Linking science to technology: the "patent paper citation" and the rise of patentometrics in the 1980s

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Abstract

Purpose – In this article, the ideas and methods behind the "patent-paper citation" are scrutinised by following the intellectual and technical development of approaches and ideas in early work on patentometrics. The aim is to study how references from patents to papers came to play a crucial role in establishing a link between science and technology.

Design/methodology/approach – The study comprises a conceptual history of the "patent paper citation" and its emergence as an important indicator of science and technology interaction. By tracing key references in the field, it analyses the overarching frameworks and ideas, the conceptual "hinterland", in which the approach of studying patent references emerged.

Findings – The analysis explains how interest in patents – not only as legal and economic artefacts but also as scientific documents – became evident in the 1980s. The focus on patent citations was sparked by a need for relevant and objective indicators and by the greater availability of databases and methods. Yet, the development of patentometrics also relied on earlier research, and established theories, on the relation between science and technology.

Originality/value – This is the first attempt at situating patentometrics in a larger societal and scientific context. The paper offers a reflexive and nuanced analysis of the "patent-paper citation" as a theoretical and historical construct, and it calls for a broader and contextualised understanding of patent references, including their social, legal and rhetorical function.

Keywords Scholarly communication, Documents, Patents, Bibliometrics, Citation analysis, Patentometrics, Linear model, Research policy

Paper type Conceptual paper

Introduction

In May 1997, a study of citations in patents made the headlines of the *New York Times*. The article, titled "Study Finds Public Science Is Pillar Of Industry" (Broad, 1997), was based on a scientific paper written by Narin *et al.* (1997). The message was clear, basic science conducted by public institutions made important contributions to industry, and this in turn motivated increasing government funding of research. A science policy advisor asked to comment on the study suggested that: "It's a wake up call for Federal investment policies". The paper tackled a key question in 20th century research policy, the relation between basic research and technology, by studying citation linkages between research publications and patents.

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The idea was that basic research (represented by scientific articles) produced by researchers at public institutions was increasingly used by industry (represented by patents). References from patents to scientific papers made the link explicit, and ultimately it could be used as a strong argument for government funding of basic research. The findings would eventually be discussed both in congressional hearings and in government reports.

In a recent study, the paper by Narin *et al.* (1997) was highlighted as a textbook example of how bibliometric studies have come to influence policy (Hicks and Isett, 2020). But how did references in patents become such a crucial indicator and argument in contemporary research policy? Typically a patent application involves claims regarding the novelty of an innovation, and these claims are often supported, and demarcated, by references to other documents. Foremost such references refer to previously granted patents, but other documents, including scientific papers also play an important role. During the 1980s, references in patents become an increasingly used statistical unit for measuring interaction between science and technology. Methodological issues took centre stage in many early efforts, yet questions regarding why patent citations were made (motives for citing) and especially the effort to understand the different roles of applicant and examiner references were a major concern. The development of methods, and new approaches, was coupled with attempts to theoretically grasp the unity of study: What did patent references actually mean? In this article, the concepts and methods behind this idea are scrutinised by following the intellectual and technical development of approaches for studying the citation link between patents and papers. The study emphasises the role of important works published in the 1980s, which was a key period for the development of "patentometrics" [1] in general and patent citation in particular. While at the same time covering important early work, subsequent studies on the role of patent citations lead up to the landmark 1997 paper. Moreover, it links the methods used and the theories developed to a broader research policy context.

The field of bibliometrics is to a large degree forward-looking, focussed on current developments, new methods and data sources. However, old concepts and ideas, such as the notion of patent citations as links between science and technology, are still important for guiding research efforts and conclusions. Actually, the use of patent citations as indicator of technology linkage has resulted in a rather large research area, which has had considerable impact on policy discussions (Hicks and Isett, 2020). A few studies, notably Meyers (2000) and Oppenheim (2000), have critically reviewed the patent citation and its use for depicting science–technology links, yet compared to its equivalent, the scientific citation, which has been the subject of various "citation theories" (Bornmann and Daniel, 2008; Leydesdorff, 1998), the patent citation, despite its frequent use in many fields, is notoriously under-theorised. Hence, while studies of wider scope and using more refined methodology have been designed, few attempts of developing a theory of patent citations exist. Meyer has highlighted the need for more detailed studies of the function of references in patents, and he suggests that "one should investigate why research papers are cited rather than counting them under the assumption that every count makes every penny spent on basic research more legitimate and thus more relevant to industry." (Meyer, 2000, p. 412). In his in-depth critique, Meyer emphasises the mediated nature of the link between science and technology by studying citer motivations in patents. Still, while the scientific citation has been studied as part of a historically emerging "citation culture" (Wouters, 2014) with specific infrastructures and actors, the history of patent citations as indicators is largely unwritten. The aim of this paper is therefore to historically situate the patent citation and at the same time provide insights to how this indicator of science and technology interaction was shaped. Such an analysis will be of use when contextualising current studies in patentometrics, and it may contribute to a more reflexive and nuanced understanding of the "patent-paper citation" as a theoretical construct. Certainly, an understanding of how this "indicator" was initially defined, argued for and the broader context on which it was reliant is important when discussing its current use in policy discussions and research.

