is the use of respectively, backward and forward citations. Patents Database, (July 2013), follows the methodology first suggested by Trajtenberg et al.(1997) and improved by Hall et al. (2001 b):

Originality Index = $1 - \sum_{k}^{np} spj^{\ 2}$

Where: “spj is the percentage of citations made by patent p to patent class j out of the np IPC 4-digit (or 7- digit) patent codes contained in the patents cited by patent p. Citation measures are built on EPO patents and account for patent equivalents”, Squicciarini and al., (2013).

Patents Economic Value and the Various Attributes in Literature:

Patent Characteristic	**Relationship with Patent Value**
Forward Citations	Positive relationship; the more a patent is cited, the more it is relevant technologically and economically, (Harhoff et al., 2003).
Backward Citations	Divergent findings: - Positive relationship, (Harhoff et al., 2003) - Negative relationship: large number of backward citations is a signal that the protected invention is incremental and not radical, the economic value of radical innovation is more important, (Lanjouw and Schankerman, 2001).
Family Size	The family size has been proved to be valuable, (Harhoff et al., 2003). The larger is the family size, the more relevant the patent is. Applicants should protect their valuable inventions in larger geographical.
Claims	The higher the number of claims, the higher is the value of patents, (Lanjouw and Schankerman, 2001).
Patent Scope	Positive Correlation, (Lerner 1994).
Renewals	Applicants renew the protection right to valuable patents. This supposes that there is a positive relationship between economic value of patents and their renewals, (Pakes, 1986).

II- Innovation’s Input and Output:

1- Research and Development Expenses:

I follow the classic reasoning by considering the technological process and defining the research and development *expenses* as the main proxy of its input. However, the lack of available data about the R&D activity inside firms was behind the use of R&D *stocks* in previous literature. The indicator is calculated on the basis of a declining balance formula and the history of R&D data, supposing that:

- The *R&D stock* of the year *t*; (KRDt) is decreasing annually according to *α*, a depreciation rate (generally fixed at 15% in the literature) such that:

  KRDt = R&Dt + (1- α) KRDt-1

- *R&D expenses* grow constantly and annually at a fixed rate *g*, (*g* is often fixed at 8% in the literature), such as: ***KRDo = RDo/ (α +g)***; where RD_O is the R&D expenses of the first observation available in the data.

In order to avoid plausible biases generated by the use of the depreciation and growth rates, I settle for the real R&D expenses available in the Database, i.e. the amounts of R&D communicated by firms. The choice of the rates’ values (8% and 15%) could be subject to some critics mainly because of heterogeneity between firms (size, sector, competitive position…). Besides, keeping the raw R&D expenses, despite the lack of information for several years, could reveal plausible strategic decisions behind communicating, or not, the R&D expenses. In European context, where there is no obligation to disclose information about the R&D budget, abstention may be explained by strategic motives; firms are more likely to disclose information only when their competitors reveal identical information. I try to detect the existence of strategic decisions by introducing a dummy variable that takes one if the information is available at year t, and zero otherwise.

2- Patent Count:

In order to be able to use the multiple patents attributes, I consider the patent count as one of the main proxies of technological innovation inside firms. I expect that the «noisy» character of this variable, noticed in previous literature, would considerably be mitigated thanks to the use of various quality indicators and the exclusive resort to patents applied in the

EPO. Unlike the USPTO where patent applications are more abundant, and where patenting rules are relatively easier, companies have higher financial and technical barriers to apply for a European patent. The scope of legal protection is wider through European patent (PCT), but implies higher fees than ordinary patents, applied in local jurisdiction or in the USPTO. The financial constraint is, thus, a considerable barrier to firms and contributes to the improvement of European patents quality compared to American documents.

III- Dependent Variable :

According to the market value approach, financial performance is measured by the ratio of market to book value; the next session provides further details about this approach. It is important to mention that in previous papers, the main dependent variable used for the same methodology was the Tobin’s Q. By definition, Tobin’s Q ratio is the market value of a firm divided by the replacement cost of its assets. However, recent study has proved that Tobin’s Q ratio is not a good measure for the financial performance because of endogeneity issues, (Dybvig and Warachka, 2010). Authors show that investment decisions have an ambiguous effect on the Tobin’s Q ratio, depending on the scale decisions and cost discipline. They take the example of underinvestment which would decrease the firm performance but increase simultaneously the ratio of Tobin’s Q. Besides, Adam and Goyal, (2000) show that market to book ratio is the most informative proxy of the firm’s investment opportunity. Seeing the importance of assessing financial performance respecting the market value approach, I keep using the market to book ratio for its higher significance and its easier interpretation.

C- Estimating the Economic Value of Technological Innovation:

Assessing the economic value of innovation inside firms could be achieved through two alternatives; using the Total Factor Productivity (TFP) formula, (Mansfield 1968), or looking at the market value of firms as a set of tangible and intangible assets, (Griliches 1984). I rely on the second methodology in this paper for several reasons;

- Inputs to Factor productivity are restricted to labor (L) and capital (K), according to the general equation, taking Cobb-Douglas form: $\mathbf{S=TFP \times K^{\alpha} \times L^{\beta}}$, where S is the matrix of innovation measures (mainly the flow of R&D expenses and simple patents count) and α and β the capital input share of contribution for K and L respectively.

- TFP valuation is constrained by the use of innovation's input (R&D) and output (simple patent count), exclusively, regardless patent quality indicators which are one the main novelties in my research.

- The strong hypothesis of constant returns to scale and competition in the markets for inputs and outputs, (Hall et al. 2007), is inappropriate seeing the significant contribution of R&D expenses to the increase in TFP, (Gold 1977).
- The considerable lag between innovation input and output makes more difficult the observation of its direct effect on TFP.
- The main goal of this study is to figure out the importance of the innovative activity inside firms as an informational signal in the financial markets. However, TFP methodology relies basically on accounting data, unable to show the real assessment of intangible assets by investors.

In this paper, I use the market value approach to assess the economic value of technological innovation. The methodology relies on the fundamental hypothesis of markets efficiency and considers companies as «bundles» of varied assets, most importantly tangible and knowledge assets. Under complementary hypothesis of «value-maximizing dynamic program» and single returns to scale, this approach allows to express market value as a multiple of book value, through market to book ratio or Tobin's Q indicator. However, the main interest behind the use of this methodology is to measure the «marginal value of an additional dollar of investment in a giver type of investment», (Hall, 1999). It is, therefore, possible to assess the increment in market value when investing in R&D expenditures and patents portfolios. One important question in modeling market value as function of the various assets that a company comprises is whether these assets are additively separable or shall take a multiplicative form. The first assumption implies that the market value of firms simply equals the sum of each asset's value; in other terms it is possible to valuate ceteris paribus, each asset independently from other constituents. Given the interest in innovation assets and according to the additive formula, the market value (V) of companies can be expressed as following: $\mathbf{V = q_t (A + \alpha_t K)}$ (1), **(**Griliches, 1984), where;

- (A) presents the conventional assets
- (K) the knowledge assets
- q_t presents the «current market valuation coefficient of the firm's assets, reflecting its differential risk and monopoly position»[5], (Griliches 1984).
- α_t is the marginal value of the ratio knowledge assets to physical assets. It measures the investors' expectations over the percentage of intangible assets on the discounted future profits of the firm.

