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Disadvantages of Patent Performance Indicators in Performance-Based Research Funding Systems

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Abstract

Although the use of patent indicators in statistics has been under discussion for a long time, there are surprisingly very few studies devoted to explaining the use of patent indicators as performance indicators in performance-based research funding systems. The widespread assumption is based on the perception that patents have some recognizable value as an element of innovation process and this value is undoubtedly transferred to patents that are created in order to fulfil performance indicators. However, there is still no established distinction in the literature between patent indicators used in statistical analysis and patent performance indicators used as goal setting and evaluation tools in the context of performance-based research funding systems. This article is aimed at filling the gap and seeks to clarify the theoretical validity of the use of patent performance indicators in such context. Based on the review of the literature, the article compares the results of seminal works on the nature of patenting and patent indicators to the purposes of its use as patent performance indicators in performance-based research funding systems. The results demonstrate at least five arguments in favour of the statement that the use of patent indicators in the context of performance-based research funding systems requires rethinking.

Keywords

Research policy, Performance-based research funding systems, Public research organizations, Performance indicators, Patent indicators, Side effects, Moral hazard

JEL Classification

I23, I28, O31, O34, O38

Introduction

Performance indicator concept in performance-based research funding systems

Performance-based research funding system (PRFS) is considered a funding mechanism, which provides competitive allocation of organizational level (institutional) funding to research organizations based on the ex post assessment of their research performance (Hicks, 2012). After the first PRFS was implemented in the UK in 1986, the use of PRFSs expanded considerably - some countries also began to implement and develop their national versions of PRFSs, shaping a worldwide trend in global research policy. This trend received particular dissemination in the European area, where one of the main priorities of the European Research Area (ERA) involves the need to increase the effectiveness of public research systems through the introduction of funding mechanisms linked to performance. By 2019, more than a half of EU members had implemented PRFSs or at least adopted some of its key features in the framework of national research policy (EC, 2019; Zacharewicz et al., 2019).

The key element of PRFS is the use of performance indicators (Cave et al., 1997; Hansen, 2010). Performance indicators serve as tools, by which funding bodies can conduct an unbiased comparison of organization performance and take decisions on incentives allocation. However, the exact definition of performance indicators in science is still being discussed in written works. The authors, describing the main feature of indicators that makes it different from simple statistic data, highlight that the creation and use of indicators are always based on accepted theoretical assumptions, hypotheses or models of scientific development and its interaction with society (Holton, 1978; Godin, 2003; Grupp and Mogee, 2004; van Raan, 2004).

This understanding of indicators nature was reproduced when indicators started to be used as performance indicators in performance-based systems. Bence and Oppenheim (2005) indicate that at the core beginning of the first PRFS introduction, Cuenin (1986) drew a distinction between simple indicators, general indicators and performance indicators. Simple indicators are usually expressed in the form of absolute figures and are intended

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to provide a relatively unbiased description of a situation or process. General indicators are mainly derived from outside the institution and can be as diverse as opinions, survey findings or general statistics. Performance indicators differ from simple indicators in that they imply a point of reference, a standard, an assessment or comparator, and are therefore relative rather than absolute in character, 'although a simple indicator is the more neutral of the two, it may become a performance indicator, if a value judgement is involved' (Cave et al, 1988, p. 17; Bence & Oppenheim, 2005).

Herbst (2007) referencing to Kells (1986) argues that the term 'performance indicator' has been reserved for the situation where indicators are tied to the allocation of resources, i.e. to performance-based funding or budgeting. Thus, the term 'performance indicator' means that recipients of public funding have them specified in agreements or just aware what will be evaluated after research is completed. This feature of performance indicators is radically in contrast to usual indicators which are used as statistical tool for interpretations and do not serve for the purposes of stimulation.

Patent indicators as performance indicators (patent performance indicators) in PRFSs

Patent activity is often considered to be worth and convenient for stimulation by default. Patents seem precisely registered, indisputable and countable units of applied research. Each patent already comprises the R&D result infringement search conducted by a patent office, which is independent from funding agencies or funding recipients. The initial data on granted patents can be clearly counted for the purposes of measurement and then provided to any interested bodies without implementing any additional tools for statistical observation.

Such attributes of patents are similar to research articles where three analogous attributes can be found: a fully-fledged item of research performance, an independent peer review, and understandable counting for performance measurement. Bassecoulard and Zitt suggest closer comparison stating that 'publications and patents as information supports have many analogous features (author/inventor, institution/assignee, bibliographic referencing/patent system referencing, bibliometric classification/official classification, abstract, full text, references to scientific literature/references to patent or non-patent literature, etc.)' (Bassecoulard and Zitt, 2004, p. 666).

