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The structure and dynamics of intra- and inter-regional research collaborative networks: The case of China (1985–2008)

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ABSTRACT

Intra- and inter-regional research collaboration are two faces of regional innovation relations. This paper develops a multilevel network model of intra- and inter-regional research collaboration using co-patents. It then applies the model and social network analysis (SNA) to the Chinese case by examining collaborative invention patent applications to China's patent office. Over the past two decades, both China's intra- and inter-regional networks have been expanding in size, becoming more cohesive, and reflecting the "core-periphery" structure. In particular, inter-regional networks have begun to reflect characteristics of a triangle in space in which the most active collaborations occur between the Yangtze River Delta, the Pearl River Delta and the Bohai Rim, with many regions from 2000 onwards shifting from the high/low quadrant to the low/low quadrant within the two-dimension quadrant (TDQ) of regional degree/betweenness centrality in the inter-regional network. Intra-regional networks also reflected a "chain-like" structure of inter-organizational collaborations, with the key organizations shifting to universities from both universities and state-owned enterprises (SOEs) in intra-regional networks of Beijing and Shanghai. Our preliminary analysis suggests the possibility of complementary relationships between inter- and intra-regional networks for regional innovation rather than ones based on relevance.

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1. Introduction

In an increasingly knowledge-based economy, knowledge has become the most important resource and innovation has become a key driving force of regional competitiveness (Krätke, 2010). In addition to the input of knowledge production, R&D expenditure and researchers, several terms such as cluster (Porter, 1994, 1998), the learning region (Florida, 1995; Hassink and Klaering, 2012) and innovative milieu (Fromhold-Eisebith, 2004) have all stressed in increasing significance of the region as a geographical unit for innovation. Several factors, including social institutions, the economic environment, public infrastructure, cultural and linguistic homogeneity, and physical proximity embedded in a geographical unit or local community, have been identified as influencing not only investment for innovation, but also the interactional relationships of organizations.

Interactions or collaborations between firms as well as between firms and academic institutions are central to research and innovation (Lundvall, 1992; Cooke et al., 1997). Organizational interaction and innovation overlap significantly with spatial organization. Several studies have already examined the relationship between location/place and regional innovation (Ter Wal and Boschma, 2009; Maggioni and Uberti,

2011). However, we know relatively little about organizational collaboration within and across regions. Indeed, inter-organizational research collaboration as an important form of interaction between organizations is central to the flow of technology and knowledge in an innovation system (Chesbrough et al., 2006; OECD, 1997).

The broader literature has provided considerable evidence of the influence of the intra- and inter-regional collaboration in regional innovation, with some studies revealing the regional patterns between intra- and inter-regional collaborative research (Marzucchi et al., 2012; Sun and Cao, 2015). Meanwhile, some scholars have argued that multilevel models of innovation and network help us to understand research collaboration within and across regions (Gupta et al., 2007; Guan et al., 2015). Beyond a general recognition of intra- and inter-regional collaborative research, more important questions are about the network structure and dynamics of inter-organizational collaboration within and across regions. However, we observe that surprisingly little attention has been given to interactions between organizations and regions. To be specific, what are the structures of an intra-regional network at the organizational level and an inter-regional network at the regional level? How is the process of network evolution related to the evolution of inter-regional and intra-regional structures? In this paper, we focus on the structure and dynamics of inter-organizational collaborative networks within and across regions, and attempt to understand the regional boundary-spanning activities through linking inter- and intra-regional collaboration.

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In reality, we are concerned with the structure and dynamics of networks in terms of how they evolve, rather than the relationship between network structure and innovation performance. There are several practical reasons. First, previous empirical studies have investigated the relations between the network structure and actors' innovation performance, and emphasized their positive relations (Grewal et al., 2006; Schilling and Phelps, 2007; Phelps, 2010). However, the advantages of the network approach may enable us to overcome this artificial division between structure and performance (DeBresson and Amesse, 1991). After introducing the network approach, we intend to reveal the structure and dynamics of networks and move beyond traditional studies that focus on structures which condition performance. Second, while Guan et al. (2015) have explored the impact of inter-city and inter-county networks on the innovation performance of cities, the likely effects of inter- and intra-regional networks on the region may be diverse, uncertain and long-term. Our approach attempts to draw on and extend research examining the structure and dynamics of intra- and inter-regional networks, and help to understand the boundary-spanning activities of inter-organizational collaboration. Lastly, in the case of China, collaborative research is scarce with only between 1.0% and 1.3% of total patents resulting from the collaborative research of organizations (Sun and Cao, 2015), suggesting a weak relationship between collaboration and regional innovation performance. It would appear that as an emerging country, China's huge investment is the key driving force of innovation performance.

2. Collaborative research networks within and across regions: a literature review

Inter-organizational research collaboration has been widely recognized as being at the heart of regional innovation systems, with differences between regional innovation networks being an important topic of academic and policy debates.

