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Distant recombination and the creation of basic inventions: An analysis of the diffusion of public and private sector nanotechnology patents in Canada

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ABSTRACT

This article explores whether the relationship between the breath of technological integration (recombination distance) and the breath of an invention's subsequent application (basicness) is moderated by the sector of activity (private or public), science-linkage strength and industry characteristics. Our analysis of Canadian nanotechnology patents granted between 1990 and 1997 shows that although private organizations generally yield smaller rates of basic inventions than public organizations, increases to recombination distance by the former increases invention basicness at a higher rate; increasing reliance upon basic science moderates the relationship between recombination distance and basicness; and increases to recombination distance in emerging science-based industries increases invention basicness at a higher rate. These findings have implications regarding the debate around the efficiency of the academic enterprise model.

1. Introduction

Basic inventions have broad technological applications and are the foundations of many subsequent *focused* inventions whose applications are confined to narrow fields (Trajtenberg et al., 1997). Studies about shifts in the rate of creation of the former type of inventions concurring with the emergence of the academic enterprise have led to a debate about a shift in the nature of academic research (Larsen, 2011).

Henderson et al. (1998) claim that the basicness of university patents seems to be declining with the emergence of the academic enterprise. Based on the observation that *recombination distance* (the breath of technological integration) is linked to invention basicness (Trajtenberg et al., 1997), the authors conclude that this change in the quality of academic patents could imply a change in the nature of academic research.

A reply to this study comes from Mowery and Ziedonis (2002) who claim that the observed decline can mostly be attributed to entry by inexperienced universities and that learning effects can improve the importance of patents produced by the latter (Mowery et al., 2002). Mowery and Sampat (2005) further stress that university–industry technology transfer has been mostly successful in science-based industries such as pharmaceuticals and biotechnology. These observations possibly imply that differences in organizational capabilities and industry characteristics can moderate the relationship between recombination distance and invention basicness.

On the subject of organizational capabilities, Banerjee and Cole (2010) show that firm entry into new application domains by a sample of biotechnology entrepreneurial firms has a negative moderating effect on the relationship between recombination distance and basicness. Is it then possible that the sector of activity from which an invention originates could also moderate the relationship between recombination distance and basicness? Do other factors related to the university–industry interface, such as industry characteristics and science-linkage strength of an invention, have similar moderating effects?

To answer the above questions, we will perform an econometric analysis by using a sample of Canadian nanotechnology patents registered in the US. This emerging multidisciplinary field can potentially breed general purpose technologies (Youtie et al., 2008; Gómez-Baquero, 2009; Shea et al., 2011) and offers the possibility to study the above-mentioned factors. We measure a patent's recombination distance and invention basicness by constructing a Herfindahl-based index of the diversity of technological classes from its backward and forward citations respectively (Trajtenberg et al., 1997). By mean of regression analysis, we measure the moderating

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effect that the sector of activity, strength of science linkage and industry emergence have on the relationship between recombination distance and invention basicness.

In line with findings of Trajtenberg et al. (1997) and Banerjee and Cole (2010), our results show that recombination distance is indeed positively linked with invention basicness. However, we also find that while private organizations are less likely to produce basic inventions, an increase in recombination distance by them increases invention basicness at a higher rate. Science-linkage strength has a negative moderating effect on distant recombination. Finally, our results show that an increase in recombination distance increases invention basicness at a higher rate in the fragmented science-based nanobiotechnology industry. The remainder of this paper is organized as follows: Section 2 reviews the literature and lists our hypotheses; Section 3 provides a complete description of the methodology; Section 4 presents the results; and Section 5 discusses the results and provides some conclusions.

2. Literature review and hypotheses

2.1. Measuring innovative activity through patenting

From a legal point of view, patents confer monopolistic power with regards to the use, production and commercialization of an invention in exchange of its disclosure. Since patents are granted to inventions that are novel, non-obvious and useful, they can generally be viewed as indicators of technological change and innovative activity (Basberg, 1987; Acs and Audretsch, 1989; Griliches, 1990; Archibugi and Pianta, 1996). Various studies, however, point out that the majority of patents have little economic value (Allison et al., 2004; Moore, 2005). Patenting can sometimes be compared to gambling where firms bet on slots (Lemley and Shapiro, 2005). Also, as Pénin (2005) points out, patents can be used as strategic devices and, consequently, cannot be used in a straightforward manner to measure innovation. Nevertheless, some patent quality indicators are known to be associated with commercial success: patent citations can be linked to firm value (Trajtenberg, 1990; Hall et al., 2005) and patents deposed in the US by foreigners have a higher expected value (Bessen, 2008).

