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Review

Indicators for measuring the impact of scientific citations in patents

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ABSTRACT

Scientific publications cited in patents are fundamental elements to assess the transfer of science to technology. Numerous studies evaluate the impact of references in patents and scientific publications and various measurement methods and indicators are proposed. This article reviewed the existing literature on the indicators used to date to determine their suitability and effectiveness to evaluate the impact of patent citations. For this purpose, we analyzed the characteristics of the studies examined and proposed a qualitative classification of indicators from both a technological (patents) and scientific-academic (scientific articles) perspective. Among the results we find that the use of scientometric indicators is primarily focused on analyzing their relevance for patents through the inclusion of scientific citations. Conversely, the same is not true from the academic point of view where gaps still persist in terms of what the impact is when scientific articles are cited in patents. Among the key conclusions is the diversity of proposals to measure scientific citations in patents, though these are conditioned on bibliographic standardization and metadata management of the patents themselves, making it possible to quantify aspects similar to the immediacy index, impact index, or h-index for authors/inventors, albeit from a technological dimension.

1. Introduction

The scientific literature cited in patents is a key indicator in the study of the synergy between science and technology. Since the 1980s, from the hand of pioneering authors such as Carpenter or Narín, the presence of these references in patents has been studied as an instrument for assessing the impact of science on technology. Until recently, the focus of these measurements was mainly centered on evaluating these citations within the technological context of patents. However, in recent years, research on the assessment of these references within the academic field in terms of scientific evaluation has emerged. In this sense, there is growing interest in identifying what it means for scientific literature to be cited in patents, giving a "technological" value to the papers and the scientific journals in which they are published.

Therefore, the indicators that measure these scientific citations in patents are important because they provide valuable information about the sources used for the development of a technology. With the application of these indicators, it is possible to know which are the most influential countries, authors or institutions for a technology, the degree of scientific dependence of a technological sector or the time of industrial application of a scientific research. In addition, through the analysis of these citations, it is possible to know the "technological" profile of an author or a journal by the number of times they are cited in patents.

In the patent granting process, these citations are provided by the applicants or by the examiners who evaluate the novelty of the invention and are included in prior art search reports as 'Non-Patent References' (NPR) or Non-Patent Literature (NPL). This type of citation, which is different from those that cite previous patents, includes other documents such as scientific publications, books, standards, technical manuals, or clinical trials, among others [1]. There is a more specific denomination—'Scientific Non-Patent References' (SNPRs)— that is related to "purely scientific" references, such as scientific articles published in journals with quality standards. The origins of citations, who references them, their jurisdiction or what coding is assigned to them according to their relevance (A, X or Y), are decisive aspects for assessing these references and designing database search strategies [2]. Abundant literature exists on this type of reference, and the vast majority of studies deal with linking science and technology through their citations, describing concepts, methodologies, and classifications, as well as analyzing references in set of patents. However, works focused on the indicators used to evaluate the science cited in patents are less abundant and more heterogeneous in nature.

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On the other hand, there are comprehensive reviews on patent citation metrics, such as the work by Aristódemou & Tietzé [3] in which they describe in detail various indicators to measure the technological impact of patent citations backwards and forwards. There is also the literature review by Sharma & Tripathi [4] on patent citation studies, in which the authors describe different phases of evolution of this research, considering as a key element the availability of data for citation analysis, the authors mention the science-technology linkage introduced by Narin through SNPRs, and in the last phase, still under development, metric studies focus on mapping and citation network analyses.

Although the appearance of indicators to assess these citations has been more significant in the last decade, there is no clear and structured classification around this concept and its different measurement parameters. The purpose of this paper is to review the existing scientific production on SNPR citation assessment indicators, with the aim of identifying, describing, and qualitatively classifying them in order to highlight those proposals that may have short-term applicability in the measurement of these references. This classification will provide a clear and structured view of the different proposals for indicators used to date, as well as the approach to their measurement and the advantages and disadvantages of their application. The purpose of this study will be to contribute to a better understanding of the use of these indicators and to serve as support for the development of future research in this area.