The article constitutes a conceptual history of the "patent paper citation", which studies how this idea emerged and became established. The paper highlights two key notions employed when making the patent–paper link through patent citations: (1) the concept of "basic research" and its relation to technological development and (2) the idea and use of patent citations as direct links between "basic science" and technology. Relevant works have been identified using direct searches and by tracing references, and while scholarly publications make up the majority of the material studied, the selection of texts extends to reports and other documents. Searches in *Web of Science*, focussing on citation to seed publications, such as Carpenter *et al.* (1980), Narin *et al.* (1997) as well as searches in key journals such as *Scientometrics*, *Research Policy* and *Journal of Documentation* have been the starting point for collecting material. Particular attention has been given to how "the patent-paper citation" has been conceptualised and theorised in the literature and how the ideas behind the approach have influenced the design of studies and the interpretation of results. While this article focusses on citation links between patents and papers, it should be noted that patent citation analysis comprises a larger area of study including analyses of "patent to patent citations", where especially the economic value of the cited patent in relation to citations received has been studied (Trajtenberg, 1990). Interestingly, during the same period examined here, attempts of using patent citations to forecast the success of products, especially medicines, were proposed (Windor, 1979). Moreover, patent citations have also been studied in relation to patent litigation (Malaspina, 2019).

First, the paper outlines important concepts, such as basic science and pure research, and their relation to the "linear model of innovation" with a special emphasis on how these notions shaped research policy after the Second World War. In the next section, attempts of empirically demonstrating the importance of basic research are discussed, with a specific emphasis on how researchers tried to solve the "objectivity vs. relevance" problem in studying the "impact" of basic research. These parts of the paper analyse the overarching frameworks and contexts in which the idea of measuring emerged and how these ideas come to shape the field of patentometrics. The study of "patent paper citations" – and its development during the 1980s – is discussed in the subsequent section. Here, the focus is on the ideas and rationale of the proposed indicator, as well as its technical and methodological improvement. The actual elements measured, references in patent documents, are scrutinised in detail: what do they actually indicate and how can they be understood in relation to more elaborated theories on the "scientific citation"? In a concluding section, the "patent paper citation" and its use in proving the relation between research and technology are considered. It is argued that a further interest in patents – not only as legal and economic documents, but also as "scientific" documents – became evident in the 1980s. At the same time as patents became an increasingly important asset for universities, the patent citation became a key indicator of societal impact assessment. Moreover, the focus on patents, and patents citations, was sparked both by a need for relevant and objective indicators and by greater availability of databases and methods.

In the next section, the background, the ideas and the resources needed for the emergence of patent citations as indicators of science and technology interaction are depicted. It paints what Law (2004, p. 27f.) describes as the "hinterland", the landscape on which a specific statement or concept relies and which is needed in order for a claim or idea to be stable over time. The hinterland involves both social (and conceptual) relations and material ones, and it decides which possibilities that are deemed as thinkable and realisable. As pointed out by Law (2004), the borders of hinterlands, much like those of a landscape, are porous, and they spread in every direction, making them difficult to delimit. Therefore, the background depicted here foremost focusses on a post-war US setting, which arguably plays an important role in the conceptual history of the patent–paper citation. Still, while the particular application of patent citations primarily had its origin in the USA, it is evident that it was part of a larger reorganisation of the "contract" between science and society which extended across many industrialised countries (Etzkowitz and Leydesdorff 1995). In this setting, the concept of "basic research" stands out as a fundamental notion around which much of the discourse on the relation between science and technology revolves.

Basic science and the linear model of innovation

The importance of basic science for technological development has been a central theme in the research policy debate since the end of Second World War. An often mentioned landmark is Vannevar Bushs *Science, the Endless Frontier: a Report to the President* published in 1945 (Bush, 1960, 1945). Stokes (2011, p. 3) provides an in-depth discussion on Bush's use of the concept "basic research" and highlights two central notions as especially important: (1) "basic research is performed without thought of practical ends", and (2) it should contribute to "general knowledge and understanding of its nature and its laws". The main message is that too much focus on practical use thwarts creativity, and the purpose of separating basic from applied science is to protect basic research from outside influence. Indeed when Carpenter *et al.* (1980), in their first paper on patent to paper citations, refer to basic science as "external" to the patent literature with its connections to technological and commercial interest, they evoke the image of a science untainted by outside interests. Bush's deliberate use of the concept helped in arguing for a continued support for basic research, and the longevity of the concept could in turn be explained by its integration in economic theories, its use in official statistics of research and development and the lack of viable alternative concepts (Pielke, 2012, p. 357).

Eventually, as the USA became more focussed on the economic progress rather than military needs, the challenges against Bush's canon became more frequent (Stokes, 2011). The idea of basic research and its role in promoting innovation had come under increased scrutiny during the 1960s and 1970s, and the overarching framework for understanding the relation between science and technology – the so-called "linear model of innovation" – was questioned (Schauz, 2014, p. 313). The focus on growth, the importance of knowledge generation for the economy and the important role of patents were further emphasised in the legal sphere by the introduction of the Bayh–Dole Act in 1980. This law allowed universities to claim ownership of inventions based on federal funding, and it resulted in an increase of university patents from roughly 300 per year in 1980 to 1200 in 1990. The increasing focus on patenting in university settings was reinforced by two high-profile cases in the Supreme Court that allowed for patenting of living organisms and computer software (Rooksby, 2016, p. 132f.) [2]. According to Slaughter and Rhoades (2004, p. 103), these changes marked a shift from a "public good knowledge regime" to a "capitalist regime" in academia. Similar developments have been documented in the United Kingdom where patents have had an increasing impact on the culture and economy of academic science (Sherman, 1994).

