INDEXES OF PATENT VALUE:

A SYSTEMATIC LITERATURE REVIEW AND CLASSIFICATION

To cite this article:

Michele Grimaldi & Livio Cricelli (2019): Indexes of patent value: a systematic literature review and classification, Knowledge Management Research & Practice, 18:2, 214-233.

DOI: 10.1080/14778238.2019.1638737

To link to this article: https://doi.org/10.1080/14778238.2019.1638737

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ABSTRACT

A proliferation of studies has been carried out on patent value indexes encompassing the most different viewpoints and considering different scale. However, the existing literature is fragmented and not properly integrated, demanding for an adequate organization in order to clarify the matter in a systematic manner. This article summarizes the results of a systematic review of the literature on patent value indexes, offering an organized synthesis according to the intrinsic and extrinsic properties of patents, which are the two extremely informatory components in every process of value recognition. This study improves on state patent value measurement by providing a thorough array of the indexes proposed in literature over a 20-year period and by empirically grouping them into core categories. Based on this classification, the authors offer a well-grounded path to achieve the intrinsic and extrinsic value of patents. The review concludes by suggesting promising directions for future investigation.

Keywords

Patent; Patent value; Patent value measurement; Intellectual property; Index; EPO categories.

Introduction

The analysis of patent value plays an important role in managerial economic and business strategy in that it helps to estimate the value of the innovative and productive capacity of R&D (Striukova, 2007;

Bessen, 2008; Dolfsma, 2011; Wu, 2011; Chen et al., 2016). The issue of valuing patents has often received considerable critical attention and can be traced back to one of the first studies by Nordhaus (1969) and to successive developments carried out by several researchers. Studies on the contribution of intellectual assets to the competitive advantage of firms' have encouraged researchers to reflect on the effectual value of patents and, consequently, their measurement (Klaila and Hall, 2000; Adams et al., 2006).

Various means can be used to obtain patent value in dependence of different perspectives. It has been proposed that most of the contributions on patent value assessment can be included in three different categories (van Zeebroeck et al., 2008; van Zeebroeck, 2011): a) those which use the measure of patent value as dependent variable; b) those which adopt particular sampling strategies; c) those which consider the number and type of explanatory variables, i.e. the potential value determinants. Moreover, a number of studies have suggested subjective evaluations of patent value through interviews, and measurements from perceptive observations (Harhoff et al. 1997; Reitzig, 2003, 2004; Lagrost et al., 2010; Kapoor et al., 2013).

In addition, results from empirical research show a positive relationship between patent value and company performance (Deng et al., 1999). The estimation of a company's performance is incomplete without the analysis of indicators accounting for its R&D capacity and innovation output (Calabrese and Costa, 2015; Zakery and Afrazeh, 2017). Company's achievement on intellectual properties, such as patents owned, has been shown to be a novel and direct measure for evaluating company performance (Chen et al., 2007). Organizations started to measure their innovative performance by using patent value indicators and, more broadly, patent-based indicators have been used to quantitatively evaluate the performance of companies (Ernst, 1995; Garg and Padhi, 1998; Hagedoorn and Cloodt, 2000).

Equally important is to remind that the nature of patent value, as every process of value recognition, is based on two extremely informatory components: the intrinsic and the extrinsic dimensions. The theory of the intrinsic value (Moore, 1903; Zimmerman, 2001; Argandoña, 2003) and its specific

application to the intrinsic value of a technology (Bessen and Meurer, 2008; Nagaoka et al., 2010) have suggested that the value of patents derives from its nature, which corresponds to its intrinsic technological significance (Bekkers et al., 2011; Thoma, 2014; Yeo and Marquardt, 2015). The patent properties that pertain to intrinsic value assume importance right after they are granted, and will maintain throughout the patents' life, allowing patents' valuation. These properties of intrinsic value are represented by all data that appear in the patent document under the forms of patent renewal data, granted patent, patent families, (backward and forward) citations, claims, oppositions, and family size. However, patents have also an extrinsic value, that is, the value they possess that is not grounded wholly in its intrinsic properties. The extrinsic value of patents is derived from their capability of developing their potentiality (the marketplace), expressed in terms of geographical scope, technological change, filing strategies, lifetime, market value, novelty and inventive activity (Noblet et al., 2011).

Furthermore, a proliferation of studies has been carried out on patent value indexes encompassing the most different viewpoints and considering different scale: research areas concerning science, technology, innovation, scientometrics, R&D, etc.; investigations on the patent life-cycle phases, from the invention to the commercialization; works at country, regional or firm-specific level.

However, the existing literature about patent value index is fragmented and not properly integrated, demanding for an adequate organization in order to clarify the matter in a systematic manner (Alyari & Jafari Navimipour, 2018; Vakili & Navimipour, 2017).

In the light of the above considerations and of the non-existence of detailed investigations on the value of patents from their intrinsic and extrinsic characteristics, this paper provides an overview of patent value indexes by means of a systematic literature review. The review offers a synthesis of the indexes of patent value and is organized according to the intrinsic and extrinsic properties of patents. Criteria for the exclusion of those papers without a clear relation to organizational performance have been determined in the aim of obtaining only those papers concerning patent value indexes. The objective of this paper is not to review the papers studying patent value under the technological,

scientific or bibliometric point of view. The aim of this paper is to provide a systematic literature review of those indexes that conceive patent value as the contribution of the patent to the company performance or those that consider patent value as the perceived importance of a patent following an internal business perspective. To do this, we have excluded the papers, centralized on specific aspects different from the organizational performance and value, such as large-scale studies on innovativeness or technological activity, and narrow-scale studies on technology, science and research activities of companies (Charband & Jafari Navimipour, 2018; Soltani & Navimipour, 2016). As an output of this systematic literature review, the proposed and/or reworked indexes of patent value are grouped into the five European Patent Office (EPO) categories by their intrinsic (legal status, technology) and their extrinsic (market, economic and strategy) properties.

The remainder of the paper is structured as follows. First, we explain the method used for the systematic literature review. Second, we present the results of this review. Finally, we discuss the existing research and conclude the article.

