Research Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

The evolution of government sponsored collaboration network and its impact on innovation: A bibliometric analysis in the Chinese solar PV sector

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ARTICLE INFO

Keywords:
Collaboration network
Network structure
Attribute proximity
Innovation performance
Solar photovoltaics

ABSTRACT

This study explores the dynamics of a government sponsored collaboration network concerning the development of solar photovoltaics (PV) technologies in China, and investigates the effect of network evolution on the subsequent innovation performance of network actors. Network structure characteristics and attribute proximity variables are jointly examined through a bibliometric methodology based on scientific publication and patent data. In addressing the evolution of the government sponsored collaboration network, this study has identified that actors are more likely to engage in collaboration with prior partners, partners of direct & indirect partners, and partners with similar attributes. These collaboration patterns, in turn, negatively impact direct ties and network efficiency, and increase the attribute proximity of an actor's network. On the other hand, the estimation results indicate that direct ties have an inverted U-shaped effect on innovation performance, while indirect ties are found to be positively related to innovation performance. As expected, a positive effect of network efficiency is found on innovation performance. The results of attribute proximity variables suggest geographical proximity is negatively related to innovation performance. Taken together, the collaboration patterns in the government sponsored network might have a negative impact on innovation performance of network actors. The empirical findings extend the network literature that collaboration network matters differently in different research contexts, and it is no longer appropriate to simply assume that collaboration is purely a good thing. As such, special attention should be paid to the network structure and composition in further policy design.

1. Introduction

Government agencies, particularly in the OECD countries, have increasingly positioned collaboration activities between the knowledge-based organizations at the core of innovation policy with the aim to facilitate the creation, diffusion and utilization of scientific knowledge and, ultimately, to boost technology development and economic growth (Autio et al., 2008; Heinze and Kuhlmann, 2008; Poirier et al., 2016). In line with this objective, an increasing amount of government funding is provided for collaborations of knowledge-based organizations – usually enterprises, universities and research institutes (Fier et al., 2006; Protogerou et al., 2013). Hence, it is important to understand how government sponsored collaboration networks influence innovation performance to provide empirical evidence of how the commitment of public money has resulted in significant and tangible outcomes (Clarysse et al., 2009).

Previous network and innovation studies reveal that network structure and partners composition (in terms of different dimensions of attribute proximity) are highly relevant in influencing the development of collaboration networks and their subsequent innovation performance (e.g., Ahuja, 2000; Broekel and Boschma, 2012; Phelps, 2010). In analyses of collaboration network evolution, scholars have adopted either a static approach at a single time point or taking a period as a whole to explain the totality of network changes (Powell et al., 2005; Rosenkopf and Padula, 2008). Less attention has been devoted to the changing nature of network formation over time (Balland et al., 2013; Ter Wal, 2014). Moreover, the question of whether innovators should occupy densely interconnected "closed" network positions, or sparsely connected "open" network positions, has yielded conflicting answers providing support for both views (e.g., Ahuja, 2000; Baum et al., 2000; Schilling and Phelps, 2007).

To address these gaps, this study develops a bibliometric methodology based on scientific publications and patent data to analyze: (a) the evolution of government sponsored collaboration networks in terms of their changes in network structural effects and attributes proximity effects from 2003 to 2013 in the Chinese solar PV sector, and (b) the impact of those changes (in network structural effects and attributes proximity effects) on the subsequent innovation performance of

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https://doi.org/10.1016/j.respol.2018.04.012
Received 31 July 2016; Received in revised form 24 June 2017; Accepted 6 April 2018

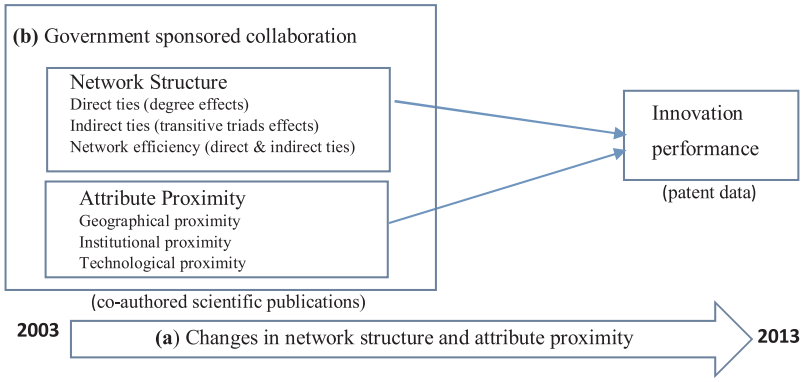

Fig. 1. Research framework of this study.

network actors. The research framework is presented in Fig. 1.