It all leads to the temptation of considering patent performance indicators as a mirror image of publication performance indicators to stimulate performance at the applied stage of research. The use of patent performance indicators as an element of PRFSs has been widely adopted, although most of the literature on PRFSs does not focus on this in detail. According to the report of the European Commission's Joint Research Centre (Jonkers & Zacharewicz, 2015), patent performance indicators have become elements of national PRFSs in at least 10 EU countries (the patent indicators are mentioned in the description of PRFSs in Czech Republic, Denmark, Estonia, France, Hungary, Italy, Lithuania, Luxembourg, Poland, Slovakia). Zacharewicz et al. (2019) indicate that patents are used as elements of funding formula in eight of them (France and Hungary are excluded). Funding formulas of this kind include the number of patents, which may be restricted to i.e. PCT and EPO patents or may also involve patent filings at national patent offices. Patent performance indicators are also used at the supranational level (i.e. Horizon 2020) and in PRFSs outside the EU.

At the same time, very few studies mention deeper theoretical explanations of the use of patent indicators as performance indicators in PRFSs and its possible impact. The widespread, implicit assumption is based on the perception that patents have some recognizable value as an element of innovation process and this value is undoubtedly transferred to patents that are created in order to fulfil patent performance indicators. In other words, despite the well-known difficulties in interpreting patent statistics, increasing patenting is considered as an absolute value, which in one way or another brings benefits. For example, regarding university sector, Azagra Caro et al. (2003) state that patents are considered the result of academic research and, at least a priori, a means of raising funding through licensing, R&D grants and contracts.

Mortensen (2011), whose study is exclusively dedicated to application of patent performance indicators in PRFSs, expresses the common view saying that the most important political motive for promoting academic patenting is to increase and improve the diffusion of knowledge from public funded science to technology, i.e. from universities and PROs to society and industry. He insists that most of the arguments regarding the usefulness and validity of patenting for universities and PROs also hold good when considering the inclusion of patent indicators in the performance indicators of universities and PROs for allocating research funding. The implementation of patent performance indicators is tied to the fact that most countries have accepted the triple-helix concept for universities, the new, third element being the communication and exploitation of research through relations with industry and society (Mortensen, 2011).

However, according to Mortensen, patent performance indicators should not be a simple calculation of the number of patents, as many countries consider them to be. The use of patent performance indicators is reasonable only if these indicators are able to encompass the estimates of patent value, indicators of cooperation and the effects of patenting (licensing, spin-offs and royalties). Thus, he suggests constructing patent performance indicators in a more sophisticated way and using for this purpose the data derived from patent documents, applications and other related information (Mortensen, 2011).

The evaluation of possible impact of the use of patent performance indicators in the context of PRFSs has also received little attention in contrast to publication indicators. One of the closest contributions is made by Vanecek (2013) who analyses annual changes in a number of various types of publications and applications including patents before and after the implementation of the Czech PRFSs. He indicates that the growth-rate of patent applications and patents has considerably increased right after the introduction of the annual evaluation of R&D institutions in 2004. At the same time, the results of patent activity stimulation occurred to be unclear because the number of the sold licenses by the Czech subjects has not increased (Vanecek, 2013).

This article is aimed at filling the literature gap and seeks to systemize the theoretical justification of the use of patent performance indicators in PRFSs context. Based on the review of the literature, the article compares the results of seminal works on the nature of patenting and patent indicators to the purposes of its use as patent performance indicators in PRFSs. This paper does not aspire to be an exhaustive review of contributions on this subject. At the same time, it reflects the consistent development of beliefs about the essence of patenting and patent indicators, and the interpretation of these beliefs provides at least five arguments in favour of the statement that the use of patent indicators in the context of PRFS requires rethinking.

Methods

The argumentation of this paper is not focused on the development of classical opposition to patent indicators as economic indicators meaning that not all innovations are patentable and not all patentable innovations are patented (Desrochers, 1998; Funk, 2018), though sometimes both inevitably overlap. In the context of PRFSs, it is assumed that the recipients of public funding have to patent patentable innovations. In contrast to the mainstream critique of patenting, which is primary in terms of economic policy, the argumentation of this article focuses on public research policy: it examines patenting and patent indicators in the context of their use as performance indicators in PRFSs and their compliance with policy makers intentions to achieve the national innovation development agenda through PRFSs. Taking into account this purpose, the two necessary attributes of patent indicators in the context of PRFSs are mentioned while patent literature is analysed.

First, patent indicators should reflect the agent’s research activity, which inevitably and regardless of the agent's biases leads to the outcome results. The outcome results can be defined as an impact on economic growth, innovation development or any other positive influence on society. The interrelation between patents (outputs) and desired outcome results should be traced on a solid, unambiguous basis.

Second, patent indicators should be able to measure the essence of efforts exerted by an agent to achieve the outcome result. It is of key importance in the context of PRFSs to have the ability to distinguish true efforts from imitation. In other words, patent indicators should significantly limit the opportunities for generating empty, useless outputs, to use the patenting in a perverse way or be a cause of any other unintended effects.