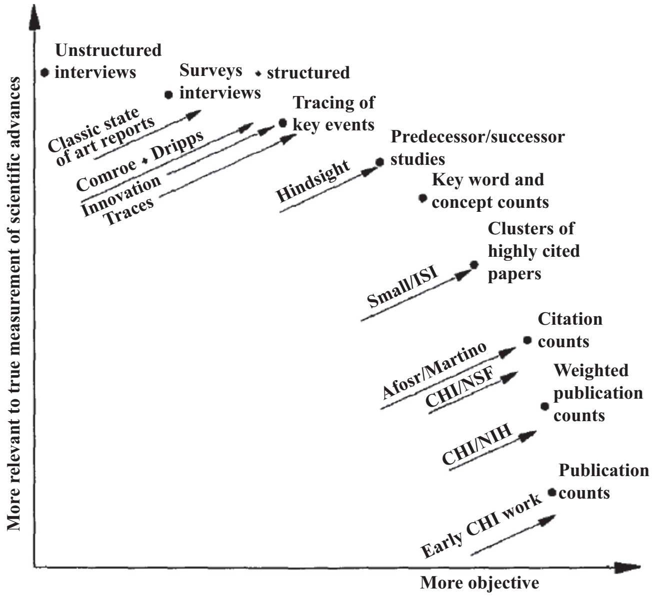
During this period, the criticism of the linear model became more persevering as the focus of US research policy changed from military advancement to economic growth (Stokes, 2011). The legal emphasis on patents as property forms further strengthened the focus on universities as engines of the economy. Consequently, those championing the importance of "basic research" needed concrete evidence of its importance for social and technological development. Yet, while being used in official statistics, basic science is inherently hard to define and operationalise empirically. A common solution in many of the early studies of patent citations is to define research as "basic" on the basis of journals. Hence, a certain set of journals are defined as basic, and patents citing these journals are deemed to be relying on basic research (Carpenter *et al.*, 1980; Narin, 1984). For example, in their 1997 study, Narin and colleagues write (p. 322, *italics added*): "The journals shown on Table 2 are clearly prestigious and influential, and for the biomedical and chemistry papers, *quite basic*." However, the journals in physics and technology show another pattern: "The physics journals, however, are *not basic*, with much of the physics cited in patents published in applied physics journals, rather than the more basic theoretical and high energy physics journals." (Narin *et al.*, 1997, pp. 323–324, *italics added*). Hence, the problem of defining basic research is complex, especially as the notion has different interpretations depending on the field. The most common method is to define basic research using classification of journals (for another example, see Van Vianen *et al.*, 1990). However, some authors refrain from separating between different kinds of research, as Coward and Franklin (1989), who instead refer to the "science universe" (papers) and the "technology universe" (patents).

Patent citations as the solution to the objectivity versus relevance problem

As shown earlier, the difficulty in providing systematic empirical data on the influence of science on technology was a major challenge. A central problem for many analysts was to find a method that was both relevant and objective. The idea of basic science driving development and innovation, the so-called "linear model" (Godin, 2017), supposed a direct link between science and technology. However, empirical evidence for the connection between basic or fundamental research and technological development was missing. An important project directed towards the question of how science influences technology was launched by the US Defence department in the 1960s. *Project Hindsight*, as it was called, investigated the role of basic science in technological development. It studied "100 critical events" in the development of 20 weapon systems and found that only 1 in 10 could be traced back to research and only 1 in 100 to "basic research" (Stokes, 2011, pp. 55–56). These results were troublesome for those claiming a strong link between basic science and technology. Hereafter, as a response, the National Science Foundation launched a project of their own, called TRACES, which looked at the trajectory of five technological innovations – videotape recorders, oral contraceptives, electron microscopes, magnetic ferities and matrix insulation – and, perhaps not surprisingly, strong links to basic science were found in all these cases.

However, a problem, associated with both *Hindsight* and *Traces*, was that events or technological developments were picked subjectively. Indeed, it could be claimed that these studies served as well-chosen and illustrative examples, rather than analytical and complete studies. Francis Narin, who himself was a driving force behind the TRACES study, did position these approaches as being highly relevant yet not very objective. In fact, he outlined an "objectivity/relevance" scale which is of particular interest if we are to understand the role that the "patent citation" was given in subsequent work. In a paper titled "Objectivity versus relevance in studies of scientific advance", he developed a scale on which studies of science could be projected (Narin, 1978, p. 38) (Figure 1).

In reviewing earlier studies, Narin related the challenges of science studies with that of Heisenberg's uncertainty principle in quantum physics, and his conclusion was that "those science policy studies which are most relevant to measuring the true rate of contribution of a science have the greatest uncertainty as to objectivity, while those which are the most objective have the greatest uncertainty as to relevance." (Narin, 1978, p. 36). He argued that qualitative studies using "hand-picked" examples of research that were used in technological development often targeted the relevant question: How is research used? Yet, it is doubtful how representative these examples are for science at large. This argument follows the same line of reasoning as expressed by de Solla Price (1965, p. 564) when arguing that the few times science has had direct influence on technological development is when "…the effect is brilliant and startling, and the situation is of considerable historical important so that the incident becomes glamorized and mythologised." Thus, single examples of how sciences have influenced technology may give an overly optimistic view on the relation between the two, and such studies may, according to de Solla Price (1965), not reflect the normal function of science in relation to technological development.



Source(s): From Narin, 1978, p. 38

Figure 1.
Narin's objectivity vs relevance scale

On the other hand, quantitative data, such as publication or citation counts, can be collected using clearly defined parameters and can therefore be said to be more objective, yet the relevance of such bibliometric measures for studying how research contributes to society can be questioned. Hence, a cut-off between relevance and representativeness (and objectivity) was constantly an issue when analysing the impact of basic research on technological development.