Knowledge assets were first measured by R&D and patents stocks, (Griliches, 1984) and amended, later, by introducing forward citations as qualitative measure of inventions, (Hall et al. 2005). To ease interpretations of the estimates and reduce the problems of highly skewed distribution, especially relative to patents count, I introduce logarithm to the equation. The final model is specified below:

$$\text{Log}V_{it} = \text{Log}(q_t) + \log(A_{it} + \alpha_t K_{it}) + u_{it}; \ (\sigma t = 1)$$

$$\text{Log}V_{it} = \text{Log}(q_t) + \log A_{it} + \log(1 + \frac{Kit}{Ait}) + u_{it}$$

$$\text{Log}(\frac{Vit}{Ait}) = \log(q_t) + \log(1 + \frac{Kit}{Ait}) + u_{it}$$

Knowledge capital was replaced by R&D stock, patent stock and citations stock as follow:

$$\text{Log}(\frac{Vit}{Ait}) = \log(q_t) + \log(1 + \frac{R\&D\ (it)}{Ait} + \frac{Patents\ (it)}{R\&D(it)} + \frac{citations\ (it)}{Patents\ (it)}) + u_{it}$$

In this paper, I try to give a more synthetic measure to knowledge assets through patents attributes; I suppose that technological process is valuated thanks to the various operations to which patents are subject after their publication date (citations , renewals) and on the basis of their main characteristics (claims, family size…). K is, thus, replaced by all measures mentioned in the variables definition section.

[5] «$q_{it} = exp(mi + dt + U_{it})$, where *mi* is the permanent firm effect, *dt* is the overall market effect at time *t*, and U_{it} is an individual annual disturbance or error term assumed to be distributed independently across firms and time periods», (Griliches ,1984).

$$\textbf{Log}\left(\frac{Vit}{Ait}\right) = \textbf{log}(\textbf{q}_t) + \textbf{log}(1+ \alpha_t \textbf{X}_{it}) + \textbf{S}_{it} + u_{it} \quad (2)$$

Where S_{it} is a set of controls, and X_{it} comprises all the measures of Innovation. I use OLS regressions in order to estimate the coefficients of the non-linear model.

The additive functional form of companies' market value provides estimates of the marginal shadow value of knowledge assets (α_t) and assumes that these parameters are constant across firms. With the additive assumption of markets equilibrium, i.e. $q_t = 1$, (Connolly and al. 1986) drew another derivative from equation (1). They showed that the excess of market value with regards to the book value can be function of knowledge assets, according to the following equation:

$$Vit(K) - Ait = \alpha_t K_{it} \quad (3)$$

On the basis of the strong hypothesis of equilibrium, equation (3) show allows a direct measurement of the marginal value of knowledge investment on the lag between market value and book value. The simpler linear model assesses the contribution of technological innovation to the incremental value on marketplaces with reference to their book values.

The second possible formulation of the market value as bundle of various assets is the multiplicative model, based on a Cobb-Douglas form, (Hall, 1999).

$$\mathbf{V_{it}\ (A, K) = q_t\ A_{it}^{\ \sigma t\ -\alpha t}\ K_{it}^{\ \alpha t}}$$

Introducing algorithms and taking into account the constant returns, the equation is the following:

$$LogV_{it} = Log(q_t) + logAit + \alpha_t \left(log\frac{Kit}{Ait}\right) + u_{it} \quad (4)$$

The main difference between the two approaches is that the Cobb-Douglas form allows a measurement of the elasticity of market value ratio to the total knowledge assets. The estimate α_t precedes the ratio of intangible assets to common assets.

DATA:

The starting point in the setting up of my sample was collecting data relative to patents and their attributes. One of the particularities of my study is my interest in the European patent which is significantly different from its American equivalent. In parallel with USPTO database which is limited to American inventions, EPO's Worldwide Patent Statistical, also called PATSTAT, gathers all data about patents filed in the European Patent Office, but also in other jurisdictions. In order to make this database more accessible and provide qualitative measures of patents, the OECD has developed a derivative directory that is updated regularly. I use the latest version of OECD Patents Database (July 2013), which assembles citations database, HAN database[6], REGPAT database[7], and as a *novelty* the «*Quality Indicators database, July 2013*». Quality indexes provided by OECD have the advantage of « relying on a set of homogenous information and being comparable across countries and over time», (Dernis et al. 2013). I use patents identifiers (number, application number …) in order to match different variables from different sub-databases.

The first selection criterion to circumscribe the large database was the definition of European countries where I would focus my research on and the observation period which is between 1990 and 2012; I use the country code of patents applicants, (companies) and *filing year*. The choice of application year is explained by its proximity to the innovation event, while granting year will be measured through grant lag attribute. I started with a total number of 20 countries which are very heterogeneous in their economic development degree, the number of listed firms and their innovative intensity; selected countries contain Germany, considered as one of the pioneers in R&D activities, as well as emerging European economies like Estonia, Lithuania… Divergence between countries also regards accountancy rules given that the pre-sample contains UK, a common-law country and France, for example, where regulation is under civil-law.

In a second step, I collect financial data of only listed companies as I resort to the market value approach in assessing the economic value of technological innovation,. Data are extracted from Datastream for the same period (1990- 2012) and belong to European financial markets, Nyse Euronext as well as local markets like the London Stock exchange, Frankfurt

[6] HAN database provides a grouping of patent applicants' names resulting from a cleaning and matching of names.

[7]) Covers patent applications to the EPO (derived from PATSTAT, April 2013) and PCT patents at international phase (derived from the OECD patent database, including patents published up to May 2013).Though the development of HAN database by OECD in order to reduce punctuations and abbreviations problems found in PATSTAT, applicants names still cannot be directly associated to their equivalents in other databases.

Stock exchange… Duplicates are eliminated and companies are ranked according to their country of origin.

Thanks to Datastream country code, I define the country of listed companies according to their head offices and not the market place in which they are quoted; subsidiaries are consolidated according to the ownership structure. Matching the two databases was particularly long given the absence of unique and common identifier of companies in Datastream and Patstat. I rely consequently on the names of firms to gather together both types of data.

However, there is no standard format to write companies names, especially in the patents database; there is more than one possible way to refer to the same company. Another important obstacle in collecting data is the notable lack in R&D information. Unlike the United States, companies in Europe do not have the obligation to disclose information about their R&D expenses. This characteristic proper to the European context could enhance companies to choose the right timing of making public their R&D expenses, according to strategic goals and competition position in the market. I keep in the final sample companies that have disclosed information about their R&D expenses for at least one year and have applied for patents in the EPO for the same period. The number of firms has, thus, dropped from 1323 to 599 units all belonging to 18 European countries, with a total number of 78384 patents. Companies should, obviously, hold innovative activities; invest in R&D and possess patents portfolios. I, thus, eliminate firms belonging to financial industry, such as banks, insurance…but keep a large range of sectors (pharmaceutical, transports, media, software…). Though the high variance in R&D intensity across these fields, I aim at evaluating technological innovation in its large aspect and do not focus on specific sector, like in most of previous studies. Dealing with patents, semi-conductors, software, biotechnology and pharmaceutical sectors are most explored in previous literature.