Considering the abovementioned necessary attributes of patent indicators in the context of PRFSs, the studies on the problems of patenting and the use of patent indicators have been analysed. Initially, the attention has been focused on the problem-driven re-interpretation of the seminal works from the 1960s to the 2010s. Simultaneously, the corpus of the considered works was broadened by references given. Additionally, to avoid the risk of missing valuable ideas, special reviews were also examined (i.e. Baldini, 2008). The results of the literature analysis are summarized in 5 arguments.

Results

Argument 1: Patents are consequences, but not the reason for economic growth

In the studies devoted to patent interpretations and patent indicators, the seminal Schmookler’s contribution is often considered as a root of all works on this subject. Schmookler’s explanation of the correlation between patent activity and economic growth is still the most comprehensive attempt to interpret the phenomenon of patenting.

Schmookler never doubts the value of patents as an important part of economic growth. He easily disputes the popular concern that there are a lot of useless papers among patents: he referenced the results of Patent Foundation research in Washington, which were, he argued, in line with other independent data, and these results showed that 40-50% of inventions patented by independent inventors and 55-65% of inventions patented by corporations were used for commercial purposes (Schmookler, 1962). Today the situation is quite different; however, Schmuckler's conviction of the importance of patents only adds value to his interpretations, since the use of patent performance indicators in PRFSs is based practically on the same belief.

Schmookler follows Simon Kuznets’s methods and investigates the big data on production output and the number of the corresponding patents that appeared over the period from the mid-19th century up to the year 1950 (in the two industrial sectors, for which he succeeded in establishing the best-documented chronology of major inventions - railroad and petroleum development). He comes to the conclusion that there is a direct correlation between production output and the level of the correspondent patent activity; patenting in this case occurs with a time lag. He argues that this correlation cannot be explained by the hypothesis that patent activity specifies production output. Rather the opposite, it would seem that necessary conditions for valuable inventions - the expected profit from inventions, the possibility of their financing, the number of potential inventors, and dissatisfaction that constantly encourages improvements, - all these most likely directly depend on the level of sales. According to Schmookler, the fact that major and minor inventions in the existing sectors tended to appear simultaneously, was further evidence that inventive efforts were a response to the economic pressure and the provided economic opportunities (Schmookler, 1962).

In his later works, Schmookler develops this idea considering technological changes the result of economic activity rather than something exogenous. For example, he shows that inventive activity in the production means directly depends on the output of the respective production means. It indicates that R&D activity is most commonly the result of a high demand for production means rather than its reason (Schmookler, 1972). Putting it more generally, the main Schmookler’s idea implies that technological progress is closely determined by economic phenomena. The society here may influence stimulation of inventive activity through market mechanisms to the same degree, to which it influences the distribution of economic resources as a whole (Schmookler, 1962).

Schmookler's ‘demand-pull’ model has not been fundamentally disputed (Scherer, 1982; Kleinknecht & Verspagen, 1990; Brouwer & Kleinknecht, 1999), although since the 1980s, this model seems to have been integrated into the ‘multidimensional’ models of explanations of technological innovations (Godin & Lane, 2013). According to Godin and Lane (2013), the most influential criticism is expressed by Mowery and Rosenberg (1979) who indicate methodology limitations of Schmuckler's hypothesis, namely that there is no clear distinction between needs and demand. ‘(Human) needs are unlimited, and therefore not capable of driving decisions about research, while market demand is identifiable using precise (economic) criteria’ (Godin & Lane, 2013, p. 634). It seems that this vague definition of demand in Schmuckler's model hampered its rigorous application in economic theory.

However, neither Schmuckler’s critics nor the creators of the new models have proposed an alternative explanation of the factors affecting the emergence of valuable patents. In Schmookler’s theory, an inventor’s productivity is determined by a set of economic factors and incentives that put pressure on the inventor encourage creating valuable objects and finally make the inventor closely interact with the market. For purposes of research policy, the most important is the fact of determining pressure existence and its close influence on the desired outcomes of invention activity – and these statements of Schmookler’s findings still haven’t been disputed.

Taking into account Schmookler’s explanations, patents are consequences, but not the reasons for economic growth. Thus, stimulating patent activity in the context of PRFSs must create an inverted system of motivation, encouraging formal manifestations instead of the primary cause. In the case of PRFSs, inventors are also under pressure, but one of non-market character artificially designed by a funding agency. The inventor, as an agent in PRFSs, has to be focused on patenting, but the dominant motivation is to fulfill the patent performance indicator. In this model, the inventors' efforts no longer necessarily follow the demand of the market; more important for them in these circumstances is the ability to find uncovered patent gaps and to thoroughly know the patenting procedure when registering an increasing number of patents. This argument shows us that the traditional assumption about valuable patents, which implicitly stands behind the use of patent indicators in PRFSs, has a vulnerability – it does not take into account the changing nature of patent purposes.