2. Methodology

The methodology used was based on a bibliographic search of the published literature on SNPR measurement indicators, as well as a content analysis of the selected studies. For data extraction, a series of items were considered in order to obtain the relevant information.

2.1. Bibliographic search/search strategy

The Web of Science and Scopus databases were consulted, as well as the Google Scholar academic platform in June 2021. The search initially focused on studies related to citations in patents, in order to later select only those that analyzed citations of scientific publications or described indicators for their measurement. The search strategy was designed with a combination of keywords, such as 'patent citations', 'non-patent references', 'non-patent literature', 'scientific articles', 'bibliometric', 'scienciometric', and ''indicators', 'metric or measure' in the title and abstract fields (Appendix A). The search was not restricted to a specific time period or language. Bibliographies included in the most recent studies were also considered in order to broaden the search.

2.2. Inclusion and exclusion criteria

This paper includes works that mainly describe indicators used to measure citations of scientific articles in patents, and excludes patent-to-patent citations or citations of other technical documents. We considered works with both theoretical and practical contributions because they define indicators and also apply them to set of references, all of which enriches the process of clarifying concepts to facilitate the classification of indicators. The selection of articles was performed manually, with an initial reading of the title and abstract used to discard those that did not meet the inclusion criteria. Subsequently, the texts were analyzed, and data was collected.

2.3. Information extraction and analysis

A structured template was designed and used to collect the relevant information from the selected studies. It included the following items.

- Type of study: a distinction was made between metric studies (m) that provide formulas for the calculation of indicators and those that did not. These formulas can be original or adaptations of metrics from other authors.
- Set of documents: this category refers to the set of patents and bibliographic references analyzed in the studies. This data set comprises the number of records, the time frame of the searches, the origins, and the areas of focus of the documents.
- Sources of information: this category includes the sources used to collect data for the studies including patent databases, scientific-academic platforms, subject classifications, and tools for data analysis, among others.
- Author affiliations: this category identifies the main lines of research and thematic areas of the authors whose studies were selected and was used to determine the focus of the studies.
- Impact indicators: this category includes the indicators described or applied in the studies, which were classified from two perspectives: technological and scientific-academic. The former, refers to the study of these indicators in the field of technology (patents) and includes those that measure the impact of scientific publications on patents—Scientific Impact Indicators, "SII" (science-technology). The latter, focuses on the study of these indicators in the academic field, and includes those that measure the technological impact that scientific publications have after they being cited in patents—Technology Impact Indicators "TII" (technology-science).
  The distinction between SII and TII is necessary because the object of evaluation is different: patents or scientific articles. The vision given by these two types of indicators will be fundamental to understand how these citations affect and value these documents, as well as the impact they have on other patents and scientific publications.

Based on the scheme from González Alcaide and Gómez Ferri [5]we added different dimensions associated with a grouping of concepts that can be measured for both perspectives. The dimensions identified are as follows.

- Individual: this dimension includes assessments that affect the document individually and not as part of a collective (a patent or a scientific article). Citation counts and document characteristics were evaluated, as well as values related to quality or potential impact on other documents (patent-to-patent, article-to-article or article-to-patent).
- Origin: this dimension defines the origin of the documents and is used to determine the degree of dependence on national and foreign science and the distribution of citations by country.
- Authorities: this dimension addresses both the author of the document as an individual and the institution the author is associated with (types and characteristics of entities). Interactions between authors and inventors and their affiliations were also considered
- Publication time: this dimension estimates values for the publication times of the documents: time lags between the publication of articles and patents, science cycle time, science-technology transfer speed, citation windows, and the age of citations.
- Focus Area: this dimension evaluates subject areas, groupings, and distributions by technological sector (patents) or scientific area (articles).
- Semantics: this dimension analyzes the influence the content of documents has on other documents (scientific articles on patents) by analyzing keywords.
- Source: this dimension shows the value of these citations in the sources that publish the documents (for example: rankings of the scientific journals that are most cited in patents), individually and by thematic categories.