Method

The purpose of this section is to describe the steps of the systematic literature review on patent value indexes. This review follows a number of steps in order to be systematic, transparent and replicable (Christoffersen 2013; Greer and Lei 2012; Meier 2011; Thorpe et al. 2005).

Step 1 – Data collection

To retrieve information, we used SCOPUS database, as it covers a broader range of scientific titles and indexes of a larger number of journals than other scientific databases (Falagas et al., 2008; Sivarajah et al., 2017).

In order to increase the relevance of the results, we have focused the search on the following itemized queries:

- Keyword “patent” at least in the title, abstract or in the keyword list of papers, for only papers related to patent as core topic be obtained;
- Keywords “index”, “indicator”, “metric” or “measure” in the title, abstract or keyword, to retrieve only those papers containing the above words as topic core “index” or its conceptual synonyms;
- Subject area filtered for “business”, “economics”, “management”, “social sciences”, “decision sciences”, “engineering” and “multidisciplinary” areas, by excluding all other areas different from those selected, in consequence of the fact that the object of the present study is the patent index, intended as a decisional implement capable of valuating technology and innovation level in business management science;
- Limit function applied to document type “article”, “article in press”, and “review”, as other forms of publication, such as trade publications, book series, books, and conference proceedings or similar, could represent still partial and not scientifically stabilized results;
- Limit function applied to the last twenty years “from 1997 onward” as it has been valued that period of time as adequate to the full maturity of the matter.

The results of the above-mentioned search parameters are represented by the research string (see Fig.1), by which SCOPUS has sorted out 1265 documents (export date December 21, 2017).

Figure 1: The Scopus research string

around here

Step 2 – Paper selection

We have analyzed the abstracts of all the 1265 selected papers in order to verify their conformity to the established search query. Doubtful cases have been resolved by going through the entire papers. In few cases, in spite of the entered research data, the search output contained some papers that did not fit the specified areas of interest, that is, business and/or management, or that looked at patents from a different perspective, such as competition law or legal studies. Few abstracts have been discarded because they were written in a language different from English (Figure 1).

We have determined the criteria for exclusion in the aim of obtaining only those papers concerning patent value indexes. In taking on this choice, it appeared reasonably foregone that such devising would have required an intense pilot trial and error testing, but, at the same time, it would have prevented that equivocal criteria could result in papers overlooked in the process (Randolph, 2009). So, we have excluded from the sample those papers without a clear relation to the organizational value of patents or to the company performance, by following two parameters of analysis to the selected papers:

a) large scale studies and general/wide conceptual analysis on performance, structure, behavior, and decision-making of great economic units;
b) narrow scale studies or/and particular investigations, centralized on specific aspects of economic entities.

The exclusion criteria pertaining to the first parameter are represented by patent and patent data considered as crucial indexes of:

- the scientific and technological output of a nation;
- the technological patent intensity of a region;
- the dynamics of technological change in countries or regions;
- nations' macro-aspects of innovativeness;
- regional or national research progress;

- the inventive, innovative or R&D activity of a nation;
- trends, innovativeness, performance, mapping of the evolving patterns or the innovation trajectories of a particular industrial sector;
- social aspects of scientometrics;
- the litigation level on a technological activity or in a particular geographic region;
- implications of the Science & Technology policy or Science & Technology policy appraisal or technological landscape mapping finalized to the identification of emerging core technologies for the future;
- a new way of measurement of the geographical scope of innovation;
- the evaluation of national or supranational Patent System;
- patterns of knowledge flows to measure the knowledge spillovers of technology forecasting.

The exclusion criteria pertaining to the second parameter are represented by firms' patent and patent data considered as measurement or crucial indexes of:

- the evaluation of science and technology, with emphasis on evaluation of industrial R&D and technology;
- the evaluation of technology capability or productivity;
- the degree of technological specialization and the competitiveness in a technological field;
- the technological level of innovativeness;
- the propensity to patent;
- predicting the future sales anticipations of a company active in the science-based industry;
- the organization's output to reflect its level of technological development;

- the life cycle stage or knowledge value of the patented invention;
- knowledge diffusion or knowledge generation capability;
- the knowledge spill-over activities;
- different modalities of innovation (open or closed).

As a consequence, by means of these exclusion criteria, we have excluded from the sample those papers not focusing on the relationship between patent value and the organizational performance. The former criteria have excluded large-scale studies focused on national, regional or country-based analysis; the latter criteria have excluded firm-level studies focused on technological, scientific and cognitive analysis.

Figure 2: Flowchart of the literature search process

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We have obtained the sample of 33 papers, listed below and all proposing indexes of patent value, in the result of the implementation of the above-mentioned criteria of exclusion: Trajtenberg et al., 1997; Lanjouw et al., 1998; Karki, 1998; Harhoff et al., 1999; Abraham and Moitra, 2001; Lanjouw and Schankerman, 2001; Shane, 2001; Ernst, 2003; Harhoff et al., 2003; Reitzig, 2003; Lanjouw and Schankerman, 2004; Reitzig, 2004; Fabry et al., 2006; Hidalgo, 2006; Bonaccorsi and Thoma, 2007; Gambardella et al., 2007; Bessen, 2008; Blind et al., 2009; Chen and Chang, 2010; Ernst et al., 2010; Ernst and Omland, 2011; OuYang and Weng, 2011; van Zeebroeck, 2011; van Zeebroeck and van Pottelsberghe de la Potterie, 2011; Hsieh, 2012; Trappey et al., 2012; Zhang et al., 2012; Caviggioli, et al., 2013; Hikkerova et al., 2013; Fischer and Leidinger, 2014; Messeni Petruzzelli et al., 2014; Thoma, 2014; Grimaldi et al., 2015.