Several of the examples in Figure 1 are from Narin's and his colleagues' work in the *Computer Horizons Inc* (CHI) consultant company. Two methods are discussed as especially promising for the future; citation counts and especially citation networks, and the possibilities offered by the analysis of key words and concepts. Patents are not mentioned, although the analysis of patent statistics, with a particular focus on citations, would be Narin's main focus during the coming years. Over time, Narin would develop an approach that he found being both highly relevant and representative. The method used the "objective" techniques of bibliometrics and citation analysis, but on a new material: patents.

Indexes and entrepreneurs: the rise of patentometrics in the 1980s

The paper "Linkage between basic research literature and patents" published in the journal *Research Management* in March 1980 marks the start for a series of papers, published during the 1980s, which uses patent citations as an important link between "basic research" and technology (Coward and Franklin, 1989). Carpenter *et al.* (1980, p. 34) presented here "a direct technique for linking patent literature, a body of knowledge of technological and commercial interest and external to basic science itself, with the standard measure of scientific research – the scientific article". While patents, and the references found within them, had been studied before, the analyses produced during the 1980s were larger, more systematic, and they primarily focussed on the link between patents and scientific papers.

The "patent citation" did offer a new and potentially fruitful response to the objectivity/relevance problem, and in arguing for the usefulness of patent citations, Carpenter *et al.* (1980, p. 34) listed three main advantages of using patents: (1) they were "external to science", (2) they demonstrate active utilisation and (3) they can be searched without pre-selection of topic areas. Most importantly, the patent citation was "objective", yet at the same time, the citations provided "direct links" between science (papers) and technology (patents). As Sherman (1994) suggests, the perceived "objectivity" of the patent is largely dependent on its origin in patent law, which allows it to "be presented as a bounded, stable object" (p. 529). Hence, in retrospect it appears as the "patent citation" was the solution to the very problem that Narin outlined in 1978, and during the 1980s, it would be studied extensively by researchers in the emerging field of patentometrics.

The work of Narin and his colleagues at *Computer Horizons* takes a central role in establishing citation analysis of patents and especially in studying the so-called "non-patent citations". However, the use of patents as indicators of technological activity was not new, as noted by Pavitt (1985) in an early review of the patent literature. Such analyses were conducted by economist such as Schmookler (1950) and Scherer (1965) already in the 1950s and onwards, and early uses of "patent statistics" can be traced back to the beginning of the 20th century (Tissell, 1907). Already in 1949, Arthur H. Seidel described a "citation system" for patents, and in 1955, the chemist and information scientist Eugene Garfield presented a prototype of a citation index of 5000 chemical patents (Garfield, 1957). Evidently, Narin and his colleagues were not unique in taking an interest in patent citations. Patent citations had been studied for quite some time, yet then often in the context of studies into documentation and information use. For example, Clark's (1976) early study of patent citations involved both patent-to-patent citations and citations to patents from the periodical literature (ISI Journals). In fact, he envisioned how paper–patent citations may be useful for wider studies of science and technology: "patents are used for their technical content independent of their legal one, and we shall propose that citations to patents from serials can index this use, together with that as sources for the history of science and technology." (Clark, 1976, p. 37). Similarly Charles Oppenheim, information scientist and for a long time working at the patent indexing company Derwent Inc. (Moore and Robinson, 2017), did publish several papers on patent citations in the late 1970s, and many of these studies were inspired by citation studies involving scientific papers (Oppenheim, 1976). For example, Ellis *et al.* (1978, p. 19) propose that patent citation networks could be linked to journal citation networks and mention that such attempts are "under active consideration". Thus, methods for tracking citations from patents to papers, and from papers to patents, were developed already in 1980, and the potential of these approaches was recognised. Yet, these early attempts were often small and of an exploratory nature due to the painstaking and time-consuming work of matching references manually.

As outlined earlier, the interest in patent citation analysis during the 1980s was motivated by the search for concrete empirical data on the science–technology interface, which could support the notion of basic research as the driver of technological progress. Yet, a prerequisite for the emergence of patentometrics on a larger scale was the availability of data, and patent citations were available for analysis on a larger scale first in the 1980s. The increasing accessibility of patent citation data was in turn dependent on the establishment of a new industry of scientific information, where entrepreneurs such as Eugene Garfield with *Institute of Scientific Information* (scientific citations), Monty Hyams' *Derwent* (patent database) and Francis Narin's *Computer Horizon* (science indicators) saw the need for gathering and organising information on scientific and technological activities. Garfield was first in providing patent citation data, as the 1964 edition of Science Citation Index (SCI) indexed both references in patents and citations to patents from scientific articles. However, due to the cumbersome work of indexing this feature of the SCI, it was abandoned already in 1966 [3]. *Derwent* had indexed patents since 1951 in various databases, but it was first in 1994 that a "patent citation index" was added to the company portfolio (Oppenheim, 2000). In more general terms, the 1980s marked the emergence of an "online information database industry" (Smith and Tenopir, 2010), and the greater possibilities of distant retrieval of records and data would eventually accelerate the study of patents and papers. Yet, for the period in focus here, researchers still primarily relied on citation data collected by themselves or by the independent research company *Computer Horizon* (also known as CHI research).