3. Results

Following a review of the scientific literature, the data obtained were organized into two main sections. The first section focuses on the characteristics of the studies analyzed and includes a chronology, the types of studies, groups of documents, the sources of information used, and the focus areas of authors. The second section centers on SNPR indicators, which were defined and grouped from both the technological and scientific-academic perspective.

3.1. *Characteristics of the studies*

The studies analyzed were mainly practical and focused on the analysis of document citations, although some also examined theoretical aspects related to indicators. It should be noted that, in the last decade, there has been an increasing number of "metric" studies, whose methodology differs from non-metric studies because the former incorporate formulas. Table 1 shows the studies in chronological order; metric studies are indicated by the symbol (m).

As Fig. 1 shows, the SII indicators have been the most widely used from the outset and continue to be used up to the present day. Despite having been mentioned as early as the 1990s in Narin's studies [9,10], the TII indicators only gained significance in 2000 when studies with metrics aimed at analyzing the academic impact of citations in patents began to proliferate. In recent years, the use of both types of indicators has become increasingly closer.

In this figure, the Y-axis represents the number of studies that have used the indicators over a 10-year interval (X-axis). For example, in the decade from 2000 to 2009, IIT indicators are used in 5 studies while SII indicators are used in 11 studies. In the last decade from 2010 to 2021, the number of studies that have used TII and SII indicators coincide at 20.

The groups of documents used in the studies analyzed are set of patents and scientific references. They typically span long periods of time, between 10 and 20 years, and are limited to specific technological sectors (such as biotechnology, nanotechnology or electronic engineering among others) or a single origin (US, Dutch, or Chinese patents). A distinction was made between technological and scientific-academic databases as sources of information. Among the patent sources, the USPTO database is the most widely used, together with the PATSTAT database of the European Patent Office. Meanwhile, the authors generally preferred the Web of Science and Scopus databases for scientific articles as the records on these platforms are standardized and easily permit the process of matching references, which facilitates data analysis. Some authors, such as Marx & Fuegi [43], believe these platforms do not include all references because they only contain publications considered to be "high impact" and, for this reason, prefer other unrestricted, open access databases such as Google Scholar or Microsoft Academic Graph, despite the inherent data cleaning problems they present. Among the patent sources, the USPTO database is the most widely used, together with the PATSTAT database of the European Patent Office. Meanwhile, the authors generally preferred the Web of Science and Scopus databases for scientific articles as the records on these platforms are standardized and easily permit the process of matching references, and data analysis.

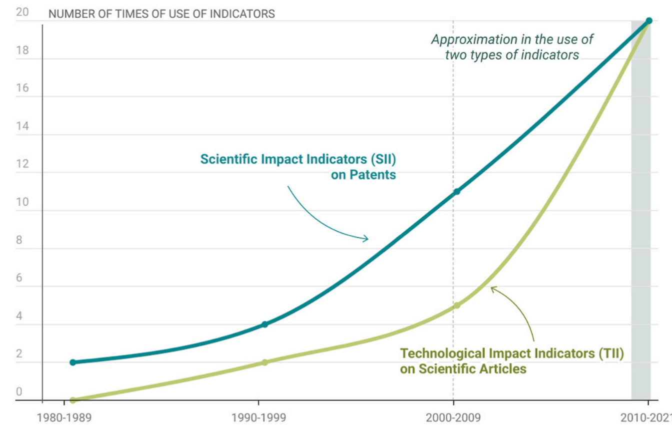

Fig. 1. Time evolution of the use of indicators in SNPR studies.

Table 1
Studies on scientific citations in patents.