Hall et al., (2007) were the first to be interested in multi-sectoral study but ended up with focalizing their empirical investigation on software field. The current research is based on 15 sectors described in Table (1). With only 14.64% share of R&D expenditures, the technological industry is the most innovative in the sample in terms of patenting with 35% of the total patents applications in the EPO. «Technologies» industry brings together computer services, software, Internet…. the higher intensity of patenting compared to R&D activities mirrors the nature of innovation inside this sector; a large capability of patenting despite a lower level of R&D expenditures may indicate an incremental innovation. Obtaining a legal protection to one's invention in technological area is compulsory to commercialize an economically valuable output.

The high intensity of these inventions makes knowledge spillover easier and contributes to more incremental inventions rather than radical ones. Seeing its larger scope and overrepresentation in the sample, Industrial Goods & Services including (aerospace, transportation services, defense…) is the leader sector in R&D expenditures with 30.30% from the total expenses. Innovation's nature is more heterogeneous in this area and could be radical as well as incremental. Besides, Health care and chemicals are highly innovative and have more balanced shares of patents number and R&D expenses, according to their frequencies in the sample. The notable divergences, in technological intensity, between sectors highlight the importance of controlling for industries in empirical investigation.

Table (2) provides further details about differences across countries in technological intensity; Germany has the leader position in both R&D expenditures (33.4%) and patents applications in the EPO (25.75%) followed by France, Switzerland and Netherland. Other things being equal, innovation's productivity seems to be more efficient in Finland where only 8% share of the total R&D expenditures contributes to 17% share of the patent applications in European jurisdiction. However, because of disproportional R&D disclosure across firms and countries, it is not evident to conclude about the efficiency of innovation in one country compared to another.

Graph1 shows that the number of patents applications in the EPO has increased dramatically in 2000 to reach the peak of roughly 8000 patents per year. This is most probably explained by the Internet bubble and the development of the New of information and communications in the very beginning of the 21^{st} century. The slight decrease at the end of the observation period (by the year 2012) is due to the lack of data regarding latest application in European jurisdictions.

Summary Statistics:

Table (3) shows that on average, companies apply for 20 patents annually in the EPO, but highlights, on the other hand, the large divergence in patents frequency; some companies manage to file up to 1559 patents by year in the European jurisdiction. The distribution plot of patents number, (figure2), supports this noticing through its remarkable asymmetry and involves implicitly the hypotheses that fewer number of patents has high economic value on the market. Statistics about R&D expenditures have similarly high value of standard deviation which indicates heterogeneity between industries and sizes; on average, firms spend around 345 million euros in R&D activities but could, according to the two previously mentioned criteria, devote 7,455 million euros to innovation's input. Qualitative measures indicate that forward citations to patents ratio is around 40%, in average, but could reach the value of 8, showing that some inventions are more important to the knowledge spillovers. According to their importance and economic value, patents are renewed from 5 to 7years. Patents attributes are highly correlated when looking at their total value per year inside a given company; it is predictable that a company with higher applications number obtains higher forward citations for their patents. Being a measure of knowledge spillovers, total values of claims, scopes and backward citations are highly correlated, these measures are calculated on the basis of both prior art and technological industries. However, correlation between ratios of technological innovation's measures is considerably low. These ratios are used in the regressions to avoid autocorrelation problems but also to ease subsequent interpretations. Unexpectedly, R&D expenditures to assets are negatively correlated to citations to patents ratio; one possible interpretation may rely on the hypotheses that radical innovation emanates mainly from smaller firms where applications per year are less frequent.

RESULTS:

Tables (5) to (8) report results of different regressions run on the basis of the non-linear model, see equation (4). In order to make comparison with literature possible, I start with the most basic proxies of innovation, i.e. R&D expenditures and the simple patent count, considered as its main output. Qualitative measures are, then, introduced gradually in order to assess the economic value of patents and see which attribute is most valuable by financial markets. Estimates are computed using OLS regression method, I control for size through net sales of companies and use a set of dummies to control for years and sectors. Tables display, as well, semi-elasticities of each estimate. The explanation is that coefficients of non-linear models do not measure the direct sensitivity of market-to-book ratio to innovation intensity but still do inform about the significance of each variable. In order to assess the marginal shadow value of each knowledge component, i.e. coefficients αi, I use the "delta" method for each observation and average them. Marginal shadow values are computed according to the following formula;

$$\frac{\partial Log(MtB)}{\partial Xitj} = \frac{\alpha j\ Xitj}{\partial 1 + \sum \alpha k\ Xitj}$$

X_{it}^{j} is the proxy of technological innovation of which it is meant to compute its elasticity on market-to-book ratio; X_{it}^{j} are mainly ratios of R&D expenses , patents number and citations to assets. In table (8), X_{it}^{j} presents, in addition, the regressor of the different parents' attributes considered as qualitative measures of innovation, (scope, family size, claims…).

X_{it}^{j} are the rest of technological innovation's measures used in each regression.

a- <u>Technological Innovation Measured by R&D Expenditures and Patents Number:</u>

Previous findings in literature are based on commonly used variables which are R&D and patents *stocks*. As explained in earlier sections, I do not construct the two measures using a given depreciation and growth rates, but keep raw data about R&D expenses and simple patent count. The use of stocks variables relies on strong hypotheses of fixing common growth rate and depreciation level of knowledge assets, irrespective of intrinsic characteristics within companies. The purpose, in this paper, is to detect a plausible reaction to an innovation event, captured by patent applications, regardless of the knowledge stock inside firms, from year to year. Taking into account stock variables puts the emphasis on the firm's capability and strategy of innovation; descriptive statistics show that R&D expenses as well as patent count are almost constant inside the same firm and across years. Looking at the trend of innovation's input and output in terms of stocks mirrors the nature of the strategy; whether it is radical or incremental and dismisses the value of each single invention protected by patent grants. Large annual stocks of patents may be explained by incremental approach rather than a significant added value created by knowledge assets. The use of annual observations allows better measurement of the innovation's quality; to each patent obtained at a given year corresponds a set of quality indicators, these attributes control for the typology of innovation.