Argument 2: Patent counting do not reveal actual efforts of agents for innovation development

The next step in the evolution of patent beliefs was made after the 1970s, when the NSF started to issue a series of Science Indicators reports for the USA Congress where patent indicators were involved among other indicators. The attention of researches was directed to the ability of patent indicators to show tendencies in the development of high-tech industries. The particular interest for policy makers was the possibility - provided by indicators - of international comparisons including the efficiency of national R&D activities.

However, the assumption that patent data describes the development of industries and thus can be used for the evaluation of national industry development was questioned. Firstly, it was emphasized that patents did not reflect the entire spectrum of R&D activity. Secondly, patent data did not allow reliable normalization for comparison purposes.

For instance, Pavitt (1982) indicates that innovation, not technology, is vital for industrial organizations. Therefore, patents can be considered as only one of the means among others, by which entrepreneurs can protect their innovations. In other words, the role of patents is limited to maximizing monopoly profits from innovation by making it more difficult for potential competitors to copy or imitate. Other methods used by industrial organizations along with patenting involve secrecy, further technological advance based on firm-specific R&D, the development of special skills of the stuff, influence over suppliers or marketing outlets, and manipulation of standards (Pavitt, 1982). Thus, patent activity and the rise of innovations and hence economic growth (the desired impact of every national research policy) are not directly tied and patents indicators do not reflect the actual national efforts for innovation development.

Another phenomenon that attracted the attention of researchers is the varying intensity of patent activity, which depends not only on industry specific features, but also on the size of a company. For instance, authors reference data on R&D dynamics and patenting in the US and UK shows that as the size of a company increases, the ratio of R&D expenses on sales also increases, but the number of patents per unit of R&D expenses decreases (Schmookler, 1966; Taylor & Silberston, 1973; Soete, 1979).

If we consider the number of patents as an indicator of the R&D output, the phenomenon mentioned above leads to the conclusion that either large firms are less efficient in performing R&D than small ones, or that R&D productivity steadily decreased since the late 1950s. However, no evidence of low R&D efficiency in large firms or a decrease in R&D productivity was revealed (i.e. Cohen et al., 1987).

Soete (1979) attempts to explain this phenomenon in terms of the propensity of larger firms to spend more on new meaningful R&D than to simply ramp up patenting as a means of protection against actual or potential competitors. Thus, studying the dynamics of patenting in the US, he suggests that the decline since the late 1950s in the number of patents on the volume of industrial R&D can be explained by the increase in the concentration of industry, which occurred in America at the same time (Soete, 1979).

Pavitt provides another explanation related to the changing nature of industrial R&D as firms grew. R&D by large firms focuses more on testing, applied engineering, systems and manufacturing know-how, which is increasingly difficult to patent. As R&D activity expands and increases, R&D statistics cover more and more types of firm innovation, with the share of patents in the observed R&D activity falling (Pavitt, 1982).

These debates demonstrate that although patent documents contain the output of R&D activity, simultaneously, patent indicators are not able to measure the actual agent's efforts for innovation. In contrast to publication indicators, where a normalized rate of publication activity can be established for scientific disciplines, the nature and intensity of patent activity depends on many additional factors, from the size of the entity and its concrete innovation strategy to the current state of an industry and the behaviour of industrial competitors.

In the context of the deliberate stimulation of patent activity by patent performance indicators, the above-mentioned arguments mean that a funding agency will not be able to judge the actual performance of agents. For example, an agent can make great efforts to innovate, involve a lot of research personnel, spend considerable amount of funds and finally may get one patent. Another agent can get ten patents without significant efforts by simply patenting around known inventions.

One may claim that this argument is just against using a simple number of patents and that patent indicators should be designed with an ability to differentiate the value of patents, as many authors suggest. However, the focus of this argument is directed at a different aspect. It explains the situation highlighting that patents are primary the means of protection, not the means of development. When, in PRFSs, development activity is stimulated by patent performance indicators, it leads primarily to the multiplication of protection means, not to the multiplication of development outputs. The particularity of patent procedures is that a patent office only verifies a certain level of technology novelty, but does not measure the value of an invention and its applicability. Without being bounded to the outcomes, agents are able to legally reproduce the same invention or unused developments numerous times with insignificant changes in order to fulfil patent performance indicators in the easiest way.

Argument 3: Patents are barriers for innovation development

The argument about the negative consequences of an increasing number of patents was first voiced in the 19th century. Michel Chevalier, the French economist, minister and active participant in the well-known intellectual property debate of the 1850–1875, warned that the patent system would produce juridical uncertainty for firms and would lead industry back to a guild system where no entrepreneur would dare to enter the market for fear of being sued by patent holders (Rouanet, 2015). This idea was resurrected and represented in a new form during the 1980s.

Hippel (1988) describes a number of studies carried out by several authors within almost 30 years (from 1957 to 1984), in which representatives of companies conducting intense activity in the field of R&D and innovations, were questioned if they considered patents useful for excluding imitators and/or acquiring income from royalty. An almost unambiguous answer was received in all surveys: the issuance of patents was useless in most industries for any given purpose (Hippel, 1988).