STUDIES IN CHRONOLOGICAL ORDER		
1983 - Carpenter & Narin [6]	2007 - Guan & He [21]	2018 - Ke **(m)** [36]
1985 - Narin & Noma [7]	2007 - He & Deng [22]	2019 - Veugelers & Wang **(m)** [37]
1988 - Narin et al., [8]1992 - Narin & Olivastro [9]	2009 - Guan & Gao [23]	2019 - Poege et al. **(m)** [38]
1997 - Narin et al. [10]	2010 - Meyer et al. [24]	2020 - Yamashita [39]
1997 - Karki [11]	2011 - Lin et al. **(m)** [25]	2020 - Gazni [40]
1997 - Schomch **(m)** [12]	2011 - Wang & Guan [26]	2020 - Onken et al. [41]
2000 - Narin **(m)** [13]	2011 - Glänzel & Zhou **(m)** [27]	2020 - Bikard & Marx **(m)** [42]
2000 - Tijssen et al. [14]	2012 - Callaert et al. [28]	2020 - Marx & Fuegi **(m)** [43]
2000 - McMillan et al. [15]	2013 - Karvonen & Kässi [29]	2020 - De Moya Anegón et al. [44]
2000 - Meyer [16]	2014 - Liaw et al. **(m)** [30]	2020 - Qu & Zhang [45]
2002 - Acosta & Coronado **(m)** [17]	2014 - Huang et al. **(m)** [31]	2021 - Wang & Verbene [46]
2002 - Verbeek et al. **(m)** [18]	2015 - Huang et al. **(m)** [32]	2021 - Guerrero –Bote et al. **(m)** [47]
2004 - Soreson & Fleming **(m)** [19]	2015 - Sung et al. **(m)** [33]	2021 - Guerrero –Bote et al. **(m)** [48]
2006 - Callaert et al. [20]	2017 - Van Raan [34]	2021 - Wang & Li **(m)** [49]
	2017 - Ahmadpoor & Jones [35]	

(m) Metric studies including formulations.

3.2. *Focus areas for the authors of the studies analyzed*

As shown in Fig. 2, the main lines of research for the authors of the studies analyzed center on two main thematic areas: business and economic policy related to innovation management (52.11%) and those linked to the information sciences and the field of scientometrics, aimed at the quantitative analysis of scientific production (28.17%). To a lesser extent, there are areas such as computer engineering (data analysis) or industrial engineering, followed by a small percentage of other more specialized sciences such as aeronautics or psychophysiology. The areas of study of the authors have been defined through the description of their affiliations in Scopus, Web of Science, Orcid, Researchgate or Google Scholar.

3.3. *Indicators proposed in the studies*

As can be seen in Table 2, the indicators are classified according to both the technological and scientific-academic perspective, and the measurement parameters are grouped for each aspect by dimension. This general classification enables identifying similarities and differences between the measurement parameters.

3.3.1. *Indicator classification from the technological perspective*

From this perspective, the SNPR indicators are classified according to the scheme specified in the methodology section, as detailed below in Table 3.

Individual. Most studies used the average number of citations in patents as the key indicator to determine their degree of scientific intensity. Some authors, such as Callaert et al. [20] and Sung [33]were more specific and separated the references that are "purely scientific" (the SNPRs) from the general set of NPR references, weighting their

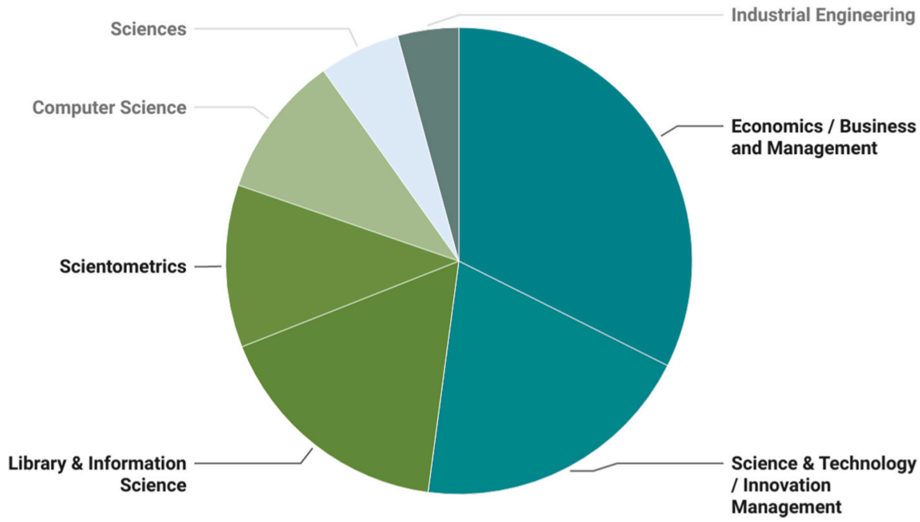

Fig. 2. Focus areas for the authors of the studies analyzed.