In the early eighties, Narin and his colleagues at *Computer Horizon* realised the potential of information available in patents and how this data could be linked to other resources such as *ISI Science Citation Index*. The incorporation of citation data from ISI allowed for more advanced analyses, for example, in studying the relation between patents and highly cited documents. Notable however is that many of the early studies, especially the ones including applicant citations, were rather small due to the time-consuming process of manual or semi-manual extraction of references. Moreover, there were several problems to overcome in linking records from different data sources (e.g. in terms of journal titles and their abbreviations), and especially standardisation names of institutions such as universities and companies were a continuing problem (Narin, 1984). The classification of patents, which in the US system is based on art – Narin gives the example of the class "rotating devices", which encompass such different entities as a jet engine and a fan – was another difficulty (Narin, 1984, p. 181). Obviously, there was a great degree of manual work involved in creating the CHI patent databases, which in 1984 covered 800000 patents and roughly 5 million references.

So, in the early 1980s, Narin and colleagues in the emerging field of patentometrics began to study patent citations in a more systematic and ambitious way, and the availability of data was a prerequisite for this development. While new databases and methods were an essential precondition for their research endeavour, it was also guided by established ideas and metaphors describing the interaction between science and technology.

Dancers: describing science and technology interaction

In their 1985 paper, "Is technology becoming science?", Narin and Noma continue to investigate the connection between science and technology through patents. Drawing on de Solla Price, they use the metaphor of science and technology as a pair of dancers, which currently "are locked in an embrace from which it is virtually impossible to separate the partners." (Narin and Noma, 1985, p. 370) [4]. The proof of this embrace is primarily citations from patents to scientific papers, but similar characteristics between papers and patents in the age distribution of references are important as well. These findings may, according to the authors, have great consequences:

> If, for example, it is true that science and technology are converging, or at least converging in key high-tech areas, then this is a powerful demonstration of the utility of basic research to technology. Clearly, if very current scientific research is as important to some high-technology patent areas, as appears the case, the diminution in support for basic research could have negative implications for technology. (Narin and Noma, 1985, p. 380).

For Narin and Noma, this observation has methodological implications for how research should be studied, and the strong connection and integration make it necessary to include patents in studies of science. Yet, despite science and technology being highly connected, it is still basic research that leads "the dance" and technology that follows. As noted by Meyer (2000, p. 411) in his review on patent citations, to determine who actually leads the dance becomes increasingly difficult as science and technology draw closer to each other and eventually become indistinguishable from each other. Consequently, Meyer criticises Narin and colleagues for relying on the traditional "linear model of innovation" when describing the relation between science and technology.

The metaphor of science and technology as "dancers" is used by Narin several times in his writings (Narin and Noma, 1985; Narin and Olivastro, 1992), and unmistakably he picked this references from de Solla Price and his essay on "Is technology historically independent of

Science: A study in statistical historiography" (1965). It seems obvious that he found the metaphor attractive and illustrative, but at the same time Narin's interpretation is markedly different from de Solla Price's. Throughout the essay de Solla Price questions the tight connection between science and technology, viewing them as two distinct spheres which develop at the same rate, but where there is little connection between them in the form of literature exchanges (de Solla Price, 1965, p. 563). In particular, de Solla Price emphasises the difference between science and technology in their use of literature where he positions scientists as "writers" and technicians as "readers". In the conclusion, he summarises his view while emphasising the importance of more detailed studies:

> I am afraid that the naïve image of technology as "applied science" will be difficult to refine and understand in greater depth. But until we know what the rhythm is and how both dancers move to it we shall not have a proper understanding of the history of technology, and until we know that we shall not be able to make intelligent judgments in such critical areas as the support of science and technology and medicine by state and industry. (de Solla Price, 1965, p. 567)

An important argument for de Solla Prices is the cumulativeness of literature and how the age span of citations can be seen as an indicative of science. This would indeed be what he refers to as the "rhythm" of science and technology. According to de Solla Price, a spectrum, from pure science to non-science, can be deduced based on the age of references used, or in his words: "the ratio of the research-front citations to archival citation." (de Solla Price, 1965, p. 558). Price suggests that references in patents do not form a "cumulative network" which in turn would place them on the "non-scientific" end of the spectrum. Clearly, this is an assumption that Narin and several contemporaries challenge, and the age of cited references in patents therefore becomes an important argument when linking science and technology through patent citations.

The metaphors of the "dancers" and de Solla Price's views on the relation between science and technology have obviously been influential in forming the research agenda in early studies of patent citations. Still, there is an inherent contradiction in the descriptions of "dances" and "interactions" and their subsequent operationalisation of the relation between science and technology. Meyer (2000, p. 410) argues that such a view builds on a simplified notion of "quasi-organizational" definitions of science and technology, in which university-affiliated academics produce science and industrial researchers produce technology. Studies of science and technology interaction tend to emphasise the increasing closeness of the two, making them almost indistinguishable, yet in designing a method for analysing the actual documents a distinct delineation is needed where papers represent science and patents represent technology and application. When the delineation is made, connections can be drawn. The main method for making this connection was, and still largely is, to study references in patents and papers. The idea was that references in patents, much like their scientific equivalent, could be studied as indicative of knowledge flows. Yet, referencing practices in patent documents did offer specific challenges both in terms of methodology and in their theoretical interpretation.

Linking through references: understanding the patent paper citation

A challenge recognised already early in the literature on patent citations is how to handle the two different kinds of references included in patent documents. In contrast to the scientific paper, two types of references exist in patent applications: those inserted by the applicant and those inserted by the examiner. Examiner references are often found on the front page, or on a separate data sheet, while references inserted by the applicant are found in the body of the text. As pointed out by Oppenheim (2000), the practice of examiner-added references is of a rather recent date starting in the beginning of the 20th century in Britain and as recently as 1947 in the USA. Generally, the references inserted by the examiner are easier to access for analysis as these are indexed in citation databases to a larger degree than the applicant citations. This is largely due to examiner citations being given in a specific section – usually on the front page of the patents, while applicant references are scattered throughout the document, which makes it more complicated to index them. This is why many studies of patent citations mainly focus on examiner references.