Forward citations can be used in various ways to measure patent quality (Squicciarini et al., 2013). One method supposes that important inventions are those that are subsequently used by a great number of inventions. This method typically consists in counting forward citations of a patent to measure its importance (Fleming, 2001; Sapsalis et al., 2006). Another method considers how the eventual use of an invention spreads over technological classes (Trajtenberg et al., 1997; Henderson et al., 1998; Mowery and Ziedonis, 2002), hence relying on the classification of a patent's forward citations in order to measure invention quality. Patents that are subsequently cited in different technological classes are believed to be more basic. Both basicness and forward citation counts have been associated with patent value (Bessen, 2008; Serrano, 2010; SreekumaranNair et al., 2011; Fischer and Leidinger, 2014). Nonetheless, metrics using forward citations can also be viewed as indicators of invention social value (Baron and Delcamp, 2012).

A few precisions are in order regarding patent citations. First, one should note that while applicants have the obligation to cite all related sources of knowledge, they are not legally obliged to perform prior art search. In fact, it is incumbent upon USPTO examiners to make sure that all appropriate sources are cited. Because patents constitute legal documents, examiners go through a thorough search process in which they attempt to add all citations that are relevant to a patent (Trajtenberg, 1990). Because a patent's scope is defined by the novel features of an invention, proper reference to prior art should be made in order to correctly define the technological boundaries legally protected by the patent (Merges and Nelson, 1990). This renders the examination process essential to the preservation of patent scope legal validity.

Based on these premises, Jaffe et al. (1993) argue that patent citations represent knowledge spillovers generated by patents. This assumption has been, to a certain degree, brought into question for two reasons. On the one hand, because citations restrict the patent's scope, applicants often choose not to perform prior art search, and when they do, they can cite other patents strategically (Sampat, 2010). On the other hand, variations among patent examiners have been found implying that some patents could contain citations that are more accurate than others (Cockburn et al., 2002; Alcácer and Gittelman, 2006). Also, time constraints can lead examiners to add citations that are only remotely linked to the applied patent in order to make sure that nothing has been missed out (Meyer, 2000). There are reasons, nevertheless, to believe that patent citations contain relevant information that can have analytical value.

A number of studies argue that applicants have more incentives to search for prior art for discrete technologies such as pharmaceuticals or chemicals while the opposite hold for complex technologies such as electronics or telecommunication (Lemley and Shapiro, 2005; Sampat, 2010; Alcácer et al., 2009). Hegde and Sampat (2009) further show that examiner added citations are better predictors of patent renewal than applicant added citations. In addition, examiner citations are more likely to be added when there is technological and geographical distance between citing and cited patent (Criscuolo and Verspagen, 2008). It is also worthwhile to note that examiners add a larger share of self-citations than the inventors themselves (Sampat, 2010; Alcácer et al., 2009). Based on these considerations, patent examination can also be viewed as a smoothing process that can sometimes close citation gaps between related inventions (Azagra-Caro et al., 2011). USPTO citations are indeed generally viewed as thorough in terms of containing links to relevant prior art (Meyer, 2000; Von Wartburg et al., 2005).

Examiner citations can also be interpreted from a social learning perspective (Amin and Cohendet, 2004). Although the validity of using patent citations to measure knowledge flows can be brought into question, it is undeniable that applicants must, to a certain degree, be aware of contemporary technological developments before engaging in R&D activities. Since learning can be viewed as a social process and that technological development is path-dependent (Rosenberg, 1994), it is difficult to imagine that in knowledge intensive industries, inventors can be totally unaware of current technological challenges and potential solutions, and yet be successful in introducing novelties. Being part of the social process of learning, inventors who search for novel solutions are embedded to their community of practice. Furthermore, the tacit dimension of knowledge spillovers implies that they do not always leave traces in the form of citations and do not necessarily require formal transfer of knowledge (Krugman, 1991). Since this embedding is likely to encompass even inventors who are employed by competitors, an applicant's failure to cite a relevant prior art does not necessarily rule out tacit knowledge about related technologies.

2.2. The emergence of academic enterprise

Viewed as providers and repositories of basic knowledge, universities have historically taken part in R&D activities that have low levels of appropriability and in which firms found little incentives to invest (Nelson, 1959; Arrow, 1962). Basic research undertaken by universities had tremendous spillovers to the industry (Jaffe, 1989; Adams, 1990; Zucker and Darby, 1996;