Step 3 - Identification of patent value indexes

We have examined the 33 papers obtained from the step 2 to extract the indexes and indicators proposed by the authors or to deduce a new index from the authors' outcomes. To this end, the following inclusion criteria have been defined, the task of which being to ascertain indicators, or measurements, or variables suggested as proxies of patent value. Thus, the patent value has to be expressed by one or more among the followings:

- an index;
- an indicator;
- an index composed of several indicators;
- a measurement that influences (as it is correlated with) the patent value only, and neither a model nor a framework or a decisional tool;
- several indicators specifically aimed at the assessment of patent value;
- a calculation, a line of reasoning, or an operation from which it is possible to deduce an index.

From the criteria of inclusion expressed above, we have retrieved 37 patent value indexes. In case the indexes, derived from research papers, were conceptually or formally similar among them, we have synthesized them into one index. When conceptually different, we have left the proposed formulations separate. We worked out these 37 patent value indexes by drawing inspiration from one or more analyses proposed by authors in literature. More specifically, patent value indexes have been:

a) gathered directly from the selected papers;
b) conceptually derived from the synthesis of one or more indicators;
c) elaborated from the analysis of the correlation between one of the patent variables and patent value.

All the above mentioned 37 patent value indexes are represented in Fig. 2 and are described in details with formulas in Section 3. This selected sample of 27 indexes synthesizes those indexes that conceive patent value as the contribution of the patent to the company performance or those that consider patent value as the perceived importance of a patent following an internal business perspective.

Step 4 - Core categories of indexes

Once obtained, we have grouped the 37 indexes into the five categories, which can be found in IPScore 2.0® (Nielsen, 2004): Legal Status, Technology, Market conditions, Finance, and Strategy (Fig. 2). These well-acknowledged categories refer to the fundamental features of the patent that help to assess its value. IPscore 2.0® is a well-acknowledged systematic tool for evaluation of patents and technological projects developed by the Danish Patent Office. Dotted boxes in Fig. 2 point out those indexes that fall into two categories since they account for two types of value drivers.

Figure 3 - The patent value indexes grouped into the 5 categories

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The patent value indexes

Patent value indexes of Legal Status

Legal status data represent the essential information on all legal events during the lifetime of a patent application grant validity or invalidity, change of legal identity, patent maintenance fee payment, patent expiration, and other related information (Wang et al 2014) that form an integral part of patents. Data are provided by the patent office of each particular jurisdiction by means of gazettes and

registers, where up-to-date information on the legal status, related to individual patent applications or patents, are reported. Both the legal status indexes advanced in literature and those that have been elaborated by the authors are listed in Table 1.

Table 1 - Patent value indexes for the category "Legal status"

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The "**Grant index**", "**Litigation index**" and "**Opposition index**" allow for values such as the number of granted patents, the number of litigation patents, and the number of opposition patents respectively. The values of these indexes, when applied to patent families, are subdivided by the number of patents of the patent family, in order to get a value comprised between 0 and 1. The "**Grant index**" is a very important indicator in assessing the potential relevance in the market. Non-granted patents have an inadequate significance, while granted patents, in consequence of their expensive validation, take on more value (Van Zeebroeck, 2011). The "**Litigation index**", on the basis of the remarkable litigation costs, indicates the effective value of patents which, all else being equal, is more valuable (six times) than a non-litigated patent (Bessen, 2008). While the opposition process has not been often considered in the economics literature, legal practitioners and scholars have highlighted its importance (Reitzig, 2003). The "**Opposition index**" concerns issues related to the opposition processes, the importance of which has been underlined by legal scholars and practitioners (Harhoff et al., 2003). Opposition cases, which do not exist in the US or the UK, make rise patents' value; indeed, it has been found that the number of oppositions is often considered as a proxy of the economic relevance of the opposed patents (Harhoff and Reitzig, 2004). The econometric assessments of opposition determinants have confirmed that a positive correlation between patent value and the likelihood of opposition exists (Caviggioli, 2013).

The "**Inventor index"** and the **"Collaboration index**" account for the ownership of the patents. These two indexes refer respectively to the number of inventors and of assignees listed in the application of the patent. Both point out that a pool of people has strived for devising the invention, thus providing information on the size of the applicant organization (Giuri et al., 2006) and on its consequent correlation with the patent value (van Zeebroeck and Pottelsberghe de la Potterie, 2011). For these two indexes, the logarithmic operator reduces the growth rate of the investors' number value and of the assignees' number value.

The same logarithmic function has been adopted for the "**Priority index**", which refers to the priority number, namely the number of patent application, in respect of which prior status of publications is claimed (van Zeebroeck and Pottelsberghe de la Potterie, 2011).

The "**Divisional index**" derives from the restriction requirements that call for no more than one invention to be claimed in a single pending patent application. Thus, "divisional" distinct applications must be filed for each independent or distinct invention, even if strictly correlated to the parent application. The index stems from the possibility that a patent can be subdivided into several patents which give rise to divisionals from the parent patent. This can be due to the need of fostering patent file procedure or to file an invention different from that one claimed in the prior application. In the index calculation, the number of divisionals is subdivided by the number of the patents of the patent family so that it is comprised between 1 and 0.

The "**Claim index**" measures the number of claims, which are "the legal definition of the invention" of the patent, and provides evidence of its breadth and therefore its value (Trappey et al., 2012). A large number of claims strengthens patents against validity attacks. Also, the number of claims is considered as strictly associated with the patent value (Van Zeebroeck and van Pottelsberghe de la Potterie, 2011). The value of the number of claims is normalized to the maximum value within the Cooperative Patent Classification (CPC) class to compensate for the asymmetric distribution of the number of claims within different technological fields.

The "**Renewal index**" uses the patent/patent family renewal data to establish the value of patents. Renewal fees are costly and sharply increase with the age of the patent, therefore, the value of a patent is demonstrated by the fact that the patent owner pays them to keep it in force (Bessen, 2008). Econometric studies have established that costs for renewing fees are strictly related to the value of the associated rents: the most valuable patents are held longer (Hikkerova et al., 2013). The "Renewal index" takes into account the priority date of the oldest patent of the family by means of the Earliest Priority Year.