Table 2
General classification of the indicators proposed in the studies analyzed.

DIMENSION	PERSPECTIVE	
	TECHNOLOGICAL	SCIENTIFIC-ACADEMIC
	Science Impact Indicators	Technological Impact Indicators
Individual	Science intensity in patents	Technological relevance of scientific papers
Origin	Dependence on foreign Science Proportion of citations by country	Origin of citations Proportion of citations by country
Authorities	Author-Inventor Research Institutions	Author-Inventor Affiliations
Publication Time	Time lag between scientific papers and patents	Citation windows. Age of citations.
Focus area	Technological sectors	Scientific areas
Semantics	Controlled language Keywords	Controlled language Keywords
Source	—	Journal impact indexes. Own technological rankings.

Own source, based on the outline of the perspectives, dimensions and research methodologies of González Alcaide y Gómez Ferri [5].

Table 3
Technological perspective. Use of indicators in the studies analyzed.

AXES	OBJECT OF ANALYSIS	STUDIES
Individual	Science intensity. Averages and proportion of SNPR citations	[8,10,11,13,16,20–23,25,26,28,29,32,33,37,38,40,41,43,45,47]
	Impact of citations on other patents	[19,35,37,38]
Origin	Dependence on foreign science	[6,14,16,26,38,47,48]
	Proportion of citations by country	[9,21,29,40,47,48]
Authorities	Author-Inventor interaction. Affiliations	[10,14,16,26,35,38,39,45]
	Institutions. Typology	[10,14,15,35,38,42,44]
Publication Time	Time lag between scientific papers and patents	[7,18,25,26,32,34,35,37,38,41,42,44,47,48]
Focus Area	Distribution and concentration of citations by technology sectors.	[6,9,11,14,17,18,20–22,25,26,35,37,40]
Semantics	Influence of content. Controlled language and keywords	[42,44]

proportion per patent. Other authors assessed the quality of publications [38] or the potential impact on other patents or articles, such as Ahmadpoor & Jones [35] and Veugelers & Wang [37] did.

Origin. Numerous studies took set of patents granted in the US as their starting point, even if they originated in other countries such as the Netherlands or China. The volume of science published in the same country of origin as the patent country determines the degree of dependence on foreign science. Other studies counted and distributed citations by the countries considered to be the main producers of a technology. Of particular interest is the work of Poege et al. [38], who established a minimum distance that measures the correlation between the value of the patent and the scientific quality of the citations through the concept of the “science-technology frontier".

Authorities. To evaluate authors, many works described their interaction with inventors and analyzed the percentage of self-citations, co-authorship, and inbreeding [14,26]. Most studies noted whether entities are public or private to identify whether the funded research later resulted in patent production [15].

Publication time. One of the most highly evaluated aspects was the so-called ‘Time Lag’ or ‘Science Cycle Time’, which specifies the time that passes between the publication date of the citation and the publication date of the patent. The citation windows used to calculate this figure were intervals of three, five, and ten years. For example, Verbeek et al. [18] noted that technologies with short scientific cycles have higher citation counts, while Poege et al. [38] indicated that shorter time lags are always associated with higher patent values.

Focus areas. This dimension was based on the distribution of citations by technological sectors associated with a specific field (Electronics or Health Sciences, among others). Of note are the contributions of Acosta & Coronado [17] and Verbeek et al. [18], which examined the interactions between technological sectors and scientific fields in terms of the concentration or distribution of citations.

Semantics. This dimension measured the presence of common keywords in scientific articles and patents. Works such as Bikard & Marx [42] measured the number of patent references and articles with the same combination of terms (MeSH or MAG); De Moya et al. [44] represented the content of patents with keyword clouds.

