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Exploring paper characteristics that facilitate the knowledge flow from science to technology

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ABSTRACT

In this study, we explore paper characteristics that facilitate the knowledge flow from science to technology by using the patent-to-paper citation data. The linear growth trajectory of the number of patent citations to a scientific paper over time is used to measure the dynamism of its utilization for technology applications. The citation data used were obtained from the USPTO database based on two 5-year citation windows, 2001–2005 and 2009–2013. The former included patent citations to the publications in the Thomson Reuters Web of Science in 1998, and the latter included those in 2006. Only the publications in the top ten most frequently cited subject categories in the Web of Science were selected. By using growth modeling, we have found that the mean slope of the trajectory is significant. Moreover, the paper citation count, the ranking factor of the journal in which the paper was published, whether the paper is an industrial publication, and whether it is a review article have been identified to exert significant effects on the growth of the citation of scientific literature by patented inventions. Some policy implications are discussed.

1. Introduction

The importance of science to support technological development has been highlighted. In knowledge-intensive industries, scientific knowledge has significant impacts on technology innovation. Citation to scientific publications is an important driver that accelerates the rate of technological innovation (Sorenson & Fleming, 2004). Patents are considered representations of technologies, while papers are viewed as representations of science (Meyer, 2002). Patents also show the interest in commercial exploitation of a new technology (Schmoch, 1997; Trajtenberg, Henderson, & Jaffe, 1997). Although there are some problems regarding the use of patents—not all inventions are patentable, not all of those that are patentable are patented, and patents differ greatly in their commercial significance and value, patent data have long been used as a measure of innovative activity and technological development because patents cover the majority of technological fields and the major patent systems such as the United States Patent and Trademark Office (USPTO) cover all countries (Debackere Veugelers, Zimmermann, Van Looy, Andries, & Callaert, 2001; Tijssen, 2001).

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Citations to non-patent references (NPRs) in patent documents signal a direct influence of science on technology (Narin, Hamilton, and Olivastro, 1995, Narin, Hamilton, & Olivastro, 1997). NPRs constitute prior scientific knowledge or ideas to which a patent is related (Trajtenberg et al., 1997). However, some scholars argue that patent-to-paper citations should not be interpreted as a direct link or influence from science to technology (e.g., Callaert, Pellens, & Van Looy, 2014; Meyer, 2000). Fleming and Sorenson (2004) argue that science alters inventors' search processes by leading them to useful combinations, eliminating fruitless paths of research, and motivating them to continue. Patent citations to NPRs can be interpreted as exchange processes (Meyer, 2006) or relevance or relatedness (Callaert, Van Looy, Verbeek, Debackere, & Thijs, 2006; Tijssen, 2001) between science and technology. The number of NPRs is used as a measure of technological opportunity (Von Graevenitz, Wagner, & Harhoff, 2013). A greater number of NPRs is associated with higher technological opportunities.

The front page of a patent issued by USPTO provides patent and non-patent references. As pointed out in Hicks, Breitzman, Hamilton, and Narin (2000) and Tijssen (2001), patent applicants are legally obliged to state prior knowledge related to the invention. US patent law requires that the patent examiner determines the novelty and uniqueness of an invention claimed by the patent application. The invention is reviewed and additional important references could be added by the examiner. Therefore, the NPRs on the front page are supplied by inventors, patent attorneys, and/or the examiner. The links to the scientific literature reflect the association between science and technological development.

Because knowledge flow is a process over time, it should be measured in a dynamic rather than static way. As suggested by Callaert et al. (2006), the introduction of a time dimension can uncover the development of science intensity. Thus, regardless of whether the number of patent citations to NPRs represents a direct link between science and technology or just a measure of relevance, the focus should be placed on the growth of citation over time rather than just citation frequencies at specific points of time. Although there exist many empirical studies using citation data, few articles addressed the change in citation over time. Hung, Ding, Wang, Lee, and Lin (2015) evaluate and compare the university performance in knowledge utilization by analyzing the growth trajectories of patent citations to scientific publications produced by individual universities. Moreover, the factors that influence the growth of the patent-to-paper citation remain unclear.

For each published article, the data of patent citations to the paper after its publication need to be obtained over time. The panel data showing the time series of the number of patent citations for individual articles are formed. As can be seen later in Section 3, the majority of scientific papers were not cited, consistent with the fact mentioned in Aksnes (2003) that the large majority of the scientific papers are never or seldom cited in the subsequent scientific literature. Therefore, we focus only on the domains whose papers were more frequently cited by patents. By using growth modeling, an application of hierarchical linear models for the analysis of trajectory (e.g., Raudenbush & Byrk, 2002), we can assess the knowledge flow from science to technology by analyzing the change in patent-to-paper citation over time (its growth trajectory) and further identify paper characteristics that influence the growth pattern to have a deeper understanding of the knowledge flow in those domains. The results obtained are informative for paper authors, patent inventors, and policy makers.

2. Paper characteristics

The paper characteristics that influence the paper-to-paper citation have been widely discussed in the literature. They may also influence the patent-to-paper citation. In this section, we give a brief review.

The number of citations can be used as an indicator of the level of impact or performance for an individual publication or a journal that aggregates publications (Wilson, 1999). It is used as a measure of research excellence (Hicks et al., 2000). Citation-based impact indicators are considered objective because they reflect the evaluations by subsequent researchers (Van Raan, 2004). It is generally accepted that the paper citation count of an article is an effective measure of its importance (the degree of impact) (Onodera & Yoshikane, 2015). Hicks et al. (2000) find that US papers that are highly cited by other papers are much more likely to be cited in a US-invented patent. They concluded that research excellence and innovation are firmly linked, and that American technology draws on the best of American science.

Prestigious journals attract potentially influential papers and articles published in prestigious journals tend to receive more citations (Van Dalen & Henkens, 2001). The impact factor is used to measure the impact of a journal. Alternatively, the ranking factor could be used as the impact factor varies considerably among disciplines. The ranking factor of a journal is the relative rank of the journal in a subject category based on the impact factor. The lower the ranking factor in the subject category, the higher the journal's impact. While the paper citation count is used to measure a paper's research impact, the ranking factor is used to measure the impact of the journal in which the paper was published.

Callaert et al. (2006) suggest drawing attention to authors as well as affiliations of the authors to gain more insight about knowledge flow. Co-authorship is a frequent and reliable measure for collaboration in scientometric studies (Glänzel & Schubert, 2004). Minguillo and Thelwall (2015) find that high quality research institutions are much more likely to establish strong links in the form of co-authorships. The number of authors would positively affect the number of citations (Aksnes, 2003; Bayer, 1982; Franceschet & Costantini, 2010; Gazni & Didegah, 2010; Sooryamoorthy, 2009; Stewart, 1983). Research collaboration generates benefits which could not have been attained if the researchers had worked on their own and enhances the quality of research, leading papers to being cited more often (Katz & Martin, 1997; Narin, Stevens, & Whitlow, 1991; Van Dalen & Henkens, 2001). Collaboration enhances the visibility of research results (Franceschet & Costantini, 2010). The article is brought to the attention of a larger number of researchers through authors' personal network. The knowledge is more likely to be disseminated to the scholars inside the network than to those outside the network (Van Dalen & Henkens, 2001).