In the US systems, the applicant is obliged to cite relevant prior art, yet but as pointed out by Oppenheim (2000, p. 408), the applicant "…naturally wishes the invention to appear in the strongest possible light" and while such motivations may be rather similar to the motives of giving references in a journal article, it could be that applicants have an even stronger incentive to focus on the uniqueness and importance of the invention. Collins and Wyatt have a similar view when describing references from applicants as "…either related to but significantly different from, or else a useful step towards, the new invention or a use of the invention." (Collins and Wyatt, 1988, p. 66).

Regarding the references added by examiners, Collin and Wyatt (1988 p. 67) suggest that they focus their reading and subsequent citing to a more limited section of the literature compared to applicants (e.g. they more often cite other patents), and when scientific publications are used, it is more frequently in the form of abstracting journals rather than in its primary form. Moreover, they claim that applicants are prone to cite academic journals, while examiners relay on a more extended set of publications including primarily patents but also reference books and abstracting journals (Collins and Wyatt, 1988). Furthermore, examiners may be more inclined to choose references that satisfy legal requirements, as they should focus on the claims made and are not obliged to cite additional sources (Oppenheim, 2000, p. 408). In more general terms, referencing practices of applicants resemble those of researchers, while examiners have a narrower focus on the legal claims. This relates to the community addressed where "[t]he author assumes a very substantial familiarity with the subject matter of the article, on the part of the intended audience of a journal article. The inventor only assumes the ability to understand the specific application for which patent protection is sought." (Meyer (2000, p. 100).

A majority of the early papers on patent citations point to applicant references being a more important, or at least as important, link between science and technology compared to references given by the examiner (Carpenter *et al.*, 1980; Narin and Noma, 1985). The importance of including applicant references is emphasised also in studies using references inserted by the examiner, and the need for more in-depth studies is stressed. For example, Vianen *et al.* (1990) find that there are considerably more applicant references to scientific papers compared to examiner given references, and they "…conclude that the analysis of inventor-given references is a necessary further step in the study of the science base." (p. 81). Hence, an additional argument for including applicant references is that they would provide a more robust statistical material for analysis. The low ratio of non-patent citation is viewed as methodical problem, and there are concerns that "random samples" would distort the findings (Schmoch, 1993).

Overall, a gradual shift in the use and discussion of the two kinds of references found in patents can be identified. Initially their similarities are emphasised, and both types are analysed to varying degrees. Several of these pioneering studies discuss citer motivations and rely upon information from applicant and examiners involved in the process. Later studies, in which examiner citations are highlighted as the most reliable, foremost studies patent citations on a larger scale using solely quantitative approaches. For example, in the influential 1997 paper by Narin and colleagues, the decision to focus only on examiner citations is justified both methodologically and theoretically: "the front page references should be the most important ones on a patent, since they are the ones relied upon, as mentioned previously, by the examiner in establishing the patent's novelty. Furthermore, from a practical viewpoint it is far more difficult to extract the non-patent references scattered through the text of a patent." (Narin *et al.*, 1997, p. 319). Gradually the differences between the two types of references are strengthened, and eventually it is argued that examiner citations are to be preferred both theoretically and practically. Again, the perceived "objectivity" of examiner citations rests on their origin in patent law, which posits the examiner as a more neutral and objective actor compared to the applicant. Evidently, this development coincides with larger studies, which do not allow for manual indexing of applicant references.

Fences or stacks: referencing practices in patents and papers

When the function of references in patents is discussed, the analysis often focusses on differences between applicant and examiner citations. Already in 1988, Collins and Wyatt suggest that very little has been published "on the cognitive and sociological function of citations in patents" (Collins and Wyatt, 1988, p. 66), and similar statements can be found in the subsequent literature (Oppenheim, 2000; Meyer, 2000). A few exceptions can be found however, and a more social and rhetorical perspective on the role of references in patents is suggested by Rip (1986). He argues that the main task of a patent application is "that of marshalling a set of forces that will withstand sceptical scrutiny" (p. 85). The applicant thus needs to erect "fences of interest", and one of the resources used for this purpose are scientific claims (Rip, 1986). Hence, references to scientific papers are used for a very specific purpose compared to the many "reasons to cite" identified in scientific texts. Rip's account of the use of references in patents highlights the social and rhetorical aspect of citations, and the analogy of "fences" points to the work that references do in the actual document. Importantly Rip's account, contrary to many studies originating in the scientometric literature, emphasises the legal character of patents.

A similar argument, but in the context of scientific texts, is made by Latour (1987) when arguing for the role of references in persuading an audience. He describes the practices of citing as "stacking" where references are used as "evidence" for a certain view point, and by lining up (famous) names, a certain claim is made more credible in the eyes of other researchers. In both cases references are used as a defence against the questioning of a scientific or legal claim, yet "stacking" and "fencing" are two distinct strategies, which imply different citation practices. Stacking is mostly a matter of adding, the higher the stack, the stronger the claim. Consequently, plentiful of references should normally work to one's advantage, as many "Allies" make it more difficult to question a specific claim. "Fencing" on the other hand requires exactness in the claims made and the borders drawn. On the one hand, the patent should include "prior art" yet too many references may compromise the "novelty" of the claim. Accordingly, giving references in patents becomes a balancing act, in which each reference is carefully selected. For example, it has been stated that "[. . .] because citations in patents have a specific legal function, they are likely to be much more carefully selected than citations in journal papers. The former will be scrutinized by patent examiners; the latter may not attract similar attention from referees." (Collins and Wyatt, 1988, pp. 66–67). This is an interesting observation as it points to an important difference between paper and patent: adding to the "stack" of references in a scientific paper comes at a low cost, and with little risk, while adding "fences" may come at considerable cost, and ultimately claims made in relation to the literature could be challenged in court (for a recent discussion, see Donato *et al.*, 2019). Moreover, this entails that references in patents can be added at various points – new "fences" can be erected – over the lifetime of a document, resulting in a complicating factor for citation analysis (Warr and Suhr, 1992).