Thus, Levin et al. (1986) surveyed 650 R&D executives in 130 different industries in the mid-1980s. Opinions on the effectiveness of patents as a means of achieving and protecting the competitive advantages of new and improved manufacturing processes and products were examined during the surveys. As a result, all but respondents from the chemical and pharmaceutical industries considered patents 'relatively ineffective' (Levin, 1986; Hippel, 1988).

Other authors obtained similar results. Hippel provides a typical example from the work of Taylor and Silberston

(1973), where the respondents were asked the following question: ‘Approximately what proportion of your R&D in recent years would not have been carried out if you had not been able to patent any resulting discoveries?’ An overwhelming majority of the answers indicates that only 5% or less of recent R&D expenditures would not have been undertaken if patent protection had not been available (Taylor & Silberston, 1973; Hippel, 1988).

What is the reason for such an opinion? If there is not any important value in patents as a way of excluding imitators, why firms are still patenting? Hippel (1988), generalising his observations and results of conversations with corporate lawyers specialised in patenting, indicates three attributes of patenting, which may jointly explain this phenomenon.

First, a patent, if it is valid, provides the right for the patent holder to exclude other people from using the invention; however, it does not give him or her the right to use it by him-/herself, if this use infringes the patents of others. Thus, in the rapidly developing high-technology industries, where many patents are issued, and the term of many of them has not yet expired, it is likely that any new patent cannot be exercised without infringing the claims of numerous other extant patents. The benefit from a specific patent for an inventor or a company will be insignificant, since in most cases the patent holder can be prohibited from using their own invention, or he/she will be forced to cross-licence competitors, who have related patents, to put the invention to practice.

Second, patent system puts a burden of finding an infringer and claiming for compensation on a patentee. Such claims are usually very expensive and are considered over a long period of time, and both plaintiffs and defendants try to avoid them. The best result for an infringer is a judicial sanction for continuation of the suspected infringement, while in the worst case an infringer will have to pay substantial penalties. The situation for a plaintiff is more ambiguous. The probability that the court will hold a patent valid and infringed - as opposed to invalid and/or not infringed - is on the order of one to three. If a patent holder has already had licensing revenues from patents, he/she has a sufficient incentive to avoid litigations, since if he/she loses the case, which is quite probable; he/she loses not only the potential payments from a specific infringer, but also the payments from all the existing licensees from that patent.

Third, there are specific technical means specified in the patent to achieve a certain market purpose. However, the patent does not protect this purpose itself, even if this purpose and, perhaps, the entire market, which it will supposedly create, are absolutely new. The potential imitator may record an analogous patent if he/she is able to find or invent alternative technical facilities not indicated in the original patent. In most industries, it can easily be done (excluding chemical and pharmaceutical industries) (Hippel, 1988).

Hippel (1988) presents a few examples illustrating typical situations in the field of patenting. Thus, firm A acts in a rapidly developing industry and, launching a new product on the market, potentially infringes the rights registered earlier by patents of firm B. To prevent the potential litigation, firm A takes preventive measures: its patent experts thoroughly examine patents in force of both firms and notify firm B of those of its patents, which potentially infringe the rights of firm A. Afterwards, the parties usually quickly arrive at the agreement on mutual cross-licensing with minor royalty payments (or even royalty-free cross-licensing often). Chemical and pharmaceutical industries are an exception in this typical situation. It is very difficult to patent alternative solutions in these sectors since, due to their specific nature, patenting of formula properly protects from copying.

These arguments demonstrate that the purposes of patenting have been dramatically changed in comparison with Schmookler’s time. Since 1980s, in rapidly developing industries, patents have not been powerful enough to provide any monopoly rights (with some exceptions), but still useful for the preparation of a negotiating position aiming to protect at least the current operational and R&D activity of firms. In other words, patents serve not so much as a means of protecting intellectual property rights, but rather as just a tool for legal support of industrial activities.

The use of patent performance indicators in PRFSs is based on assumptions that patents are outputs of research activity and can serve as a means of knowledge transfer. However, the investigations show us that patent stimulation occurs in the world where patents are considered by industrial firms foremost as serious, legal obstacles to innovation. It inevitably leads to the conclusion that if agents refuse to imitate invention activity and are able to patent in the most promising areas, they will make innovation development for industrial firms more complicated. The multiplication of license agreements in this case, indeed, will create a perception of successful knowledge transfer but the actual purposes of such kind of processes seem to be ambiguous.

One may argue that public agents, fulfilling patent performance indicators, can play the role of research departments for industrial firms, reducing for them R&D costs by patent licenses. We will show some studies in the next argument, which indicate that this assumption should not be valid. The patents as a result of full-fledged R&D are not interesting for industrial firms because the most reliable tools for the protection of valuable inventions are secrecy and lead time. An issued patent means that either this invention is too late for innovation, since it is available for copying by everyone, or this invention is not essential, or it imitates others.

