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Borders and distance in knowledge spillovers: Dying over time or dying with age?—Evidence from patent citations

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ABSTRACT

This paper explores the effects of distance as well as subnational and national borders on international and intranational knowledge spillovers through patent citations across the 39 most patent-cited countries and 319 metropolitan statistical areas (MSAs) within the U.S. In contrast to previous findings that knowledge localization fades over time, border and distance effects increase over time for the same-age citations. This increasing effect of borders and distance is associated with strengthened knowledge agglomeration over time. Nevertheless, both border and distance effects decrease with the age of patents. Aggregate border effects are often overestimated due to various aggregation bias. Moreover, business travels and knowledge quality effectively attenuate the effect of subnational borders in knowledge flows.

1. Introduction

The degree of localization of knowledge spillovers remains contentious. Recently, Thompson and Fox-Kean (2005a) claimed that only national boundaries restrict knowledge flows and that there is no strong evidence to support significant subnational barriers to knowledge diffusion. In contrast, Henderson et al. (2005) (among others) asserted that knowledge spillovers are localized internationally and intranationally at the state, the consolidated metropolitan statistical area (CMSA), and even the standard metropolitan statistical area (SMSA) levels.[1] These conflicting ideas raise the question of the extent to which knowledge spillovers are localized and further challenge our understanding of the causes of knowledge localization. Are knowledge spillovers restricted more by physical distance or national (and subnational) boundaries? If knowledge spillovers are localized, does knowledge localization truly fade over time, as suggested by the existing

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[1] For example, Peri (2005) found that pooled citations as proxy for knowledge spillovers are strongly localized at the state/province level within one country. Jaffe et al. (1993) reported significant localization of knowledge spillovers at the SMSA level. Thompson (2006) and Alcáer and Gittelman (2006) found that inventor citations and examiner citations are both localized within the U.S.

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literature?[2] The answers to these questions have significant implications for public policy on knowledge dissemination and industrial agglomeration.

To better understand patterns in the localization of knowledge spillovers and their potential sources, this paper tackles three questions. First, how localized is the diffusion of intranational and international knowledge? To address this question, I decompose the frictions affecting knowledge spillovers to national and subnational borders and the effects of average distance and internal distance. Second, if national and subnational borders significantly impede knowledge diffusion, what are the potential sources of border effects in knowledge spillovers? Alternatively speaking, are there any factors which contribute to reducing the effect of borders in knowledge diffusion? Third, how does the pattern of border and distance effects in knowledge diffusion change over time and with age? In this paper, "age" refers to the age of knowledge flows, measured by the time interval between the citing and cited patents.[3]

This definition of "age" highlights two different ways of representing patterns of knowledge flows over time. One approach is to investigate existing knowledge spillovers cross-sectionally and year by year to obtain the temporal trends. Another approach is to track the lifetime of knowledge (embodied in patents) to observe how spillovers change as knowledge gradually ages, which are shown here in the age profiles. The existing literature has not highlighted the difference between the temporal trends and the age profiles,[4] although they may generate completely different patterns of knowledge flows. For instance, one might think that a patent is more likely to receive citations across regions as it ages because of the time required to establish its reputation. In other words, it takes time for the knowledge embodied in this patent to be diffused to other regions. If this hypothesis were true, one would expect new knowledge spillovers to be more localized than old ones. The localization of knowledge would then fade over patents' lifetimes. However, if the proportion of new citations to total citations increases over time, a pattern that has been observed (Hall et al., 2001), it is possible for all knowledge spillovers to become increasingly localized over time. Other mechanisms could also lead to strengthened knowledge agglomeration over time. Therefore, it is necessary to distinguish temporal trends and age profiles of knowledge spillovers.

To answer the three questions stated above, I use a gravity model to estimate the magnitude of and the changes in the border and distance effects of knowledge flows. Following a common approach in the literature of knowledge spillovers, I use patent citations to trace knowledge flows. Patent citations are a good proxy for knowledge flows because patents embody new ideas (or knowledge) and award to inventors the right to exclude others from the unauthorized use of the disclosed invention. The applicant of a patent has the legal duty to disclose any knowledge of the "prior art", and hence, citations to previous patents are included in the patent documents. Intuitively, if patent B cites patent A, patent A then represents a piece of previously existing knowledge upon which patent B builds. When patents generate citations, they leave a paper trail of knowledge flows (Jaffe et al., 1993). Therefore, when patents invented in region *i* cite patents invented in region *j*, it is viewed as equivalent to the fact that knowledge flows from region *j* to *i*.[5] Here, *patent citations*, rather than the patent stock itself, provide interesting information tracking the direction and intensity of knowledge spillovers (Peri, 2005).[6]

Using different specifications of gravity equations, I estimate the effects of distance and borders on knowledge spillovers at the aggregate level and by different criteria (age, technology category, and time), controlling for technology compatibility between regions and the pre-existing distribution of technological activities by 3-digit patent class. Based on those estimates, I analyze the changing patterns (age profiles and temporal trends) of border and distance effects for knowledge spillovers. I also try to decompose the data along different dimensions to examine the potential sources of border effects.

The main data used in this paper are from the NBER Patent Citations Database, which contains more than 3 million patents and more than 16 million cross-patent citations. Border and distance effects are examined at both the intranational and international levels through patent citations across 319 metropolitan statistical areas (MSAs) within the U.S. and the 38 most cited countries.[7] These regions include more than 93% of patents and citations in the NBER database between 1980 and 1997. I employ the data at the MSA level because a study of the geography of innovation has shown that the majority of innovations are located in major cities, indicating that innovation is mainly an urban activity (Audretsch and Feldman, 2004). This observation raises doubts about the validity of large effect of state borders in the previous literature.[8] The finer data set at the metropolitan level allows for fuller exploration of the sources of subnational border effects and the nature of frictions affecting knowledge flows. In addition, I apply subnational level data regarding business travels, industrial composition and patent quality to tackle relevant factors that could potentially affect subnational border effects.

[2] Jaffe et al. (1993) find that knowledge localization fades over time, but only very slowly.

[3] Citation lag is equal to the grant year of the citing patent – the grant year of the cited patent. For example, if patent A cites patent B which is 20 years old (i.e., B was granted 20 years ago), this is a relatively "old" knowledge flow, and the age of this knowledge flow is 20; if patent A cites patent B which was granted 2 years ago, this is a relatively "new" knowledge flow, and its age is 2.

[4] For example, the finding of that "localization fades over time" in Jaffe et al. (1993) actually means that localization fades over a patent's lifetime.

[5] It should be noted that this paper only addresses the "pure" knowledge flows embodied in patent citations and all knowledge flows studied in this paper refer to those associated with patents and citations since the general concept of "knowledge" contains extensive content and is difficult to quantify.

[6] Measuring knowledge flows in a consistent, systematic way is a difficult task. Peri (2005) provided a concise summary, including some alternative approaches using trade flows or foreign direct investments as proxies for knowledge flows.

[7] These 319 MSAs include 270 typical MSAs, defined by the U.S. Census Bureau in 1990, and 49 phantom MSAs, one for each state (except New Jersey), containing all locations in non-metropolitan areas.

[8] For example, Peri (2005) estimated that knowledge flows will be diminished to 20% when crossing state or province borders within one country. In other words, Peri (2005) reported that around 80% of initial knowledge spillovers will be lost when crossing state/province borders.