It could be argued that comparisons with "scientific" references offer little in terms of understanding the referencing practices of patents. While this might be true, it does emphasise the problem of assuming that all citations are alike. Similarly Oppenheim (2000, p. 421) claims, on the basis of a study by Kaback *et al.* (1994), that

> . . . patents are not governed by the same rules of etiquette as journal articles. The references that are made by the applicant rarely look like the bibliography of a journal article. The authors of the patent application wish to avoid any implication that the current application grew naturally out of earlier work. Thus, most prior art that is cited by the applicants relates unsuccessful approaches to the question.

In regard to references given by the examiner, Oppenheim (2000) emphasises that these are exclusively focussed on the claim and not used for background information. Hence, references in patents are used for distinctively different purposes compared to their function in academic papers. Moreover, while referencing practices in science are rather uniform across national contexts, the giving of references in patents is dependent on the specific patent legislation of a particular country or region. Meyer (2000) emphasises that the requirements of patent applications in particular legal systems result in large variances in the number of references given (more references in the USA compared to European countries) as well as differences in the kind of materials cited (more international references in Sweden compared to e.g. Germany). Another important difference is the social function of citations. The patent reference is, for example, rarely used for making friends and Allies, while an important function of the reference in scientific publications is to show membership and identity. The patent's references are, as suggested by Rip (1986), more about drawing boundaries and showing independence. As, suggested by the "stack" metaphor, scientific references have emerged as a currency on the academic market, the problem of strategic referencing, for example, by citing key figures in the field, or for that matter, possible reviewers, has become a debated issue. Such considerations are less pronounced in the context of patent citations as examiner and applicants have little to gain from engaging in "citation gaming" or flattery citations.

To summarise, the specific purposes of scientific paper and patents, as well as the spheres (scholarly, legal and commercial), which they address, influence why and how references are given. Largely referencing practices have been "black boxed" in research on patent citations, and few attempts have been made to theoretically explain why references are made by applicants and examiners. A fully fledged theoretical framework of the patent citation is probably not feasible given the many possible layers and perspectives (social, legal, historical and rhetorical) involved. Still, informed considerations regarding the specificities of referencing in patents may result in a more nuanced and contextualised understanding of how the different practices, and "rhythms", influence empirical findings.

Conclusion

The purpose of this paper has been to depict the setting, or "hinterland", from which the idea of the patent–paper citation as the link between science and technology grew. By analysing the background in terms of policy setting and theoretical foundations, the emergence of patentometrics can be placed in a historical context. In paraphrasing Law (2004, p. 29), what is described here is the orchestration of the material and conceptual arrangements that underpin the notion of the "patent citation". As shown earlier, the emphasis on citations as links between patents and papers, between basic science and technology, in the 1980s, was dependent on several factors. American research policy, in which the relation between science and technology came to the fore, had a large influence on the development of patent bibliometrics. Indeed, the article shows how a further questioning and renegotiation of the post-war research agenda resulted in a need for studies supporting the view that basic research supported technological development. This development was reinforced by legal reforms that put additional emphasis on "patenting" within universities. While earlier attempts mostly had operated on the level of case studies, patent citations – and the new databases that indexed them – offered a systematic and "objective" method for studying science and technology interactions. The strong focus on policy relevant studies resulted in that other approaches for studying references in patents, such as the work by Oppenheim (1976) and Rip (1986) on patent networks and keywords, largely were overshadowed.

It would therefore be tempting to describe the focus on patent citations as a result of a further influence of capitalism and neoliberalism in the academy, yet while such a narrative may be both intuitive and powerful, it should be supplemented by an intra-scientific account of how old questions – such as those posed by de Solla Price – were reinvigorated through new methods and approaches. Issues regarding the relation between science and technology had for a long time been of great importance in the sociology of science and in related fields such as economics. However, established systematic methods for studying the relation between science and technology were largely lacking. Studies of individual cases – what de Solla Price (1965) described, as rare exceptions from everyday scientific practices – did not contribute with empirical findings that could substantiate claims of how science supported technological development. The patent–paper citation provided a solution, especially as it was deemed as a more objective method compared to previous attempts. Studies of patent citations were thus part of a longer tradition of approaches for understanding science and technology interaction, and the method of using patent citations was developed in dialogue with these earlier studies. The so-called "linear model" was an influential, and questioned, concept in these efforts, and it came to influence the development of methods for studying science and technology interaction. Hence, while the political and economical context is important, not the least for subsequent impact and interpretation of the results, it is essential to consider how new research constantly engages with that which has been found before, or as formulated by Latour (1987, p. 19): "The social context of a science is rarely made up of a context; it is most of the time made up of a *previous* science."