Source. This dimension was not included because no studies were identified that evaluated patent issuing sources based on citations of scientific articles.

Fig. 3 shows the percentage use of indicators from this technological perspective grouped by dimensions. It is very common for several indicators to be used in the same study. As can be seen, the most commonly applied indicators are those referring to measuring the

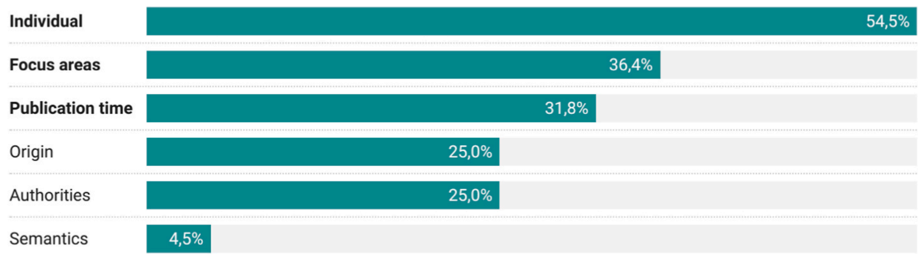

Fig. 3. Technological perspective. Percentage use of indicators in studies by dimension.

scientific intensity of patents at the individual level (54,5% of the studies used these indicators), as well as the time lag between the publication dates of scientific papers and patents. Those related to the Focus area dimension are also widely used.

3.3.2. Indicator classification from the scientific-academic perspective

As can be seen in Table 4, the same classification scheme was used for the scientific perspective. The indicators from this perspective show the technological value associated with a scientific publication based on the fact that it was cited in a patent.

Individual. Most studies based their analysis on quantifying the number of times articles are cited in patents or their correlation with the number of citations received by science (articles) and technology (patents), as in the work of Ke [36] and Gazni [40]. Other authors, such as Wang & Verbene [46], examined the characteristics of citations, analyzing aspects such as interdisciplinarity, novelty, and basic character, among others. Poegde et al. [38] measured the scientific quality of citations to determine the value of the patent (e.g., if they are registered on Web of Science). Likewise, Veugelers & Wang [37] asserted that the novel character of scientific publications gives them a higher probability of being cited in patents. In this line, Meyer et al. [24] and Glänzel & Zhou [27] add that articles cited in patents are also more cited by other works, as they tend to be published in high impact journals, which makes them more visible. Guerrero-Bote et al. [47] proposed technological impact indicators of articles that measure the average of their citations in patents based on certain parameters such as patent families, countries, publication dates, types of documents, and scientific areas, among others.

Origin. This dimension included the same studies as those described in the technological perspective, since they evaluated the origin of citations and their distribution by the countries that produced the published science. However, it should be noted that the focus of these studies was usually on the evaluation of patents and not scientific articles. It is worth highlighting the contribution of Guerrero-Bote et al. [47], who considered the GDP of the countries applying for patents as a parameter to be evaluated, since, according to these authors, it affects the propensity to cite scientific literature.

Authorities. As with the previous dimension, the same indicators of the studies of the technological perspective were included, evaluating the authors by their interaction with the inventors: self-citations, co-authorship, and the frequency of citation, both jointly and separately. In this line, the studies highlighted the lack of standardization in matching authors' names in patents, such as their affiliations. The evaluation of authors in terms of academic impact was not considered.

Publication Time. To determine the age of citations, citation windows of three, five, and ten years were considered and calculated with respect to the date of publication of the patent. In this sense, many authors took as their reference the patent application date, and not the grant date, since patent processing takes several years. It is worth noting the contribution of Van Raan [34] that also considered the articles cited by SNPR references because they may be relevant in the technological field.

Focus areas. This dimension grouped indicators that assess the scientific fields of citations. Some of them examined the degree of diffusion of science, measuring the interactions of cross-references with various technological sectors and scientific fields [17,18]. Others established indexes to measure the technological diversity of science, looking at the concentration of scientific fields in one or several technological sectors.