When, first, measuring innovation's intensity through only its input and output, R&D expenditures have the higher and most significant impact on market-to-book.

$$Log(Market\_to\_Book) = \log(q_t) + \log(1+ \alpha_{1t} R\&D/Assets + \alpha_{2t} Patents/Assets) + S_{it} \quad (i)$$

$$Log(Market\_to\_Book) = \log(q_t) + \log(1+ \alpha_{1t} R\&D/Assets + \alpha_{2t} Patents/R\&D) + S_{it} \quad (ii)$$

<u>R&D productivity versus Patents by size:</u>

In order to compare my findings with literature, I use two indicators of patents applications inside firms; the productivity of R&D expenses; i.e. patents count to R&D expenditures and patents to assets ratio, which is a normalized indicator to firms' size. Correlation between R&D to assets ratio and patents to assets is higher and proves that larger companies invest more on R&D activities and apply for higher number of patents, which highlights an important *size effect*. Despite a higher correlation level between patents to assets and R&D to assets, variance inflation factors are quite low with a mean of 1.5. However, R&D to assets ratio is not correlated with R&D productivity. This noticing is on behalf of the hypothesis that innovation is a strategic decision inside large firms; the productivity of innovation is not always higher in large companies. Table (5) shows that R&D to assets ratio is always significant and positively correlated with market-to-book ratio; according to semi-elasticities, an additional increase in innovation's input leads to 24% increase in market-to-book ratio when output is measured only through patents to R&D ratio. The impact is alleviated when innovation's output is measured by patents count by total assets, an increase in R&D ratio leads to 15% increase in market-to-book ratio. These findings are in compliance with literature where authors speak about "horse race" phenomenon between R&D and patent count, Trajtenberg (2006). On the other hand, patents are significantly evaluated by financial markets only when they are normalized to the size of companies, R&D productivity does not have a significant effect in the market-to-book ratio. An increment in patents applications in the EPO, per assets increases firms' performance by nearly 2%.

At a first glance, the absence of significant effect of R&D productivity on market-to-book may be explained essentially by two factors. The first one argues in favor of the weakness of patents as good proxy of innovation's productivity; markets are aware that few number of patents contain significant added value from a technological and economic point of view. The second explanation could be that innovation's productivity is evaluated once patents are granted; markets may react to an innovation event at the grant date rather than in the application year.

The importance of patents as indicator of innovation intensity varies considerably between the US and European countries. As explained in previous section, it is expected that obtaining a legal protection in the EPO can generate more economic value because of higher barriers in terms of cost. Hal et al.(2007) found that patents filed in the EPO are not valuated by financial markets, unless they have US equivalents i.e. a parallel legal protection in the USPTO. In this paper, I do not control for patent authority but take into account the concept of family size. Regardless authorities of application, patents are significantly related to market-to-book value when they are normalized by firms' size, but do not have economic value when considered as innovation's measure of productivity.

b- *Forward Citations, a first Proxy of Innovation's Quality:*

$$\text{Log(Market\_to\_Book)} = \log(q_t) + \log(1+\alpha_{1t}\text{R\&D/Assets}+ \alpha_{2t}\,\text{Forward\_Citations}_j\text{/Assets}) + S_{it} \quad \text{(iii)}$$

Where Forward_Citations$_j$ are respectively:

- Forward Citations received within 5 or 7 years
- Forward Citations received within 5 or 7 years and considered as highly relevant

The use of forward citations is based as well on simple annual count without computing citations stocks (given a depreciation and growth rates). The strong inherent hypothesis of market efficiency implies an immediate reaction to innovation event; investors are supposed to be able to distinguish patents with future high economic value since the application date. As explained in hypotheses section, it is expected that patents with more forward citations are those with higher economic value, though looking at application year as reference date is prior to citations. Table (6) shows that the average number of citations received within 5 years for all patents applied at year "t" has a positive but not significant effect on market-to-book ratio. This result is also valid for citations received within 7 years, even when forward citations are considered as particularly relevant. However, when looking at the cumulative number of forward citations by total assets, the positive impact on market-to-book ratio becomes statistically significant, on the longer run (7 years), when prior art is considerably relevant . Semi-elasticities show that an increase in the mentioned quality measure leads to a better performance of companies by 1.3%. Different impacts of two citations ratios (average forward citations and total citations per assets) on companies' financial performance are explained by the cumulative aspect of citations. The positive reaction to innovation occurs when measuring the quality of each invention per year, at the contrary of average forward citations where all applications are gathered and considered as having the same level of economic value. Surprisingly, backward citations do have most significant and important predictive power on market-to-book ratio compared to prior art; they contribute up to 3.14% it unlike previous studies that put the emphasis on prior art as quality indicator, I found that knowledge transfer is more valued in the European context thanks to the specificities of establishing prior art in the EPO. The more a patent refers to previous works inside the same company via self-citations or outside the organization through knowledge transfer channel, the more the innovation has solid basis from a technological point of view. This is due partially to the strong hypothesis of market efficiency; while forward citations require the capability of predicting the economic value of patents, prior art are per se common and accessible information to investors. The use of different measures of forward citations keeps almost constant the impact of R&D expenses on market-to-book ratio. The "horse-race" phenomenon is conspicuous in tables (1) and (2) which confirms the importance of innovation's input compared to its output for the financial performance of companies. The absence of continuous information disclosure about R&D expenditures in European countries contributes to its importance as informational signal for investors.

c- Patents Attributes as Quality Proxy:

One of the novelties of this paper is to try to give exhaustive measure of patents quality which is considered, according to the market value approach as extension of knowledge assets. However, the main empirical problem is the excessively high correlation between all ratios of claims, cope family size… by total assets. The total number of each measure by company and per year is significantly correlated with other measures. This is quite expected since all attributes are constructed on the basis of patents' main characteristics i.e. technological classes and citations. The more a company applies for patents the higher is the probability to get its stock of attributes larger (scope, claims and family size) as it has more chance to be cited by other documents. Table (5) reports results of regression (iv):

$Log(Market\_to\_Book) = log(q_t) + log(1+\alpha_{1t}R\&D/Assets+ \alpha_{2t} Attribute_{(j)}/ Assets) + S_{it}$
where $Attribute_{(j)}$ = {Claims, Scope, Family Size, Renewal}

The equation above does respect the rule that knowledge assets might be presented by both input and output. I kept R&D expenses to assets as the main input and dropped patent count in order to avoid its noisy character in equation. It is obvious that qualitative measures are different from zero when companies apply for patents. Equation (iv), aims, thus at assessing the quality of R&D investment in each company. Knowledge assets are measured by the very beginning of innovation's efforts and their value's indicator which appear at the end of innovation process. Likewise previous tables, R&D expenditures to assets have strong and significant effect on market-to-book ratio, its elasticity remains as well constant as it fluctuates between 14 and 15%. This noticing is in favor of the "horse race" phenomenon described in literature by Hall et al.(2007), where financial performance is very sensitive to the R&D measure; no patents attribute was proved to have higher and more significant impact on the market to book ratio in literature. When taking quality measures separately, results show that renewals have the most significant impact on dependent variable followed by family size. In accordance with hypotheses, renewed patents have higher and longer economic value; companies are able to pay renewal fees (which are particularly high in EPO compared to USPTO), in order to protect the invention. Family size is the second attribute considered as efficient quality measure of patents filed in the EPO, they have nearly the same semi-elasticity on market-to-book ratio as renewals. European patents are more valued when applied in more than one jurisdiction to obtain legal protection in several European countries. Finally, technological spread of patents has as well significant impact on market-to-book ratio through scope attribute with smaller elasticity on financial performance. These findings prove the importance of geographical and technological scopes of patents quality regardless the technical content of patents since claims have positive but insignificant effect on financial performance of companies.

d- <u>Generality, Originality and Radicalness indexes:</u>

Log (Market_to_Book) = $\log(q_t) + \log(1+ \alpha_{1t}$R&D/Assets+ α_{2t}Patents/Assets+α_{3t}Quality Index(j)) + S_{it} , (v), Where quality Index (j) is radicalness, originality or generality variable.