All the indexes of the category "Legal status" described above have derived from literature as the result of accurate and traceable studies. These studies have examined intrinsic aspects of the "Legal status" of patents from various perspectives in order to assess their value on the basis of the processing of data obtained (sometimes at not negligible costs) both from specialized databases and/or provided by patent offices. It would be therefore advisable to ensure a fast and economically advantageous track to access and obtain the necessary patent data.

Patent value indexes of Technology

For the purpose of this article, the "technology" of a patent refers to the breadth of its technologic background, its innovative capacity, originality, prospects and applicability, as well as its innovation typology described in the patent, in addition to the possible existence of concurrent or alternate technologies in respect of that one which is undervaluation. All the above-mentioned factors contribute to the so-called strength of the patented technology and represent the intrinsic value of the patent. Both the "Technology" indexes advanced in literature and those that have been elaborated by the authors are listed in Table 2.

Table 2 - Patent value indexes for the category "Technology"

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The "**Radicalness index**", based on the backward citation number, is founded on the assumption that patents which are characterized by a high degree of innovation and by economic, commercial, and strategic technologic attractiveness are considered radical for the value of that technology. Indeed, radical innovations, due to the development of competences and technologic knowledge, cause a sort of revolution in the previously available technology (Shane, 2001). At the same time, the new technologic theoretical framework of reference acts as a trigger for the introduction of new products/processes and the identification of new markets.

The "**Backward patent relevance index**" and "**Backward patent impact index**" are based on the calculation of the backward citation number in order to evaluate the relevance and the impact of the patents, respectively. The former measures the significance of the patent within the technology background of the patent family, thus, accounting for science, originality, and generality (Fischer and Leidinger, 2014). The latter measures how much the patented technology influenced subsequent developments of that technology (Trajtenberg, 1997). As for the normalization process of the two indexes, the former is normalized to the maximum value of the CPC class in consequence of the asymmetric distribution of the number of backward citations among the various technological fields of the patent family; the latter is normalized to the maximum value of the CPC class in consequence of the asymmetric distribution of the number of backward citations among the various technological fields of the patent family.

Similarly to the previous indexes, "**Backward document relevance index**" and "**Backward document impact index**" are based on calculations carried out on references to the scientific literature, that are "informative about the patent's value, though the average effect across all technology areas is smaller than for backward citations of patents" (Harhoff et al. 2003). The two measures are derived "from the relationship existing between a given patent and the body of

knowledge that preceded it" (Trajtenberg, 1997). Both are normalized to the maximum value of the CPC class in consequence of the asymmetric distribution of the number of citations among the various technological fields of the patent family.

The "**Forward citation index**" and the "**Normalized forward citation index**" measures the number of forward citations of a patent family but, while the former one is normalized to the maximum value within the CPC Class in consequence of the asymmetric distribution of the number of citations among the different technological fields, the latter is normalized to the maximum value of patents, belonging to the same CPC Class of the evaluated patent.

The "**Originality Index**" is based on those characteristics of innovation which are considered seminal parts of a technological flow, having its root in the preceding segment of knowledge, and contemporarily acting as a springboard for the following one. In this sense, the level of originality of a patent is inherent in the relationship between its "technological antecedents" (Trajtenberg et al., 1997), traced by patent citations, namely its prior art. According to its construct, we have put this index also in the category "Strategy".

The "**Applicability Index**" measures one of the sanctioned criteria of patentability: the industrial applicability of the invention in a large number of technological fields. It is reasonable, therefore, that those patents which can be applicable to a wide technological sector have a greater value than those patents which can be applicable to scarcely dimensioned sectors. According to its construct, we have put this index also in the category "Strategy". The measures of the index derive from the evaluation of the distribution of its forward citations within the various CPC Classes.

The "**Technology Strength Index**" of patents is calculated from the product of the geographic coverage of the patent (an indicator of the commercial relevance) by the number of forward citations (an indicator of the technological importance). Wider the market coverage, therefore, more important the technology, in particular, for the development of following technologies and products (Reitzig, 2004; Ernst and Omland, 2011). The number of forward citations of a patent represents the main

indicator of its technological strength and, consequently, it is a valid indicator of its value. According to its construct, we have put this index also in the category “Market conditions”. Also, in this case, the index is normalized to the maximum value of the patents of the same CPC Class of the evaluated patent.

The “**Innovative Scope Index**” measures the level of innovation, required for granting the patent. As not all patents own the same innovation capability, it is conceivable that citations of old patents show a low innovation capability. For this reason, in order to measure the innovativeness, it is necessary keeping into account the mean age of the prior art.

All the indexes proposed in the category “Technology” make reference to the item “citation”, both backward and forward and to citing or cited patents. There is a general agreement of researchers on the fact that patent citations represent the better approximation of the technologic value of a patent, even though some difficulties arise in applying these indexes in consequence of the complexity of the calculation of the variables relative to the citations themselves.

Patent value indexes of Market conditions

“Market conditions” expresses the valuation of the several factors which influence the marketing options and the business opportunities of the technology which are embedded in the patent. If in line with the legal status of the patent and with the technology prospects, these extrinsic factors show the potential value of the patented technology. The whole value of a patented invention severely depends on the importance of the markets where the patent has been protected (Ernst and Omland, 2011). All indexes of “Market condition” are related to the value of patents that are usually filed not only to protect inventions but also to produce revenues from commercialization initiatives. Both the “Market condition” indexes advanced in literature and those that have been elaborated by the authors are listed in Table 3.

Table 3 - Patent value indexes for the category "Market conditions"

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Patents are protected in national and international markets as the width of coverage of the markets is strictly related to the patent value. The **"Market Coverage Index"** is a measure of the extent of patent protection in global markets, namely, it considers the number of States where the patent is granted. It is important to consider that, as suggested by Ernst and Omland (2011), countries are to be treated as differently important in terms of their size (Sapsalis and van Pottelsberghe de la Potterie, 2007). A possible proxy for the country size is represented by the Gross Domestic Product of the country. This proxy can be furtherly improved by using the industry-specific or product-specific market information.

The "**Government Interest Index**" is a peculiar index in that it concerns the particular case of Government's interest in supporting the patent financially, or adopting actions of match-funding, or making use of it (Messeni Petruzzelli et al., 2014).