Argument 4: Patents spur extortionate behaviour

The ambiguous nature of patenting attracted further investigations. The most seminal contribution was made by

Cohen (2000) who conducted surveys of 1,484 R&D laboratories in the US industrial sector in 1994. According to these surveys, firms typically protect their profits received due to invention with a range of mechanisms including patents, secrecy, lead time advantages and the use of complementary marketing and manufacturing capabilities. Of these mechanisms, however, patents tend to be least emphasized by firms in the majority of manufacturing industries, and secrecy and lead time tend to be emphasized most heavily (Cohen, 2000).

Generally, Cohen’s investigation simply confirms the results of similar surveys from previous decades. However, one can observe a new emerging trend in comparison with Hippel’s explanations. Cohen notes that although a number of respondents in the electronics industry continued to report that cross-licensing negotiations often resulted in cross-licensing without royalties, one of the respondents noted that ‘…now it was more typical for money to change hands: "You make comparisons of patent portfolios [interviewee measures spaces with fingers, one twice the other]. You recognize the difference. Even THAT gap might create multiple millions of dollars in payments from the weaker company to the stronger. To cancel out the gap, you have to pay. You have 10 good patents, I have 15, you owe for the 5 good patents. Ten or 15 years ago, the two companies would negotiate a royalty free cross-license patent peace. But, given the huge size of the business, even a small, delta, gap creates multimillions of dollars in value." (Cohen, 2000, p. 26).

As subsequent events showed, a competitive struggle between companies rapidly developed with the use of such patent gaps, and by the 2000s a separate type of activity had been recognized - patent trolling. Entities specializing in the search for patent gaps and the use of patent law appeared and were engaged in patenting or buying specific patents only for the purpose of threats of filing lawsuits and compelling license and fine payments. Some investigations show that public universities have been implicitly involved in this activity, too (Lemley, 2007; Choi & Gerlach, 2018; Leiponen & Delcamp, 2019).

The use of patent performance indicators in PRFSs leads to an increase in the mass of patents and, consequently, to a closer patent cover of perspective technology areas. Public agents in PRFSs are motivated in selling and licensing patents, but are not able to verify or influence the goals of buyers and licensees. It leads to the situation where public stimulation of patent activity indirectly contribute to the patent troll activity, because the latter can easily include public supported patents in their patent portfolios for the purposes of extortionate behaviour.

Argument 5: Patents indicators are not able to distinguish outcome values

The ambiguous nature of patent indicators in statistics and its controversial ability to measure actual situation in national R&D sector have been attracting the attention of many authors (Griliches, 1990; Harhoff et al., 2002; Frietsch et al., 2010). Harhoff et al. (2003) express the common point of view that despite accepted opinion that patent counts themselves do not constitute a good measure of inventive output, the naive use of patent statistics is continued due to the lack of practical alternatives.

Taking into account this weakness of patent statistics, since the 1980s attempts have been made to propose some upgraded types of patent indicators, which would be more appropriate for policy makers. Researchers focused on the data contained in patent documents or tried to use any other sources of information about patent behavior in order to compose a patent indicator, which could identify among multiple patents only those that have a high value and thus correspond to the objectives of patent statistics and economic analysis.

Table 1 below provides a brief overview of types of patent indicators proposed by researchers in order to distinguish the value of patents in statistics.

Table 1. Patent indicators suggested distinguishing patent values in statistics.

Types of patent indicator	Brief description
Renewals	The indicator is based on the hypothesis that if the copyright holder pays patent renewal fees, he expects to earn at least the cost of the fee (either by using technology in a particular product that is profitable, by licensing it to a third party and/or as a part of a larger patent portfolio that can be used for commercial purposes in general). Thus, this indicator is based on accounting for patent renewal fees (Schankerman & Pakes, 1986).
Forward citations	The forward citations indicator is based on the fact that inventors (have to) mention prior art (patent and non-patent documents); front page references are references withheld or introduced by examiners to qualify the claims of the patent. These processes generate forward citations, as some existing patents are being cited by new patents; the more a patent is cited, the more important it is (Narin and Noma, 1987; Trajtenberg, 1990; Hall et al. 2005; Harhoff et al. 1999; Lanjouw, Schankerman 2001; Harhoff et al. 2003).
Opposition	Opposition as an indicator of value stems from the observation that there seems to be a market for the invention and that both the applicant and the opposing party are willing to incur additional costs to safeguard their property rights (Van der Drift, 1989; Harhoff et al., 2003; Harhoff & Reitzig, 2004; Lanjouw, Schankerman 2001; Lanjouw, Schankermann 2004).