Because of high correlation between the three indicators; generality, originality and radicalness, I use the same equation of market value approach and try to assess separately the effect of each indicator on the market-to-book ratio. The information given by each indicator is different from the two others and allows mainly a comparison of the patent's value with other documents belonging to the same technology class. The three indicators allow, consequently, easier interpretation and positioning of patents values on the market. It is more relevant to take a benchmark when assessing the value of knowledge assets; receiving, for example, high number of citations remains relative and not precise information as investors are not aware of the characteristics of other comparable patents.

Table (6) reports results of estimation described below; R&D expenses to assets remain very significant and positively related to market-to-book ratio with constant semi-elasticity; from 13% to 15%, regarding previous tables. Only radicalness and originality indexes do have significant and positive impact on firms' financial performance. Though the week coefficients of both variables, semi-elasticities are proved to be considerably high (3.15% for radicalness and 2.3% for originality). These results mirror the importance of patents prior art and knowledge transfer phenomenon; when legal protection of innovations is based on variety of prior art that belong to different technology classes, the quality of the invention becomes higher and significantly valued through financial markets. Besides, patents quality is highly related to its originality which confirms the importance of the technological breadth on which patents are based. The absence of a significant effect of generality index on market-to-book ratio argues in favor of previous results about forward citations received within 5 years as generality index is computed on the basis of forward citations within 5years. The predictive power of patents to assets is almost constant when adding quality indexes as innovation's measures; the semi-elasticity remains considerably high and varies around 2.7%.

Dealing with Endogeneity:

As it was shown in this paper and in accordance with literature, patents have been criticized for their "noisy" aspect and their lack of qualitative information, hence the use of various attributes as main measures of knowledge assets, according to market value approach. Unfortunately, the richness of information given by various attributes cannot be empirically used in a unique regression because of high correlation. The repetitive use of each qualitative proxy in separate regressions may be at the root of measurement error. As it was supposed at the beginning of the paper, market value shall reflect the sum of different kinds of assets inside the firm; one of the main novelties of this paper is to consider patents characteristics (citations, claims…) as main constituents of knowledge assets. Dropping panoply of patents attributes because of correlation is, thus, contradictory to the additive principle of market value approach and may be seen as a shortcoming in the measurement of technological innovation. In order to avoid endogeneity problem and check the robustness of the previous results, I make use of instrumental variables. In response to the stem of literature that criticizes the use of patents as one of the main proxies of technological innovation, I instrument patents count to total assets for their common noisy aspect. As it was explained in previous sections, looking exclusively at the simple output of technological innovation process was proved to cause serious heterogeneity problems; it does not take into account various aspects of innovation (mainly the degree of employees' qualifications, some of the relevant innovations that were not disclosed publicly by patenting and particularly in the European context, undisclosed R&D expenses from year to year…), it does not inform about the economic value of the knowledge assets (which is the role of patents attributes) and do not provide sufficient information about the nature of innovation; whether it is incremental or radical. Henceforth, endogeneity stems from two main channels, measurement error when defining patents as reliable proxy and omitted variables when not taking into account the mentioned variables of skills and undisclosed information. It is, thus, compulsory to find the good instrument correlated with patent count but without a direct impact on market to book ratio.

Relevancy and Excludability of Instrumental Variables:

The choice of instrumental variables stems from the characteristics of patents which are not correlated with market-to-book ratio. As it was shown in previous regressions, the number of claims per total assets does not have a significant impact on market-to-book ratio, according to the non-linear shape of market-to-book regressed to patents attributes. Besides, table of correlations highlights the strong link between total patents to assets and claims ratio argues in favor its use as good instrument, (90% of correlation).

The absence of direct relation between the extent of patents protection and financial performance of companies may be explained by the technical characteristic of claims. Unlike other attributes, claims do not rely on citations or technical/geographic scopes but define the validity of a given patent. The information mirrored by this attribute is, thus more interesting for applicants themselves, but does not help investors assess precisely the economic value of inventions. The number of claims may be considered as "purely technical" characteristic of patents compared to common attributes such as forward citations or technological classes. Rule 43 of European Patent Convention states that "The claims shall define the matter for which protection is sought in terms of the *technical features* of the invention", European Patent Office Website. The information provided by claims is, thus, more relevant for examiners to grant the patentability character to inventions, but does not afford direct valuation instrument for investors. The ex ante character of claims may be at the root of its insignificance as good determinant of patents economic value. Unlike forward citations which occur after the grant lag, claims are defined since the application date. While citations testify the importance of inventions in the market by other applicants, claims cannot foresee its economic value despite of large boundaries of protection.

The aim behind using instrumental variables technique is to give a robust aspect to previous results that may be subject to some critiques because of plausible measurement error or omitted variables that cannot be measured directly in empirical work. When defining innovation, in general, and its technological aspect, in particular, it is obvious that it could be defined through a wide variety of variables; some of them can be unobservable. Technological intensity inside companies can be assessed through the degree of skills of its workers, the secrecy of some important inventions kept inside the firm in order to avoid litigation problems or that social returns on R&D investment exceed private one.

- The initial model used in previous regressions is the following:

$$\text{Log}(\frac{Vit}{Ait}) = \log(q_t) + \log(1 + \frac{R\&D\ (it)}{Ait} + \frac{Patents\ (it)}{R\&D(it)}) + u_{it}$$

- By choosing claims to assets ratio as instrument to patents to assets ratio, I suppose that:

$$\text{Covariance }(\frac{\text{Claims(it)}}{\text{Assets(it)}}, u_{it}) = 0 \text{ and Covariance }(\frac{\text{Patents(it)}}{\text{Assets(it)}}, \frac{\text{Claims(it)}}{\text{Assets(it)}}) \neq 0$$

- First stage regression equation:

$$\frac{\text{Patents(it)}}{\text{Assets(it)}} = \alpha_1 \frac{\text{Claims(it)}}{\text{Assets(it)}} + u_{it}$$

- Second stage regression equation :

$\text{Log}(\frac{Vit}{Ait}) = \log(q_t) + \log(1 + \frac{R\&D\ (it)}{Ait} + \frac{Patents\ (it)}{R\&D(it)} IV) + u_{it}$ where $\frac{Patents\ (it)}{R\&D(it)} IV$ is taken from the first stage regression.

It is important to mention that the use of market value approach is a strong argument against the large hypothesis of the existence of measurement error; when constructing the "hedonic price" model i.e. market value approach, knowledge assets are defined through innovation's input and output. However, instrumental variables can still eliminate or alleviate endogeneity issues caused by high correlation and omitted variables.

Appendix A illustrates econometric details of using claims to assets ratio as instrumental variable of patents ratios (patents to total assets and patents to R&D expenses). In a first stage, I verify the validity of claims as good instrument through a set of econometric tests, mainly over-identification and endogeneity. Hansen J test approves the absence of over-identification while Cragg-Donald Wald F statistic confirms that claims are strong inctrument for both patents to assets and patents to R&D expenditures. Results of 2SLS regressions are not relevant in the assessment of the impact of innovation's measures on financial performance as they do not respect the non-linear relation imposed by market value approach. However, they do allow for preliminary tests of instrument validity.