2.1. Intra-regional network of research collaboration

Within regions, formal networks of research collaboration, together with informal networks, are effective means for knowledge creation, sharing and spillovers since geographical proximity constitutes a clear advantage for establishing or maintaining collaborative and interactive relationships between organizations (Fritsch and Schwirten, 1999; Hussler and Rondé, 2007). The innovation network is central to a regional innovation system, and social network analysis also has the potential to contribute further to the analysis of regional innovation systems (Cooke, 2001).

Intra-regional innovation networks are often formed from a heterogeneous group of different actors including firms, universities, technology centers and development organizations (Pekkarinen and Harmaakorpi, 2006). Of them, the role of universities is central to a regional innovation network. Graf and Henning (2009) found that universities and non-university public research institutions are key actors in all regional networks based on the analysis of four East German regional networks of innovation. Based on empirical analysis of eighteen German regional innovation networks, Kauffeld-Monz and Fritsch (2013) showed that public research organizations, especially universities, are profoundly involved in knowledge-exchange processes and possess more central positions within their regional innovation networks than private firms.

It is widely acknowledged that the regional difference of innovative performance seems to be related to difference in the structural properties of networks (Graf and Henning, 2009). Fritsch and Kauffeld-Monz (2010) found that strong ties are more beneficial for the exchange of knowledge and information than weak ties in a sample of 16 German regional innovation networks. Eisingerich et al. (2010) suggested that high performing regional clusters are underpinned by network strength and network openness, but that the effects of these on the performance

of a cluster as a whole are moderated by environmental uncertainty. Through a case study of Sophia-Antipolis in France, Ter Wal (2013) revealed that a local network of collective learning emerged only in Information Technology and not in the Life Sciences. Randelli and Lombardi's (2014) empirical study suggested that among all the clusters of Italian small and medium-sized leather enterprises, only the Florence cluster had an asymmetric path in the period 1995–2011, which led by Gucci, continues to have a positive rate of new firm formation, compared to a general trend of decline in the number of firms.

Meanwhile, the intra-regional network is also determined by talent flow, specialization of technology and innovation intensiveness. Cantner and Graf (2006) described the evolution of the innovator network of Jena, Germany resulting from the job mobility of scientists and the technological overlap between actors in the period from 1995 to 2001, rather than past cooperation. Cantner et al. (2010) has examined the differences across three regional innovator networks in Germany, and as a region that is relatively specialized in a number of broad technologies fields, it exhibits the least fragmented network structure. Using patent data, Óh Uallacháin and Kane (2014) analyzed the association between intraregional collaboration and levels of invention in nine developed countries within the OECD, and show that inventors in highly inventive regions co-patent more with own region partners.

2.2. Inter-regional network of research collaboration

It is possible that overemphasizing intra-regional collaboration could create regional development barriers. For example, a region might be stuck in its current knowledge base and lack knowledge diversity, which is likely to induce local technological trajectories mainly directed towards inferior solutions, thus entering the status quo of "path lock" (Belussi et al., 2010; Fitjar and Rodríguez-Pose, 2011). So, inter-regional collaboration that increases knowledge diversity within the local knowledge base is also crucial for regional innovation (Gertler and Levitte, 2005; Boschma and Ter Wal, 2007).

Indeed, inter-regional networks of research collaboration are of central concern to European countries. Based on the inter-regional networks of co-inventors in Sweden, Ejermo and Karlsson (2006) found that spatial affinity extends beyond the region if it has less own R&D-related resources (business R&D, university R&D and patenting), and it is relatively small and close to the other region. Maggioni et al. (2011) revealed that within single industries inventors are spread across Italy, but applicants are geographically concentrated in few areas (i.e. industrial districts and metropolitan areas) and "drain" brains from other provinces. Hoekman et al. (2009) found that inter-regional collaboration is more likely to occur between regions of excellence measured by publishing and patenting activities and between regions of political capitals in 29 European countries based on analysis of scientific publications and patents. Sebestyén and Varga (2013) found that quality of inter-regional knowledge networks in Europe is related to the level of knowledge accumulated by partners ('knowledge potential'), the extent of collaboration among partners ('local connectivity') and the position of partners in the entire knowledge network ('global embeddedness'). Wanzböck et al. (2014) investigated the embeddedness¹ of European regions in different types of inter-regional knowledge networks, namely project-based R&D collaborations within the European framework programs (FPs), co-patent networks and co-publication networks, and the results reveal conspicuous differences between the knowledge networks. European experience shows that while the ongoing process of European integration is removing territorial borders, this does not render collaboration less sensitive to physical distance, knowledge distance and political distance. Recent studies on the geography of knowledge networks have documented a negative impact of physical

¹ Embeddedness refers to the network positioning of regions captured in terms of social network analytic (SNA) centrality measures.

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