Semantics. The same studies were evaluated as those from the technological perspective, since they assess the same concept: the influence the content of articles has on patents, through controlled language or keyword clouds.

Sources. This dimension evaluated the technological value or impact of academic journals as the main source of scientific citations. Some of the studies established metrics with adaptations of the impact factor of journals, using citations in patents instead of citations of articles and extended the citation windows by five or ten years. Again, the work of Guerrero-Bote et al. [48] stands out, in which the journal Technology Factor (TF) indicator was proposed, based on the weighting of citations of a family of patents according to the GDP of the countries. In other works, there was significant interest in establishing rankings of the most influential journals of a specific technology according to the field of study.

Fig. 4 shows the percentage use of indicators from the scientific-academic perspective grouped by dimension. It is very common for several indicators to be used in the same study. In contrast to the previous perspective, one of the most commonly applied indicators are those referring to measuring the impact of the sources (scientific journals), 31,8% of the studies use it. However, metrics relating to the technological relevance of individual articles or to the time lag between article-patent publication dates are still widely applied.

Table 4
Scientific-Academic Perspective. Use of indicators in the studies analyzed.

DIMENSION	OBJECT OF ANALYSIS	STUDIES
Individual	Technological relevance. Number of citations in patents	[27,35,37,39,40,43,44,47]
	Characteristics of citations	[19,38,46,49]
	Impact on other papers	[24,27,35,36,38]
Origin	Origin of citations and Proportion of citations by country	[6,9,14,15,21,26,38,40,47,49]
Authorities	Author-Inventor interaction. Affiliations	[10,14,26,35,38,39]
Publication Time	Citation windows and age of citations	[9,18,34,36,39,48,49]
	Time lags between publication date of articles and patents.	[32,35,38,47,48]
Focus area	Diffusion and technological diversity of science by field.	[17,18,21,27,36,37,39,40,47]
Semantics	Influence of content. Controlled language and keywords	[42,44]
Source (Journals)	Technological Impact Factor	[30,31,42,44,48]
	Analysis by subject category. Own rankings. Miscellaneous	[10,15,18,20,21,25,26,30,36,37,44,48]

4. Conclusions

The evolution of the use of indicators aimed at measuring the technological impact of scientific production has seen a notable increase in recent years, though it has been on a par with other indicators that are more focused on the evaluation of patents. Until now, the metrics

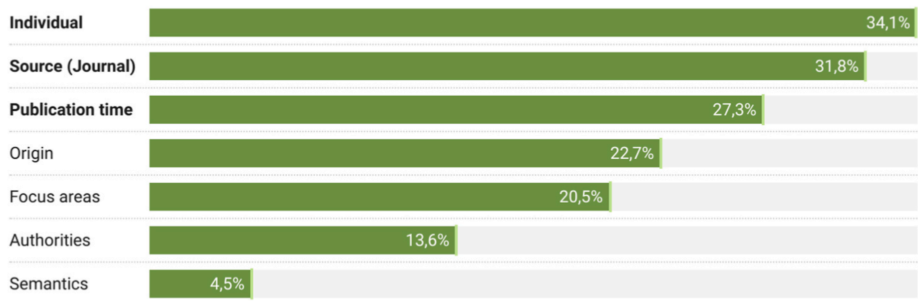

Fig. 4. Scientific-Academic Perspective. Percentage Use of indicators by dimension.

proposed have been more associated with the scientific evaluation of inventions as an instrument to justify the application of innovation or business management policies, mainly due to the subjects studied by the authors of the works. Recently, there have been new contributions from lines of research framed in the information sciences with a new scientometric perspective focused on assessing the academic impact of patent citations within the scientific community.

The use of information sources with high quality standards in the studies examined, such as USPTO, PATSTAT, Web of Science or Scopus, does not solve the records standardization problem which limits data analysis. In this sense, there is an unending proliferation of works dedicated to the establishment of methodologies and algorithms to match references. Nevertheless, we believe that the solution will involve, among other aspects, the adoption of persistent identification systems in patent databases and scientific article databases, such as the use of ORCID for authors and/or inventors.