The "**Licensing Index**" (only EP) verifies the number of patent licensing events within a patent family. It has long been acknowledged the economic contribution acquired by firms by licensing patents (Gambardella et al., 2007). More protected patents have more possibilities to be licensed, and the higher the technological level of patents, the greater their economic value.

The **"Market Share"** measures the result achieved by the company which owns the patent and holds its exploitation, in terms of specific economic percentage of revenues compared to its competitors. It is a firm-specific index, so its calculation is strictly related to the availability of company's market share data. According to its construct, we have put this index also in the category "Finance".

The "**Herfindahl-Hirschman index**", commonly accepted to measure market concentration, is used to define "the concentration of patents across patent class and to measure the concentration level of a

firm's technology capability", (Chen and Chang, 2010). According to its construct, we have put this index also in the category "Finance"

In addition to these indexes, also the **"Technology strength index"**, which has been already defined in the category "Technology", falls into this category.

A limited number of indexes have been set forth to derive the value of patents usually filed to produce revenues from commercialization activities. As it is well recognized, these indexes have great potential: in fact, they succeed in matching different quantities and in taking into accounts various aspects concerning opportunities and performance of the market conditions.

Patent value indexes of Finance

The "Finance" category of patents, related to the extrinsic factors of the patented technology, evaluates the contribution provided (or which can be potentially supplied) by the patent to the firm profitability in terms of investments in the development of the product and of production and revenues of investments in R&D. Both the "Finance" indexes advanced in literature and those that have been elaborated by the authors are listed in Table 4.

Table 4 - Patent value indexes for the category "Finance"

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The three indexes "**Revenues From Patent**", "**Economic Relevance**", and "**Patent ROI**" get measures of the capability of patents to generate economic returns. In particular, in spite of the complexity of its calculation, the "Patent ROI" allows understanding whether a patent is profitable and in which field, in consequence of which operational components it is not profitable, and whether it is possible to evaluate to abandon it.

The two indexes "**Payback Period**" and "**Estimated Economic Relevance**" make use of information derived from cash-flow. In both cases, data derive from final outcomes or from accounting estimates available in business plans, depending on which phase of patent life-cycle is under evaluation, namely whether the patent has already generated revenues or not. The "Payback period" calculates the number of years necessary to reimburse the investment by means the cash-flow produced by patents. The "Estimated Economic Relevance" calculates the net present value of a patent. These two indexes are the only indexes that have not been normalized in order to comprise values between 0 and 1 since the index "Payback Period" is expressed in temporal measures and the index "Estimated Economic Relevance" is expressed in monetary terms.

In addition to the above-mentioned indexes, also the "**Innovative scope index",** which has been defined in the category "Technology", falls into this category, as well as "**Market share index"** and "**Herfindahl-Hirschman index**", which have been defined in the category "Market conditions".

The indexes proposed in the literature for the category "Finance" measure the contribution provided by the patent to the firm profitability in terms of investment in the development of products and of production of revenues of investment in R&D. These indexes are well known and usually applied in business management. They refer to already proposed financial indicators brought back to measure the patent value, such as the capability of patents to generate economic returns, the ROI, the payback period or the net present value.

Patent value indexes of Strategy

The "patent strategy" consists in the strategic purpose of patents. This evaluation field is centred on the degree of alignment of the patent with the corporate strategy. The firm analyzes if its patenting trend, in the technological class of the considered patent, is aligned whit that of its principal competitors and with that of the pertinent sector of activity, as well as it evaluates modalities and

frequency of usage data of the patent. Indeed, the patent can be used as a short-term defence tool, if connected to one or more products, or as a long-term attack tool, allowing firms to develop new products for new markets and giving them new business opportunities. All the strategic purposes of patents can be easily recognized as the result of the extrinsic dimensions of patents. Both the "Strategy" indexes advanced in literature and those that have been elaborated by the authors are listed in Table 5.

Table 5 - Patent value indexes for the category "Strategy"

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The "**Firm trend index**", the **Sector trend index**", and the "**Competitor index**" are three indexes that allow investigating the technological growth of the firm patent activity at different levels of strategic planning purposes, in order to modify investments to be more competitive.

The "**Relative patent position**" measures the level of the leading role of a firm in a specific technological field by means of the number of patents owned in that field by the firm compared to the leader in the same technological field (Chen and Chang, 2010).

The "**Patent development index**" measures the technological maturity of the invention (Hidalgo, 2006), developed in 11 steps, representing the strategic importance of the patent within the company.

The "**Product index**" measures the number of products linked to a patent and marketed, in order to analyze the level of strategy of the products (OuYang and Weng, 2011).

The "**Patent investment index**" measures the amount of investment made on a patent in consequence of the strategic interest of the company in that technology. The application of these last three patent value indexes is strictly related to the availability of company's patent data, such as levels of development, production, and investment.

In addition to these indexes, also the **“Applicability index”**, which has been already defined in the category “Technology”, falls into this category.

The indexes of the category “Strategy” advanced in literature aim at measuring the extrinsic dimensions of patents in relation to their strategic purposes and their degree of alignment with the corporate strategy. These indexes cover a large number of quantities to be measured that extend from the technologic trend analysis of the patent activity to the level of intensity of the investments and to the measurement of the technologic maturity of the invention.

Discussion, Conclusions and Future Research

In this paper, we have presented a systematic survey of all indexes, proposed in literature from 1997 to 2016 and utilized to measure the value of patents. The survey provides a piece of exhaustive landmark information on patent value measurement by means of calculable entities. We have analyzed the functions of each index proposed in the literature and, in some cases, we have re-elaborated their formulation to provide a comprehensive index, deriving from multiple contributions. Then, we grouped the indexes into the five categories as suggested by the European Patent Office and distinguished for their intrinsic (legal status and technology) and extrinsic (market, economy, and strategy) features.

The analyzed and classified indexes, singled out in our review, are able to take into consideration both the technologic and economic worth of patents, that is, both the aspects related to the innovation process and the peculiarities concerning the commercialization activities. In addition, among the practical benefits for business users of the present review, there is the possibility of finding, within the wide range of the indexes of the five proposed categories, the most appropriate answer for measuring the value of patents.