Moreover, it is important to emphasise that the hinterland analysed here depicts a certain view on the "patent citation" and its emergence as an indicator of science and technology interaction. As argued by Law (2004), the borders of any hinterland are dim, and in this case it may take another shape if viewed from an economic or political perspective rather than a scientific one. Patents, and the references found in these documents, have been studied from a wide range of perspectives, and patent indicators are an established approach in research on entrepreneurship and innovation. Patents have also for a long time been used as official indicators of research and development, in fact Godin (2005, p. 123) argues that patent statistics was the first indicator to emerge in the history of research and development statistics. Moreover, the silhouettes of the landscape may look rather different in other national contexts, with the primary focus in this paper being on an US context. Consequently, the "hinterland" of the patent–paper citation depicted and analysed here should not be taken as complete or exhaustive account.

It is evident that several main conceptual problems identified in the early research on patentometrics still are central to the field despite the availability of vastly superior methods, large online database, availability of full text analysis and so on. One challenge of particular importance is the role of references in patents and how their function influences the interpretation of citation patterns. Notably, patent citations are seldom studied beyond their use as indicators of science and technology interaction. This marks a clear difference compared to scientific citations, which are an integrated part of academic culture and research practices. In fact, most scientometricians, economic researchers or research policy analysts would have their own experience of what it means to cite in a scientific context, while knowledge about patents in citations is derived trough questionnaires and interviews with patent attorneys and patent examiners. As discussed by Oppenheim (2000, p. 409), this may be one of the reasons why few theories on patent citations have been developed: "There can be little doubt that the relative lack of patent citation studies compared to journal citation studies is because patents and patent information are not well understood by many who study bibliometrics." Moreover, it has been suggested that patent attorneys are not very willing to share information about references and how they are motivated, and consequently researchers interested in referencing practices in patents have less access to the views of citers.

So what differences would a patent citation theory actually make? Theories are important as our view of why references are used guides the questions we ask and our interpretation of the results. For example, the finding that patents tend to cite highly cited papers may be interpreted rather differently depending on the theoretical perspective. According to a "normative view" such a finding would lead to the conclusion that scientific work, which is in high esteem in the scientific community, also is important for technological development. From a perspective where references are viewed as rhetorical and social devices, the referencing of highly cited documents could be interpreted rather differently. Then the reason for applicants and examiners to cite the most visible and well-known studies would be to create legitimacy and trustworthiness rather than to cite the most relevant and useful research. Such a pattern would be reinforced by the so-called "Matthew effect" in which citers are biased towards already highly cited publications. As a consequence, the empirical findings of a study might be interpreted rather differently depending on theoretical stance. Hence, understanding the epistemological framework, as well as the theoretical hinterland, which underpins concrete methodological choices and definitions, is of great importance when interpreting citation patterns in patents. Theoretical considerations decide what can be said and done, and ultimately it forms what Law (2004) would describe as "a topography of reality possibilities" (p. 34).

To conclude, the historical analysis provided here depicts how a further interest for patents as scientific documents from several domains, including research policy, bibliometrics and the sociology of science was evident during the 1980s. In many ways the patent become just another document containing scientific information, and the patent citation become a readily available indicator for answering key questions in contemporary deliberations on the role of scientific research in relation to technological development. Patent citation analysis has foremost focussed on the relation between science and technology, yet references in patents can be studied from a range of perspectives and methods. Still, while scholarly publications and the references therein have attracted quite a lot of attention, also from a theoretical and qualitative viewpoint, patents have received considerably less consideration within the sociology of knowledge. However, as argued by Hemmungs Wirtén (2019, p. 588), patents can be of particular interest due to their positions as intermediaries, as documents with dual purposes: "Because they both enclose and open information, patents can tell us something new about the value and power of information across seminal distinctions between pure and applied, between open and enclosed, between secrecy and disclosure." Analogous arguments can be made in relation to patent citations as these, through the methods of patentometrics, come to represent "links" which connect the domains of law, science, technology and business. In representing these links, patents, and patent citations, become a common point of reference which allows for measurement and comparison of entities that otherwise appear as separate and non-calculable (cf. Sherman, 1994). A broader more reflexive understanding of patent references, including their social, legal and rhetorical function, may thus further our understanding of patents and their role in scientific communication and documentation.

Notes

1. The concept of "patentometric" is here used to denote the systematic analysis of patents using methods developed within the field of bibliometrics. In this regard, it is more specific than related terms, often used in economic research and in policy documents, such as patent statistics or patent metrics. The origin of the concept of "patentometrics" is of recent date. Qu *et al.* (2017) point to Narin (1995) as the source of the concept. Yet in this paper, the term "patent bibliometrics" is used, not

"patentometrics". Rather, to my knowledge, the first to use the term was Popper (1995, p. 11) in Rand-cooperation report titled *Economic approaches to measuring the performance and benefits of fundamental science* in which he writes: "To address this lacuna, patent analysis or patentometrics applies bibliometric methodology to patents or patent citations." (p. 11.).

2. These cases were Diamond vs Chakrabaty and Diamond vs Diehr. The rulings in these cases resulted in "an influx of applications." (Rooksby, 2016, p. 134).
3. Notably, Seidel's and Garfield's primary interest was to increase searchability, and similarly to the "scientific citation index', which Garfield launched in 1965, he saw a patent citation index primarily as helpful in enabling a more effective search process (Garfield, 1957).
4. The metaphor is taken from Arnold Toynbee, who, in a note, writes: "Physcial Science and Industrialism may be conceived as a pair of dancers, both of whom know their steps and have an ear for the rhythm of music. If the partner who has been leading chooses to change parts and to follow instead, there is perhaps no reason to expect that he will dance less correctly than before" (*A Study of History: The Geneses of Civilizations, Introduction*, vol. I, p. 3, 1962). In the main text, Toynbee refers to a "pre-established" harmony between the "Industrial system" and "Physical Science" (Toynbee, 1962).

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