In our proposal for the classification of SNPR indicators, the metrics related to the individual dimension stand out, the objective of which is to give documents a value of scientific or technological relevance based on citations. However, it is significant that, thus far, only the subsequent impact of these citations on other patents has been weighted, while the same is not true for scientific articles. An interesting area for continued research would be to determine the probability of being cited in other articles after being referenced a certain number of times in patents, as has already been considered by Meyer et al. [24] and Glänzel & Zhou [27].

The study of publication times between articles and patents is also a widely used indicator in SNPR studies, which, once again, is more focused on patent evaluation and more highly values the speed of the science-technology transfer. This is not the case from the scientific perspective, where the time of applicability of the scientific article and the value of its technological contribution are not analyzed. In this sense, much remains to be explored with respect to citation windows or the age of citations, which would make it possible to measure aspects similar to the immediacy index of journals or obsolescence, as well as the effect on subsequent citations in other articles, as occurs in the academic world.

With respect to the evaluation of authors, the interaction with inventors, citation frequency, and co-authorship (as criteria for the selection of references for state-of-the-art reports) are valued from the technological perspective. However, from an academic point of view, there is a gap in terms of the technological relevance of the scientific production of an author. Another area for future studies would be a measurement index similar to Hirsch's in which the "technological profile" of the authors would be assessed, together with other scales such as participation in technological development projects or their role as an inventor in patents.

Moreover, there is interest in the bibliometric assessment of the technological impact of sources. Along these lines, interesting proposals for indicators have been made, such as those of Huang et al. [31], Bikard & Marx [42] and Guerrero-Bote et al. [47,48]. These measured the technological impact factor of scientific journals, similar to the well-founded JCR or SJR indicators, though with the aim of establishing more "technological" rankings of journals by scientific areas.

The particularities of patents, which differ from those of scientific publications, are taken into account when creating metrics. An example is considering the slower dynamics of publishing applications—they take an average of 18 months—to establish citation windows, or taking into account the subsequent contributions of references in patent families to calculate citations. Some authors have suggested that these peculiarities limit the direct application of more consolidated bibliometric indicators because the result would be inaccurate and inconclusive.

The use of these indicators in the field of scientific production evaluation does indeed present new challenges. Achieving exhaustive indicators is no easy task, especially when considering that patents and their sources do not always facilitate the consultation of citations and the extraction of references. However, specialized databases and search engines, such as PATSTAT or Lens.org, which incorporate bibliographic citation management services and are connected to academic platforms, are becoming increasingly common. This in turn simplifies applying metrics.

In this line, the most feasible indicators proposed in the studies over the short term are those of the consolidated bibliometric evaluation type, such as the technological impact of journals or authors, given that well-established standards favoring the analysis of bibliographic documents already exist.

It would be interesting that future research could approach the relevance of these indicators on heterogeneous sets of patents and scientific articles in order to determine their suitability to evaluate citation impact from multiple facets.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDIX A

Some search strategies:

SCOPUS (www.scopus.com)

((TITLE-ABS-KEY ("patent citation*" OR "patent reference*") AND TITLE-ABS-KEY (non-patent OR scientific))) AND (measur* OR *metric* OR indicator* OR evalua*) AND (LIMIT-TO (DOCTYPE , "ar"))

WEB OF SCIENCE (www.webofscience.com)

(TS=("patent citation*" or "patent reference*")) AND TS=(non-patent or scientific*) and *Metric* Or Indicator* Or Evalua* Or Measur* (Search within topic) and Articles (Document Types)

GOOGLE SCHOLAR (https://scholar.google.es/)

Combination between keywords, between exact phrases or between keywords and exact phrases:

Exact phrase (with two or more words in quotation marks) : “non patent references”; “non patent literature”; “patent citations analysis”; “patent indicator”; “technological impact”; “research impact “; “citation analysis indicators”; “scientific articles”; “scientific literature”

Keywords: bibliometric; scienciometric; metric; measure; analysis; impact; indicator; citation; patent; evaluation; value; influence; impact.

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