Table (10) consolidates previous results found in table (5); patents to assets ratio does have a positive and significant impact on market-to-book while innovation's productivity measured by patents to R&D does not mirror the economic value of innovation inside companies for the same reasons explained previously; average patents to R&D do not mirror the value of each single invention. Despite of its lower impact on market-to-book ratio (2.518 instead of 2.601 in model (1) and 2.842 instead of 3.151 in model (2)), I find that R&D expenses are still considered as the most powerful innovation's measure in predicting the financial performance of companies.

Robustness check through the use of instrumental variables confirms hypothesis number one where I have expected that patents filed in the EPO are less noisy and more significant than American patents. It is important to remember that in this paper, innovation's output is measured directly by its simple count, unlike previous studies where knowledge stocks are computed. Even after controlling for endogeneity, simple patent count is considered as reliable proxy of technological innovation in Europe; this is due to more "rigorous" policies of patenting in the EPO (citations procedure various conventions such as PCT…), higher barriers to apply for legal protection and the less resort to European jurisdiction.

CONCLUSION AND DISCUSSION:

One of the important novelties of the paper is the use of a rich range of patents attributes as quality measures for technological innovation. In addition to forward citations, family size and technological field used in the paper of Torrisi and al. (2007), I collect data about claims, patent scope, backward citations and three quality indexes provided by the latest database of OECD, (July, 2013). Unlike all previous studies, I do not use patents stocks constructed in literature on the basis of depreciation and growth rates because of the absence of persuasive argument in their favor. I think that the mentioned rates vary considerably across companies because of their different sizes and intrinsic characteristics, especially their intensity of innovation. I resort, consequently to simple annual patent count and find different results compared to literature when measuring the impact of innovation's productivity and forward citations on market-to-book ratio. While previous findings highlight the importance of patents stocks to R&D expenses as good proxy of innovation, I prove that simple count ratio to R&D expenditures is not valuated by investors. However, total patent count per total assets does have positive and significant impact on financial performance. Different findings on the basis of different ratios highlight the cumulative character of knowledge assets inside companies. It is more interesting for investors to consider the value of total assets rather than average the productivity of R&D efforts. This may be the result of R&D disclosure policy in

Europe; the absence of regular information about R&D expenses makes investors reluctant to use it as the basis of good indicators. When looking at the average number of patents and average attributes by patent count, it is hard to distinguish the value of each invention; measures, in this case, mirror the shape of innovation's value per year by patent but omit its cumulative aspect. One of the possible improvements is to control for patents equivalents, i.e. when applicants resort simultaneously to the EPO and USPTO. The economic value of patents could be more important when knowing that companies pay higher fees for larger protection scope and are able to respect different patenting procedures in both jurisdictions. The control test for equivalents has been mentioned in Hall et al.'s papers (2007); they found that only patents "taken out in both offices" do have a positive and significant impact on market-to-book ratio.

In accordance with literature, I find that markets are particularly sensitive to R&D disclosure; none of the innovation's measures can defeat the predictive power of R&D expenses on market-to-book ratio. The strong effect of innovation's input is explained by the strategic aspect of announcing one's R&D budget. Accountancy policies in European countries do not make disclosure compulsory which make investors sensitive to unexpected announcements.

Besides, I found that only forward citations on the long run (7 years) which are considered as particularly relevant, by examiners, do have a positive and significant impact on performance ratio. The later result arguments in favor of the specificity of innovation as a long run investment and approves implicitly the hypothesis of market efficiency on the long term. Unlike previous literature that put the emphasis on forward citations, I prove that backward citations are considered as strong qualitative measure of innovation, which mirrors the importance of knowledge transfer in Europe, between companies and across sectors. The selective prior art in the EPO of most relevant inventions contributes to its consistency as reliable proxy for investors. Finally, when resorting to comparative quality indexes, I find that originality and radicalness are more related to patents quality; it is more relevant for investors to have benchmarks when assessing the value of knowledge assets. These findings are in accordance with the importance of knowledge transfer; both of indexes rely on backward citations and the breadth of technology classes.

The use of patents as measurement of innovation has been criticized in literature for its noisy aspect and the lack of qualitative information. In order to mitigate endogeneity problems caused by omitted variables and plausible measurement error, I used claims to assets ratio as instrumental variable of patents to assets because of its noisy aspect. Findings consolidate initial results of market value regressions which highlight the cumulative aspect of innovation. The constraint of high correlation between quality measures has inhibited the study of possible reaction between these terms. The richness of information given by all attributes may, thus be gathered in unique index thanks to common factor technique, Lanjouw and Schankerman (1999).

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Table 1- Distribution of Patents Applications in the EPO and R&D expenditures by industry

Industry	Freq.	Percent	*Cum.*	R&D expenditures *Amount*	Share	Patent Aplications in the EPO *Number*	*Share*
Food and Beverage	87	2.20	2.20	652334	0,09%	153	0,20%
Health Care	742	18.73	20.92	132026832	19,10%	13417	17,57%
Petrolium and Gas	131	3.31	24.23	10075075	1,46%	630	0,82%
Technology	441	11.13	35.36	101192920	14,64%	26570	34,79%
Automobiles & Parts	302	7.62	42.98	143401376	20,75%	6768	8,86%
Industrial Goods & Services	1,098	27.71	70.70	209352576	30,29%	17762	23,26%
Media	33	0.83	71.53	25953	0,00%	56	0,07%
Personal & Household Goods	258	6.51	78.04	2887097	0,42%	1151	1,51%
Construction	300	7.57	85.61	9255992	1,34%	1350	1,77%
Commodities	102	2.57	88.19	1615486	0,23%	337	0,44%
Telecommunications	62	1.56	89.75	4380786	0,63%	1342	1,76%
Retails	7	0.18	89.93	3850	0,00%	10	0,01%
Chemicals	331	8.35	98.28	67403056	9,75%	6498	8,51%
Services aux collectivites	65	1.64	99.92	8902903	1,29%	317	0,42%
Travel and Leisure	3	0.08	100.00	0	0,00%	4	0,01%
Total	3,962	100.00		691176236	100%	76365	100%

Table 2- Distribution of Patents Applications in the EPO and R&D expenditures cross country

			R&D expenditures		Patent Aplications in the EPO	
Country Code	Freq.	Percent	*Amount*	*Share*	*Number*	*Share*
FR	796	20.09	147750016	21,3766%	14005	18,341%
NO	246	6.21	2569581	0,3718%	4494	5,885%
NL	341	8.61	104560864	15,1280%	7143	9,354%
LU	18	0.45	863604	0,1249%	130	0,170%
CH	225	5.68	84452048	12,2186%	9356	12,252%
DE	917	23.14	230805632	33,3932%	19667	25,756%
ES	67	1.69	505491	0,0731%	185	0,242%
GB	145	3.66	1138667	0,1647%	560	0,733%
BE	85	2.15	9329249	1,3498%	680	0,891%
IE	31	0.78	1623006	0,2348%	113	0,148%
FI	210	5.30	54835560	7,9337%	12926	16,928%
DK	258	6.51	6265716	0,9065%	2624	3,436%
IT	452	11.41	45208388	6,5408%	3615	4,734%
PL	34	0.86	71333	0,0103%	115	0,151%
AT	79	1.99	432216	0,0625%	424	0,555%
SI	15	0.38	481303	0,0696%	82	0,107%
AN	32	0.81	280746	0,0406%	221	0,289%
CZ	6	0.15	1774	0,0003%	20	0,026%
Total	3,962	100.00	**691175194**	100%	**76360**	100%