Types of patent indicator	Brief description
Family size	It refers to the number of countries for which a patent has been applied for (or granted). The family size indicator is based on the fact that a patent should be more valuable if protection has been sought in a larger number of countries (Putnam; 1996).
Number of claims	The number of claims provides an indication of the legal breadth of patent protection. It is a sign of the complexity of a patent. The idea is that breadth and complexity of a patent should coincide with its value (Tong and Frame, 1992; Lanjouw and Schankerman, 2001).
Number of IPC classes	A patent that has a higher technological diversity is seen as broader in scope. As inventions are considered to be a combination of existing ideas, inventions based on a wider set of ideas should be more valuable. Hence, the more classes are specified in the patent, the more valuable it is (Lerner, 1994; Guellec, van Pottelsberghe de la Potterie, 2000).
The number of inventors	This indicator is based on the hypothesis that a patent resulting from the research of several inventors should be more valuable than a patent which was developed by a single inventor (Reitzig, 2004)
Backward citations	Backward citations refer to references to previous patents providing information about the technological background of the invention. Backward citations reflect the scope of the patent. Backward citations are available much faster than forward citations, as they can be retrieved directly from the patent document (Harhoff et al. 2003).
Filing routes	It is assumed that grants received under the PCT procedure are of great value (Schmoch 1999; van Pottelsberghe de la Potterie, van Zeebroeck 2008).
Surveys of patent value	Surveying inventors or owners of the patent (Harhoff et al., 2003; Harhoff et al., 1999)
Index of patent-value indicators	It is based on the combination of the above-mentioned indicators. The hypothesis is that the above-mentioned indicators weakly correlate with each other and just reflect different aspects of patenting. Combined into a single index, they can provide a more comprehensive assessment. For example, Lanjouw and Schankerman (2004) built a composite index of patent quality, which is composed of the number of claims, forward citations, backward citations and family size (Lanjouw and Schankerman, 2004; Gambardella et al., 2008; van Zeebroeck, 2008).

Source: The table is based on Frietsch et al. (2010).

Some of the mentioned indicators have already been used in patent analyses. However, closer examination shows that practically none of them is appropriate in the context of PRFSs.

Four types of the suggested indicators are not able to provide data for interpretation promptly enough: Renewals, Forward citations, Opposition, Number of claims. Though they are referred to as relatively reliable economic indicators, years must pass before there is an opportunity for the rigid interpretation of agent's performance. Besides, the outputs provided by Forward citations, Opposition, Number of claims are heavily dependent on accidental factors and more importantly, contain implicit incitement to agent's extortionate behavior.

The Surveys of patent value is one more indicator that is difficult to use promptly. In addition, the survey of agents on the performance of their patent activity, as in the case of Renewals indicators do not meet the requirements of objective assessment because of conflicts of interests.

The remaining six types of patent indicators, even though reasonable as economic indicators, however, either have serious shortcomings or contain causes for unintended effects in PRFSs. The two main problems can be distinguished: unreasonable influence on the structure of R&D and creating circumstances which lead to moral hazard emergence when suggested patent indicators are fulfilled in PRFSs.

For example, backward citations indicators allow quickly to obtain data for interpretation, since the citations of previous patents are already contained in patent applications. However, the use of this patent indicator will lead to the imposition of a biased R&D strategy, as this will force agents to patent foremost in previously well-developed areas. The situation is similar to the Number of IPC classes' indicator, which will tend to limit R&D activity mainly to inventions with a large enumeration of IPC classes.

Patent indicators such as Family size, the number of inventors, Filing routes when used as performance indicators in PRFSs provide incentives for the emergence of the moral hazard problem. Agents who are forced to perform this kind of patent indicators do not have any objective obstacles to fulfil them in the easiest and formal way. For instance, it will not be difficult for agents to file patent applications in several countries, invite several co-authors, or file applications under the PCT procedure if the value of the received funding is high enough for them.

Lastly, it seems evident that integrating any combinations of the abovementioned indicators into one composite index will not solve the problems that arise when using each of them separately. Undoubtedly, the index of patent-value indicators has a rationale for use in different types of analyses, as they are able to disclose more comprehensively the structure of patent activity but they are not as rational as performance indicators in performance-based funding mode.

Discussion

The present study has certain limitations due to the lack of supporting empirical research in the context of specific PRFSs. This is because, firstly, PRFSs are a relatively new phenomenon, and comprehensive studies of the performance of such national systems are just beginning to develop. Secondly, in PRFSs, the focus is usually on publication performance, so researchers often equate the performance of PRFS with the performance of publication activity. A rare exception is the analysis of the Czech PRFS, where the results reflect both publication and patent activity, and which confirm the hypothesis of this work: despite the increased number (growth-rate) of patents and patent applications, the number of the sold licenses by the Czech subjects has not increased (Vanecek, 2013).

If we consider the situation more broadly, outside the context of PRFS, but related to public funds directed to stimulate patent activity, then we can also observe indirect confirmation of the hypothesis of this work. For example, Svenson (2006) indicates that projects with soft government financing in the R&D-phase have a significantly inferior performance compared to projects without such financing, whereas those receiving government loans on commercial terms perform as the average. Gong and Peng (2018) conclude that Chinese research policy to stimulate patenting in universities, although leading to a multiple increase in their number, has a negative impact on the ability of universities to commercialize them. Riviezzo et al (2019), based on a survey conducted by heads of university departments in four different European countries (Italy, Spain, the United Kingdom and Portugal), have found out that the entrepreneurial orientation of universities was negatively associated with the number of university patents. Kang and Motohashi (2020), analysing the patents of Japanese universities, observe that patents created under competitive (public) funding are not likely to diffuse, whereas those produced from industry funding are likely to diffuse.