For the analyzed categories we have highlighted here below those sides that lay open to criticism. Several papers have dealt with the intrinsic aspect of the “Legal status” of the patents from various perspectives in order to assess their value. However, although the information acquired provides a great potential for measuring the “legal” value of patents, it is necessary to consider that the calculation of these indexes, in spite of their easy implementation, depends on the availability of data: these must be retrieved from specialized databases or provided by the patent offices. These data are essential for obtaining indexes and this means that all firms that cannot access to patent information databases to source the necessary elements, at an economically acceptable price and in a reasonable time, are unable to calculate the “Legal status” indexes and to take advantage of their implementation. Therefore, greater efforts would be needed to ensure them a fast and economically advantageous track to access and obtain the necessary data.

As for the category “Technology”, all indexes proposed in the literature refer to the item “citation”, relative to backward or forward and to citing or cited patents. The calculation of the variables revealed to be complex for those citations like the “number of backward citations which do not have the same CPC class” or the “number of forward citations of the backward citations of a patent”. A reasonable approach to tackle this issue would be the formulation of alternative indexes, inspired by the patent intelligence, able to quantify and evaluate the technologic positioning of a patent, maybe by means of a comparative technologic analysis with other patents of the same CPC, or by the study of new product/process development deriving from that patent.

Indexes of the category “Market conditions” have the advantage of being well known as they are usually utilized in business and management activities and have been expressly reconfigured and applied to patent valuation. On the other hand, it seems that greater efforts are needed to ensure that extrinsic factors concerning the valuation of the business opportunities of the technology are more investigated. Indeed, there is a need for further indexes to measure quantities as the market position

of the patent owner in the market, or to account for the commercial performance of its products and technologies, or to determine the commercial value of a patent.

As for the indexes of the category “Finance”, in spite of the fact that familiarity with these indexes facilitates their application, it should be noted that their effective calculation is not easily made, as it is necessary to mine patent data out of financial company information storage, such as revenues, earnings, investments, costs, and cash flow of the patent. Furthermore, in case the patented technology is tied to numerous products or processes, the procedure is more complex and even more difficult is the identification of the financial value of a multi-patented technology. In this connection, it would be appropriate to encourage studies designed to investigate models and methods to calculate the value of the main financial quantities directly ascribable to a patent. A further point that should be noted is that, in the managerial activity, financial quantities are often measured through intangible valuations or internal analyses as perceived by managers; therefore, it would be worthwhile to direct future investigations towards this research branch. Finally, it would be interesting to promote studies that allow the benchmarking between the analyses carried out by means of financial indexes valuation and those by managers’ perceptions.

As for the indexes in the category “Strategy” it should be noted that, in spite of their - wide potential, there is evidence in the literature that more research is required to determine indexes based on patent intelligence instruments or on competitive benchmarking or on the analysis of the competitive landscape. A further study, also, could obtain indexes able to quantify the strategic positioning of a patent, by means of the technologic-strategic analysis of other patents within the same CPC class or of similar patents that belong to different CPCs class.

The more significant outcome to emerge from this review is that patent indexes are managerial and evaluative tools, well consolidated by their use in the field of patent value assessment. In literature, there are numerous indexes, aimed at the identification of proxies of patent value. Despite the substantial potential of such indexes, there are some areas that have been little explored and that could

be further investigated. Moreover, according to what has been said here above in the discussion on the indexes proposed in the literature, the research has thrown up many questions in need of further consideration. Indeed, it seems necessary to go beyond the quantitative analyses of the mere dimensions retrieved from database or registers of patent offices, by advancing qualitative indexes to be applicable easily by firms that cannot access to patent information databases. Future research should concentrate on the definition of further indexes that refer to patent intelligence and quantify the strategic-technologic positioning of patents. Another possible purpose would be to measure the business opportunities of the technology or, more in general, the potential value of the patented technology. Moreover, considerably more work will need to be done to determine indexes able to account for the commercial value of a patent and the commercial performance of patent products and technologies. In addition, a fruitful area for further work would be to propose indexes for the measurement of the patent financial quantities through intangible valuations or firm analyses, based on managers' perceptions. Finally, future trials should assess the strategic positioning of a patent by means of patent intelligence instruments or the analysis of the competitive landscape.

Summing up the examined points, the natural progression of this work would be to put forward the definition of an aggregation of quantitative procedures based on indexes, able to measure various patent value features. Indeed, the systematic analysis of this review has put into evidence the lack of a strategic managerial implement, based on a dashboard of quantitative indexes, that would make it possible to measure the contributions from the various value areas of patents in order to set up the appropriate management strategy to exploit patents or patent portfolios value. It appears that most patent value indexes, proposed in the literature, consider patent value as a single, specific topic: this assumption seems to differ from the opinion held by many researchers who think that the dimensions of the patent value embrace a wide range of perspectives. With this in mind, future research should, therefore, concentrate on the investigation of the specific characterization of the aggregate value of each of the five categories by examining all the pertinent indexes, or on the identification of

managerial tools, finalized to understand which category would mainly influence (both positively or negatively) the aggregate value of a patent or of a patent portfolio.

We are deeply aware of the fact that, dealing with a systematic literature review, the contribution of the present paper is theoretical in nature. Nevertheless, the classification of indicators is of great interest to those who are involved in patent value definition. The paper, indeed, in addition to providing a complete overview of the indexes proposed in the literature to the present day, makes it possible to focus the attention on a specific area of major concern, such as the legal or technological one, rather than the market, or financial, or strategic ones. The indexes selected and then listed in this paper can act as founding elements of managerial tools and of the patent valorization, both aimed at the comprehension of the causal dynamics of the value creation. Overall, we are confident that our study offers a valuable systematization and consolidation of extant research and will serve as a platform for future research efforts and practical applications on patent value measurement.

References

Abraham, B. P. & Moitra, S. D. (2001). Innovation assessment through patent analysis. *Technovation*, 21, 245-252.