Table 3 - Descriptive Statistics of Technological Innovation's Measures in millions of Euros

				--------------	--------------	Quantiles	--------------	--------------
Variable	N	Mean	S.D.	Min	.25	Mdn	.75	Max
R&D Expenditues	2003	345.07	855.92	0.01	12.86	38.30	209.01	7455.00
Total Assets	3011	8302.95	21772.95	0.07	155.80	810.77	4400.67	262215
Net Sales	3956	4650.30	12996.75	0.00	0.17	286.03	2318.64	160331
Total Patents(it)	3957	19.30	79.29	1.00	1.00	3.00	9.00	1559.00
Patents/R&D	2003	0.86	7.22	0.00	0.05	0.15	0.47	285.71
Patents/Assets	3011	0.07	0.62	0.00	0.00	0.01	0.03	29.41
∑bwd_cits(it)	3957	84.82	327.16	0.00	6.00	14.00	45.00	5851.00
∑fwd_cits5_xy	3957	4.44	24.02	0.00	0.00	0.00	2.00	734.00
∑fwd_cits5(it)	3957	7.93	41.45	0.00	0.00	0.00	4.00	1262.00
∑claims(it)	3957	286.49	1476.88	0.00	15.00	41.00	136.00	38076.00
∑renewal(it)	3957	99.87	409.21	0.00	5.00	16.00	48.00	8705.00
∑familysize(it)	3957	126.67	587.62	1.00	7.00	18.00	58.00	11760.00
Attribute(j)(it)/Total Patents(it)								
Patent Scope	3957	1.85	0.94	0.00	1.00	1.67	2.03	9.00
Family Size	3957	6.45	4.18	1.00	3.75	5.48	8.00	32.50
fwd5_xy	3957	0.23	0.49	0.00	0.00	0.00	0.28	11.00
fwd7	3957	0.54	1.00	0.00	0.00	0.04	0.78	14.00
fwd7_xy	3957	0.26	0.53	0.00	0.00	0.00	0.33	6.00
claims	3957	13.95	8.05	0.00	9.00	12.38	17.00	101.00
bwd_cit	3957	4.68	2.50	0.00	3.25	4.25	5.58	43.67
renewal	3957	5.75	4.46	0.00	2.13	5.00	8.50	20.00

Table 4 – Matrix of Correlations

	R&D/Assets	Pat/R&D	Pat/Assets	Log(NetSales)	Bwd_Cit/Assets	Cit(5)/Assets	Cit(5XY)/Assets	Cit(7)/Assets	Cit(5)/Pat	Cit7/Pat	Cit(7Y)/Assets	Cit(5XY/Assets)
R&D/Assets	1.0000											
Pat/R&D	-0.0081	1.0000										
Pat/Assets	0.8150	0.0579	1.0000									
Log(NetSales)	-0.3363	-0.0832	-0.3021	1.0000								
Bwd_Cit/Assets	0.7924	0.0446	0.9737	-0.2533	1.0000							
Cit(5)/Assets	0.0906	0.0792	0.3131	-0.1991	0.2118	1.0000						
Cit(5XY)/Assets	0.0902	0.0627	0.2651	-0.1870	0.1655	0.8964	1.0000					
Cit(7)/Assets	0.0840	0.0818	0.3122	-0.1950	0.2123	0.9907	0.8629	1.0000				
Cit(5)/Pat	-0.0358	0.0003	-0.0142	0.0239	-0.0166	0.2085	0.1674	0.2044	1.0000			
Cit7/Pat	-0.0401	-0.0017	-0.0193	0.0279	-0.0204	0.1727	0.1389	0.1810	0.9412	1.0000		
Cit(7Y)/Assets	0.0864	0.0653	0.2662	-0.1862	0.1667	0.9061	0.9949	0.8817	0.1716	0.1459	1.0000	
Cit(5XY/Assets)	-0.0269	0.0057	-0.0064	0.0070	-0.0105	0.1828	0.1931	0.1802	0.7225	0.7711	0.1920	1.0000
Cit(7XY)/Pat	-0.0308	0.0046	-0.0083	0.0196	-0.0128	0.1987	0.2038	0.2003	0.7871	0.8383	0.2126	0.8837
Originality	-0.0015	-0.0033	-0.0031	0.0119	-0.0025	0.0080	-0.0015	0.0092	0.0094	0.0138	-0.0021	0.0040
Generality	0.0011	-0.0031	-0.0039	-0.0099	-0.0033	0.0006	-0.0002	-0.0002	0.0723	0.0521	-0.0003	0.0514
Radicalness	-0.0058	0.0668	-0.0167	-0.0143	-0.0108	-0.0125	-0.0083	-0.0116	-0.0181	-0.0257	-0.0082	-0.0229
Scope/Assets	0.7125	0.0633	0.9625	-0.2960	0.9154	0.3501	0.2832	0.3439	-0.0162	-0.0212	0.2803	-0.0079
Bwd_Cit/Assets	0.7924	0.0446	0.9737	-0.2533	1.0000	0.2118	0.1655	0.2123	-0.0166	-0.0204	0.1667	-0.0105
Renewal/Assets	0.5265	0.0780	0.7966	-0.3565	0.7200	0.5707	0.4470	0.5835	0.0123	0.0071	0.4573	0.0155
Size/Assets	0.7609	0.0460	0.9632	-0.2379	0.9708	0.1614	0.1169	0.1599	-0.0209	-0.0235	0.1167	-0.0156
Claims/Assets	0.7359	0.0595	0.9586	-0.3119	0.9170	0.3568	0.3005	0.3477	-0.0173	-0.0237	0.2974	-0.0070

Table 5- Market to Book regression with Simple Patent Count Ratios

2506 observations for the period 1990-2012
Dependent Variable = log Market to Book

	Model(1)	Model(2)
	Model(1)	Model(2)
R&D/Assets	2.601***	3.151***
	(4.58)	(5.01)
Pat/Assets	0.616*	
	(2.18)	
Pat/R&D		0.00116
		(0.44)
Log(Net Sales)	0.00433	0.00792
	(0.54)	(0.91)
Dummy R&D=0	0.0334	0
	(0.81)	(.)

