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# Pattern Discovery on Networks of Geographical Co-invention

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**Abstract**

Due to the development of international division of labour and advanced information and communication technologies, an alternative perspective stresses interregional collaborative networks in which individuals groups are embedded in wide-ranging webs of relationships. The existence of collaborative networks raises challenges for understanding the new geography of invention and innovation. The study explores the pattern of the network of geographical co-invention by comparing the co-patenting network in the year of 2009 and 2015. By focusing on the U.S. semiconductor devices patents and particularly their inventors and assignees' geographical locations, the study uses social network analysis to reveal the phenomena of creative knowledge flow and international collaboration. Moreover, the study uses spatial statistics approach to investigate nodal associations, network dependence, and the relationships between the networks and city's inventive competitiveness. The importance of the study is to clarify the pattern of co-invention in the semiconductor industry. The findings will enhance the co-inventive platform between cities and worldwide megacenters for the restructuring on major technology industries.


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*Keywords:* Networks; Knowledge exchange; Co-invention; Co-patenting; Semiconductor device

## 1. Introduction

Geographical concentration of economic actors--inventors, firms, and research institutions--in clusters enhances personal interaction and communication, labor mobility, and research collaboration [1, 2]. Clusters of invention and

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innovation, tied to localized knowledge spillovers in and among developed countries, regions, and cities, have been extensively documented [3, 4, 5, 6, 7, 8]. Recently, new information and communication technologies reduce costs of moving knowledge and enhance access to distant partners [9]. Knowledge flows also circulate in wide-ranging collaborative networks of social relationships and linkages [10, 11, 12]. Network-based proximity links economic actors in different countries and cities, especially in dynamic technologies such as semiconductor industry where research collaboration has become crucial for inventive productivity [2, 13]. This article focuses on the U.S. semiconductor patent data, while the previous paper was the U.S. biotechnology patent data [14]. I illuminate structural properties of the geographical co-invention in the U.S. patents of semiconductor devices. A central goal is to figure out the nature and strength of co-invention among countries and cities. The existence of co-invention networks raises critical challenges for understanding the new geography of invention and innovation. I focus on co-invention networks of semiconductor patenting because technological advance in this field involves the deepening of collaboration and the broadening of inventor relationships. Networks are constructed by tracking inventors who participate in co-patenting in 2009 and 2015, while my previous paper compared 1979 and 2009 in the U.S. biotechnology patents [14]. I attribute each co-patent to the corresponding metro areas where the inventors reside. Investigating specific structural properties of the networks helps answer the following interrelated questions. Are closely connected groups of areas evident in the system, are some groups more critical than others, are the groups international, national, or regional, and are the groups stable over time? What are the pivotal metro areas, are centrality rankings stable? Finally, as collaboration grows, has enhanced complexity allowed knowledge flows to follow more routes?

## 2. Knowledge exchange through interregional networks

Scholars have long recognized that knowledge is key to economic development. Nelson and Winter [15] initiated economic interest in how tacit knowledge exchange shapes technological advance. Maskell and Malmberg [16] argued that tacit knowledge including intuition, know-how, and personal skills is a prime determinant of the geography of invention and innovation. Interpersonal knowledge flows that are restricted in space influence local inventive activity through interactive learning and sharing [13]. Geographical proximity makes such interaction easier and speeds up the flows of ideas. Gertler [17] pointed three related elements to this argument: (1) tacit knowledge is difficult to exchange over long distances, which makes it spatially sticky; (2) economic actors exchange tacit knowledge only if they share common social contexts, which are locally defined; and (3) the dynamic nature of innovation requires the process of 'learning through interacting. These three elements lead to the development of localized knowledge spillovers (LKSs), which constitute knowledge externalities bounded in space [17]. Considerable research effort has been made to identify the nature and strength of LKSs. Jaffe's [3] empirical work found that industrial patenting (an indicator of innovative output) responds positively to knowledge spillovers from university research (an indicator of innovative input) conducted in the same US state. Building upon Jaffe's work, Acs *et al.* [5] and Audretsch and Feldman [6] found significant evidence in favor of the agglomeration advantages by using innovation counts instead of patent data. Approaches that are more direct have tracked the geography of patent citations [4, 19]. Estimating regional knowledge production functions permits incorporation of spatial effects in the form of spatial autocorrelation to understand the distinctive roles of industrial and university research on invention and innovation [7, 20, 21]. The empirical studies have found that knowledge flows are localized by showing that higher rates of R&D, invention and innovation, entrepreneurial activity, high-technology production are bounded in space [22].

Other empirical studies stress an increasing necessity for access to external knowledge to trigger successful innovation and regional technological development. Breschi and Malerba [23] argued that strong external links with other regions are vital competitive advantages. Bathelt *et al.* [24] showed that dynamic firms in successful clusters build and maintain a variety of internal and external knowledge resources. In addition, advanced information and communication technologies (ICTs) reduce costs of moving knowledge and increase access and availability of universal resources [25]. Understanding the role of knowledge in driving regional economic growth is shifting from a focus on closed territorial relationships, towards an emphasis on extra-local links with distant markets and technological resources [26, 27, 28]. The concepts of extra-local links and external knowledge resources provide new ways for explaining the dynamics of invention and innovation. Recent technological and commercial successes of many firms, for example, many ties between firms in Silicon Valley and Taiwan are shaped by interpersonal connections between Taiwanese nationals with educational and working experience in both places [29]. Amin and