Adams, R., Bessant, J., Phelps, R. (2006). Innovation management measurement: A review. *International Journal of Management Reviews*, 8, 21–47.

Alyari, F., & Jafari Navimipour, N. (2018). Recommender systems: A systematic review of the state of the art literature and suggestions for future research. *Kybernetes*, 47(5), 985-1017.

Argandoña, A. (2003). Fostering values in organizations. *Journal of Business Ethics*, 45(1-2), 15-28.

Bekkers, R., Bongard, R., Nuvolari, A. (2011). An empirical study on the determinants of essential patent claims in compatibility standards. *Research Policy*, 40(7), 1001-1015.

Bessen, J. & Meurer M. (2008). Patent failure: how judges, bureaucrats and lawyers put innovators at risk. Princeton, NJ: Princeton University Press.

Bessen, J. (2008). The value of US patents by owner and patent characteristics. *Research Policy*, 37(5), 932-945.

Blind, K., Cremers, K., Mueller, E. (2009). The influence of strategic patenting on companies' patent portfolios. *Research Policy*, 38, 428–436.

Bonaccorsi, A. & Thoma, G. (2007). Institutional complementarity and inventive performance in nano science and technology. *Research Policy*, 36, 813–831.

Calabrese, A. & Costa, R. (2015). Strategic thinking and business innovation: Abduction as cognitive element of leaders' strategizing. *Journal of Engineering and Technology Management - JET-M*, 38, 24-36.

Caviggioli, F., Scellato, G., Ughetto, E. (2013). International patent disputes: Evidence from oppositions at the European Patent Office. *Research Policy*, 42, 1634– 1646.

Charband, Y., & Jafari Navimipour, N. (2018). Knowledge sharing mechanisms in the education: A systematic review of the state of the art literature and recommendations for future research. *Kybernetes*, 47(7), 1456-1490.

Chen, D.Z., Lin, W.Y., Huang, M.H. (2007). Using essential patent index and essential technological strength to evaluate industrial technological innovation competitiveness. *Scientometrics*, 71(1), 101-116.

Chen, Y. S. & Chang, K. C. (2010). The relationship between a firm's patent quality and its market value—the case of US pharmaceutical industry. *Technological Forecasting and Social Change*, 77(1), 20-33.

Chen, Y.M., Liu, H.H., Liu, Y.S., Huang, H.T. (2016). A preemptive power to offensive patent litigation strategy: Value creation, transaction costs and organizational slack. *Journal of Business Research*, 69(5), 1634-1638.

Christoffersen, J. (2013). A review of antecedents of inter-national strategic alliance performance: synthesized evidence and new directions for core constructs. *International Journal of Management Reviews*, 15, 66–85.

Deng, Z., Lev, B., Narin, F. (1999). Science and technology as predictors of stock performance. *Financial Analysts Journal*, 55(3), 20-32.

Dolfsma, W. (2011), Patent strategizing, *Journal of Intellectual Capital*, 12(2), 168-178.

Ernst, H. (1995). Patenting strategies in the German mechanical engineering industry and their relationship to company performance. *Technovation*, 15(4), 225-240.

Ernst H., Legler S., Lichtenthaler, U. (2010). Determinants of patent value: Insights from a simulation analysis. *Technological Forecasting & Social Change*, 77, 1–19.

Ernst, H. (2003). Patent information for strategic technology management. *World Patent Information*, 25(3), 233–242.

Ernst, H., Omland, N.(2011). The Patent Asset Index – A new approach to benchmark patent portfolios. *World Patent Information*, 33, 34–41.

Fabry, B., Ernst, H., Langholz, J., Köster, M. (2006). Patent portfolio analysis as a useful tool for identifying R&D and business opportunities—an empirical application in the nutrition and health industry. *World Patent Information*, 28, 215–225.

Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., Pappas, G. (2008). Comparison of PubMed, Scopus, web of science, and Google scholar: strengths and weaknesses. *The FASEB journal*, 22(2), 338-342.

Fischer, T. & Leidinger, J. (2014). Testing patent value indicators on directly observed patent value -An empirical analysis of Ocean Tomo patent auctions. *Research Policy*, 43, 519–529.

Gambardella, A., Giuri, P., Luzzi, A. (2007). The market for patents in Europe. *Research Policy*, 36, 1163–1183.

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., … Hoisl, K. (2006). Everything you always wanted to know about inventors (but never asked): Evidence from the PatVal-EU survey. *Centre for Economic Policy Research*.

Garg, K. C. & Padhi, P. (1998). Scientometric study of laser patent literature. *Scientometrics*, 43, 443–454.

Greer, C.R. & Lei, D. (2012). Collaborative innovation with customers: a review of the literature and suggestions for future research. *International Journal of Management Reviews*, 14, 63–84.

Grimaldi, M., Cricelli, L., Di Giovanni, M., Rogo, F. (2015). The patent portfolio value analysis: A new framework to leverage patent information for strategic technology planning. *Technological Forecasting and Social Change*, 94, 286-302.

Hagedoorn, J. & Cloodt, M. (2003). Measuring innovative performance: Is there an advantage in using multiple indicators? *Research Policy*, 32, 1365–1379.

Harhoff, D., Narin, F., Scherer F. M., Vopel, K. (1999). Citation Frequency and the Value of Patented Inventions. *The Review of Economics and Statistics*, 81(3), 511-515.

Harhoff, D., Scherer, F. M., Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy*, 32, 1343–1363.

Hidalgo, A. (2006). Planning for new products in the extended enterprise: the automotive scenario. *International Journal of Product Development*, 3(2), 214-231.

Hikkerova, L., Kammoun, N., Lantz, J.S. (2013). Patent life cycle: New evidence. *Technological Forecasting & Social Change*, 88, 313-324.

Hsieh C.H. (2012). Patent value assessment and commercialization strategy. *Technological Forecasting & Social Change*, 80(2), 307–319.

Karki, M.M.S. (1998). Patent Citation Analysis: A Policy Analysis Tool. *World Patent Information*, 19(4), 269-272.