At the same time, public patents remain an integral part of the innovation process. The results of this study should not be considered as a basis for refusing to develop any alternative mechanisms to stimulate public patents. More research on the stimulation of inventive activity in the context of PRFS is needed.

Research Policy Implications

The vulnerabilities of patent indicators as statistic ones have been under discussion for a very long time. As pointed out by Harhoff et al. (2003), the naive use of patent indicators in research policy is due to the lack of alternatives. However, if in statistical analysis we are talking only about distortions at the stage of interpretation of patent statistics, in PRFS the situation is completely different. Here, with the help of patent performance indicators, there is actually an element of intervention in the planning and conducting research. Thus, in this situation, the PRFS context contributes to an even stronger manifestation of the known deficiencies of patent indicators. It should be noted that in the light of the results of this study, the complex patent-based indicators that Mortensen (2011) is hoping for will not save the day.

For the purposes of research policy, there can be two ways out of the situation. The radical way is to refrain from using patent-based performance indicators. The second option is to use them without reference to funding (as statistical and with a time lag) in order to mitigate as much as possible the potential moral hazard associated with the active coercion of public scientific organizations and universities to patenting. It is also necessary to note the exceptions in areas like chemistry and pharmaceuticals, where the specificity of the results (chemical formulas) retains the ability of patents to protect the results (the core ideas) obtained: in such cases, the use of patent performance indicators remains meaningful.

Conclusion

The findings from existing studies on patenting and patent indicators show that the common assumptions ascribed to patent indicators for their use as performance indicators in PRFSs seems to be misleading. This view has at least five reasons.

First and foremost, nowadays there is no theoretical background for the hypothesis that the increase of patent activity leads to economic growth. Schmookler's theory that patent activity is a consequence of economic growth, and not its cause, still has no decisive refutation. According to Schmookler, the value of inventive activity, its significance for the innovation process is determined primarily by the fact that the inventor is under strong pressure from many factors of economic nature, and above all, dissatisfaction with demand and a strong temptation to multiply their own benefits from increased sales. Thus, the value of inventive activity and its success directly depend on the ability of the inventor to capture technological gaps, clearly represent the needs of consumers, and anticipate promising areas of market development.

In the context of PRFSs, the use of patent indicators as performance indicators radically changes the nature of the factors that initially created pressure for the inventor. The registration of the result acquires an independent, comprehensive value. Thus, in PRFSs, the value of inventive activity and its success depend largely on the ability of an inventor to patent quickly and in the easiest way. Patent procedures allow doing it: patent office's only verifies a formal level of technology novelty, but does not evaluate the essence of an invention and its applicability. Agents are able to legally reproduce the same invention or unused developments numerous times with insignificant changes in order to fulfil patent performance indicators in the easiest way. Thus, PRFSs probably pushes an agent to the nature of activity, which is different from the one he or she would have without any state support, and this nature of activity is hardly in the interests of policy makers.

Arguments 2-4 develop the first argument in various aspects. Patent indicators in PRFSs are unable to assess the essence of the efforts of agents to achieve the outcome and, therefore, do not correspond to the very concept of PRFSs as a tool for identifying and promoting the best performers (the second argument). The focus of PRFSs agents on patenting creates additional patent barriers for industrial firms, since now firms when planning R&D must consider not only the intellectual rights of competitors, but also the ever-increasing number of patents of public science entities (the third argument). The results of public patent stimulation facilitates patent trolls' activity since publicly supported patents easily end up in the hands of non-practicing entities expanding their patent portfolio for extortionate behaviour (the forth argument). The fifth argument describes known attempts to construct patent indicators (in statistics) in the way that they can distinguish the true value of patents. However, their use as performance indicators in PRFSs is inevitably hampered by such problems as conflicts of interest, unacceptably large time lags needed to evaluate performance, unreasonable influence on the structure of R&D and high risks of moral hazard.

Thus, taking into account the entire above, patent indicators do not seem suitable for the role of performance indicators in PRFSs. The use of patent indicators as patent performance indicators in the context of PRFS requires rethinking. Primarily, more research on the performance of public patents created under PRFSs is needed to collect comprehensive data to confirm or refute conclusions drawn from the analysis of problems in the patent literature. Until the side effects of patent performance indicators in the performance-based mode have not been fully studied and alternative mechanisms for stimulating public patent activity have not been proposed, it seems rational to refrain from using patent-based performance indicators or use them without directly including in the funding formulas (use them only as statistical and with a time lag) in order to mitigate the potential moral hazard associated with active coercion of public research organizations and universities to patenting.

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