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Semi-Elasticities, Delta-method

	Elasticity	Std. Err.	z	P>z	[95%Conf.	Interval]
R&D/Assets	.1562242	.0302441	5.17	0.000	.0969468	.2155016
Pat/Assets	.0276556	.0124897	2.21	0.027	.0031762	.052135

R&D/Assets	.2429929	.039525	6.15	0.000	.1655252	.3204605
pat_rd_mill	.0012358	.0028004	0.44	0.659	-.0042528	.0067244

Table 6- Market to Book regression with Citations to Patents

2506 observations for the period 1990-2012
Dependent Variable = log Market to Book

	Model(1)	Model(2)	Model(3)	Model(4)	Model(5)	Model(6)
Const	-0.289	0.0417	0.0407	0.0416	0.0409	0.0410
	(-0.42)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
R&D/ Assets	2.925***	3.151***	3.183***	3.152***	3.144***	3.147***
	(4.77)	(5.01)	(5.01)	(5.00)	(5.01)	(5.01)
Pat/R&D	0.669	1.161	1.148	1.160	1.183	1.171
	(0.27)	(0.44)	(0.44)	(0.44)	(0.45)	(0.44)
Log(Net Sales)	0.0104	0.00792	0.00809	0.00793	0.00788	0.00789
	(1.17)	(0.91)	(0.93)	(0.91)	(0.90)	(0.90)
Cit(5)/Patents			0.0210			
			(0.66)			
Cit(7)/Patents				0.000879		
				(0.04)		
Cit(5xy)/Patents					-0.0160	
					(-0.33)	
(Cit7xy)/Patents						-0.0103
						(-0.25)

Table 7- Market to Book regression with Citations to Assets

2506 observations for the period 1990-2012
Dependent Variable = log Market to Book

	Model(1)	Model(2)	Model(3)	Model(4)	Model(5)
R&D/Assets	2.718***	2.739***	2.726***	2.727***	2.603***
	(4.87)	(4.89)	(4.88)	(4.88)	(4.60)
Cit(5)/Assets	0.642				
	(1.55)				
Cit(7xy)/Assets		1.231*			
		(2.09)			
Cit(7)/Assets			0.575		
			(1.78)		
Cit(5xy)				1.227	
				(1.84)	
Bwd/Assets					0.153*
					(2.49)
Log(NetSales)	-0.00101	-0.0000597	-0.000590	-0.000578	0.00584
	(-0.13)	(-0.01)	(-0.08)	(-0.08)	(0.73)
Dummy R&D	0.0379	0.0390	0.0386	0.0382	0.0339
	(0.92)	(0.95)	(0.94)	(0.93)	(0.82)

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Semi-Elasticities, Delta-method

	Elasticity	Std. Err.	z	P>z	[95%Conf.	Interval]
R&D/Assets	.1645511	.0729667	2.26	0.024	.021539	.3075633
Cit(5)/Assets	.0097776	.0074479	1.31	0.189	-.0048201	.0243752
Cit(5xy)	.0111969	.0060446	1.85	0.064	-.0006503	.0230442
R&D/Assets	.1648137	.0296753	5.55	0.000	.1066512	.2229763
Cit(7xy)/Assets	.0130388	.0061608	2.12	0.034	.0009639	.0251137
R&D/Assets	.1651876	.0296298	5.58	0.000	.1071143	.223261
Cit(7)/Assets	.0116827	.0087903	1.33	0.184	-.0055459	.0289114
R&D/Assets	.1647349	.0868236	1.90	0.058	-.0054362	.3349061
Bwd_assets	.0314259	.0123312	2.55	0.011	.0072572	.0555946
R&D_assets	.1558824	.0300416	5.19	0.000	.097002	.2147628

Table 8- Market to Book regression with Patents' Attributes

2506 observations for the period 1990-2012
Dependent Variable = log Market to Book

	Model(1)	Model(2)	Model(3)	Model(4)
R&D/Assets	2.624***	2.636***	2.569***	2.430***
	(4.62)	(4.63)	(4.56)	(4.30)
Claims/Assets				
	32.08			
	(1.94)			
Scope/Assets		341.8*		
		(2.17)		
Renewal/Assets			205.6***	
			(3.60)	
Size/Assets				158.7**
				(3.24)
Log(Net Sales)	0.00303	0.00370	0.00708	0.00835
	(0.39)	(0.47)	(0.91)	(1.05)
Dummy R&D=0	0.0341	0.0362	0.0326	0.0311
	(0.83)	(0.88)	(0.80)	(0.76)

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Semi-Elasticities, Delta-method

	Elasticity	Std. Err.	z	P>z	[95% Conf.	Interval]
Claims/Assets	.0223596	.015151	1.48	0.140	-.0073359	.052055
R&D/Assets	.1580143	.0722933	2.19	0.029	.0163221	.2997065
Scope_Assets	.0263923	.0119714	2.20	0.027	.0029287	.0498558
R&D_Assets	.1581484	.0302568	5.23	0.000	.0988462	.2174505
Renewal/Assets	.0453176	.0121283	3.74	0.000	.0215466	.0690885
R&D/Assets	.1521521	.0295918	5.14	0.000	.0941532	.2101509
Sizee/Assets	.0450444	.0275421	1.64	0.102	-.0089371	.0990259
R&D/Assets	.1446927	.080155	1.81	0.071	-.0124082	.3017936

Table 9- Market to Book regression with Quality Indexes

2506 observations for the period 1990-2012
Dependent Variable = log Market to Book

	Model(1)	Model(2)	Model(3)
R&D_Assets	2.292***	2.365***	2.543***
	(4.23)	(4.32)	(4.52)
Pat/Assets	0.459	0.487	0.584*
	(1.67)	(1.78)	(2.08)
Radicalnes	0.0000181**		
	(3.21)		
Originality		0.000667**	
		(2.91)	
Generality			0.000182
			(1.25)
log(Net Sales)	-0.00665	-0.00318	0.00275
	(-0.79)	(-0.39)	(0.34)
Dummy R&D=0	0.0166	0.0248	0.0307
	(0.40)	(0.60)	(0.75)

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Semi-Elasticities, Delta-method

	ey/ex	Std. Err.	z	P>z	[95% Conf.	Interval]
Radicalnes	.0314758	.0150278	2.09	0.036	.0020219	.0609297
R&D/Assets	.1368196	.0648357	2.11	0.035	.0097439	.2638954
Pat/Assets	.0204774	.0155606	1.32	0.188	-.0100209	.0509756
Generality	.0040229	.0032268	1.25	0.213	-.0023016	.0103474
R&D/Assets	.1528715	.0300941	5.08	0.000	.0938882	.2118548
Pat/Assets	.0262373	.0124141	2.11	0.035	.001906	.0505686
Originality	.0230385	.0115901	1.99	0.047	.0003222	.0457547
R&D/Assets	.1416251	.0661659	2.14	0.032	.0119424	.2713079
Pat/Assets	.0217754	.0157666	1.38	0.167	-.0091266	.0526773

Table 10- Market-to-Book regression with Innovation's Input and Output Patents Ratios are instrumented by Total Claims to Assets Ratio

	Model(1)		Model(2)
R&D/Assets	2.518***		2.824***
	(11.76)		(13.63)
Patents/Assets	0.489*		
	(2.51)		
const	0.484***		0.462***
	(29.26)		(3.57)
Pat/R&D			18.76
			(0.12)
Patents/Assets		Pat/R&D	
Claims/Assets	47.03***	Claims/Assets	0.0219*
	(260.56)		(2.06)
_cons	0.00845***	_cons	0.000836***
	(3.62)		(5.16)
N	3011		2000

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Graph1- Patent Applications in the EPO, (1990-2000)