Klaila, D. & Hall, L. (2000). Using intellectual assets as a success strategy. *Journal of Intellectual Capital*, 1(1), 47-53.

Lagrost, C., Martin, D., Dubois, C., Quazzotti, S. (2010). Intellectual property valuation: how to approach the selection of an appropriate valuation method. *Journal of Intellectual Capital*, 11(4), 481-503.

Lanjouw, J. O. & Schankerman, M. (2001). Characteristics of patent litigation: a window on competition. *RAND Journal of Economics*, 13, 129–51.

Lanjouw, J. O., Pakes, A., Putnam J. (1998). How to Count Patents and Value Intellectual Property: The Uses of Patent Renewal and Application Data. *The Journal of Industrial Economics*, 46(4), 405-432.

Lanjouw, J. O. & Schankerman M. (2004). atent Quality and Research Productivity: measuring innovation with multiple indicators. *The Economic Journal*, 114, 441–465.

Meier, M. (2011). Knowledge management in strategic alliances: a review of empirical evidence. *International Journal of Management Reviews*, 13, 1–23.

Messeni Petruzzelli, A., Rotolo, D., Albino, V. (2014). Determinants of patent citations in biotechnology: An analysis of patent influence across the industrial and organizational boundaries. *Technological Forecasting & Social Change*, 91, 208-221.

Moore, G.E. 1903. Principia Ethica. Cambridge: Cambridge University Press.

Nagaoka S, Motohashi K, Goto A. In: Hall BH, Rosenberg N, editors. Patent statistics as innovation indicators, in the handbook of the economics of innovation. Elsevier Ebook; 2010.

Nielsen, P. E. (2004). Evaluating patent portfolios - a Danish initiative. *World Patent Information*, 26(2), 143-148.

Noblet, JP., Simon, E., Parent, R. (2011). Absorptive capacity: a proposed operationalization. *Knowledge Management Research & Practice*, 9(4), 367-377.

Nordhaus, W. D. (1969). An economic theory of technological change. *The American Economic Review*, *59*(2), 18-28.

OuYang, K. & Weng, C. S. (2011). A New Comprehensive Patent Analysis Approach for New Product Design in Mechanical Engineering. *Technological Forecasting & Social Change*, 78, 1183–1199.

Randolph, J. J. (2009). A guide to writing the dissertation literature review. *Practical Assessment, Research & Evaluation*, *14*(13), 1-13.

Reitzig, M. (2003). What determines patent value? Insights from the semiconductor industry. *Research Policy*, 32, 13–26.

Reitzig, M. (2004). Improving patent valuations for management purposes —validating new indicators by analyzing application rationales. *Research Policy*, 33, 939–957.

Sapsalis, E., van Pottelsberghe de la Potterie, B. (2007). The Institutional Sources of Knowledge and the Value of Academic Patents", *Economics of Innovation and New Technology*, 16(2), 139-157.

Shane, S. (2001). "Technological Opportunities and New Firm Creation. *Management Science*, 47(2), 205–220.

Sivarajah, U., Kamal, M.M., Irani, Z., Weerakkody, V. (2017). Critical analysis of Big Data challenges and analytical methods. *Journal of Business Research*, 70, 263-286.

Soltani, Z., & Navimipour, N. J. (2016). Customer relationship management mechanisms: A systematic review of the state of the art literature and recommendations for future research. *Computers in Human Behavior*, 61, 667-688.

Striukova, L. (2007). Patents and corporate value creation: theoretical approach. *Journal of Intellectual Capital*, Vol. 8 No. 3, 431-443.

Thoma, G. (2014). Composite value index of patent indicators: Factor analysis combining bibliographic and survey datasets. *World Patent Information*, 38, 19-26.

Thorpe, R., Holt, R., Macpherson, A., Pittaway, L. (2005). Using knowledge within small and medium-sized firms: a systematic review of the evidence. *International Journal of Management Reviews*, 7, 257–281.

Trajtenberg, M., Henderson, R., Jaffe, A. (1997). University versus Corporate Patents: a window on the basicness of invention. *Economics of Innovation and New Technology*, 5, 19-50.

Trappey, A. J. C., Trappey, C. V., Wua, C.Y., Lin, C.W. (2012). A patent quality analysis for innovative technology and product development. *Advanced Engineering Informatics*, 26, 26–34.

Vakili, A., & Navimipour, N. J. (2017). Comprehensive and systematic review of the service composition mechanisms in the cloud environments. *Journal of Network and Computer Applications*, 81, 24-36.

van Zeebroeck, N. (2011). The puzzle of patent value indicators. *Economics of Innovation and New Technology*, 20(1), 33-62.

van Zeebroeck, N., van Pottelsberghe de la Potterie, B., Guellec, D. (2008). Patents and academic research: a state of the art, *Journal of Intellectual Capital*, 9(2), 246-263

van Zeebroeck, N., van Pottelsberghe de la Potterie, B. (2011). Filing strategies and patent value. *Economics of Innovation and New Technology*, 20(6), 539–561.

Wang X., Zhao, Y., Zhang J., et al. (2014). Patent portfolio analysis model based on legal status information. *Chinese Journal of Library and Information Science*, 7(1), 69-83.

Wu, M.C. (2011). Antecedents of patent value using exchange option models: Evidence from a panel data analysis. *Journal of Business Research*, 64(1), 81-86.

Yeo, R. & Marquardt, M. (2015).To share or not to share? Self-perception and knowledge-sharing intent. *Knowledge Management Research & Practice*, 13(3), 311-328.

Zakery, A. & Afrazeh, A. (2017). Analysing intellectual capital management and growth based on dynamic modelling. *Knowledge Management Research & Practice*, 15(1), 101-113

Zhang, S., Yuan, C.C., Chang, K.C., Ken Y. (2012). Exploring the nonlinear effects of patent H index, patent citations, and essential technological strength on corporate performance by using artificial neural network. *Journal of Informetrics*, 6, 485– 495.

Zimmerman, M. J. (2001). The nature of intrinsic value. Rowman & Littlefield Publishers.