This study, first, examines network evolution of government sponsored collaboration in research; therefore, in contrast to the predominant focus on industrial actors in past literature, the focus is on the science community (universities and public research institutes) when addressing the impact of government funding on network collaboration. Second, instead of the predominant focus on network structure, the effects of both network structure and attributes proximity are included. Finally, similar studies have not been done in the emerging energy technologies sector; the predominant focuses of network evolution have been in the fields of biotechnology, chemicals, and semiconductors.

2. Scientific collaboration and innovation

Scientific collaboration, also referred as research collaboration (Katz and Martin, 1997; Lee and Bozeman, 2005) or R&D collaboration (Bjerregaard, 2010), is defined in many ways. Following previous research (Lee and Bozeman, 2005; Ynalvez and Shrum, 2011), scientific collaboration is viewed as the process through which scientists work together in a research project with one or more specific goals, including the common goal of producing new scientific knowledge. As public and private research funding agencies increasingly require inter-organizational collaboration for funding and research (Lee and Bozeman, 2005), this study focuses on inter-organizational scientific collaborations concerning government funded research involving two or more organizations in the solar PV sector in China.

The solar PV sector is a suitable research setting for three reasons. *First*, the solar PV sector is a high technology industry, where knowledge and innovation are fundamental to the pursuit of competitive advantage (Schilling and Phelps, 2007; Wu and Mathews, 2012). *Second*, due to its nascent and science-based nature, the solar PV sector has been characterized by a wealth of inter-organizational collaboration networks for innovation activities (Cattani and Rotolo, 2013). *Third*, there is a large consensus in the international community that government R&D investments are the key to foster technological improvements in solar PV technologies. The Chinese government has set up multiple national science and technology plans to support the R&D of PV technologies (Sun et al., 2014). *Additionally*, as previous scholars argued that innovative competence is strongly sector-specific, and the knowledge base and learning processes related to innovation differ across sectoral systems of innovation (Quintana-García and Benavides-Velasco, 2008), a single industry study is preferred.

The evolution of collaboration networks, in terms of ties establishment and termination between different network members (e.g., Balland et al., 2013; Gulati and Gargiulo, 1999), is driven by a series of endogenous effects, such as the search for repeated ties, or the tendency of actors to form closed networks (friends of friends become friends), and exogenous effects which depend on external attributes (e.g., various attribute proximity dimensions). These collaboration patterns, in turn, determine directly a number of network structural variables and attributes proximity-related variables.

Several dimensions of attribute proximity, such as geographic, organizational, cognitive, social, cultural, institutional, and technological proximity, have been considered as relevant in the development of collaboration networks and the subsequent innovation performance (e.g., Balland, 2012; Broekel and Boschma, 2012), but the proliferation has generated conceptual ambiguity and overlap that may dilute the significance of the proximity notion (Capaldo and Petruzzelli, 2014; Knoben and Oerlemans, 2006). Three fundamental dimensions of proximity, namely, geographical proximity, technological proximity and institutional proximity, are highlighted in the literature and, thus, are considered in this study together with three network structure variables – direct ties, indirect ties and network efficiency (or non-redundant ties). The changes of these network structural and attribute proximity variables in the network collaboration patterns of the solar PV sector from 2005 to 2013 and their effects on innovation performance are examined.

3. Method

This study considers co-authored scientific publications from government funded research projects (co-authored by scientists affiliated to different organizations) as proxy indicators of network properties to derive structural and proximity variables. Patent data is considered as proxy indicator of innovation performance. The visualization of the network evolution patterns are created by Ucinet 6 and the network pattern changes examined by SIENA.

To analyze the impact of the changes in network structural effects and attributes proximity effects on the subsequent innovation performance of network actors, hypotheses relating to the influence of each structural and proximity variable on innovation performance are developed and tested by binomial regression. The hypotheses of the network structure and attribute proximity variables are discussed next.

3.1. Direct ties

The variable of direct ties in collaboration networks refers to the number of direct partners maintained by the focal actor, providing three substantive benefits. First, direct ties provide potential access to other organization's knowledge elements (Wang et al., 2014) and the number of direct ties indicates its combinatorial potential with other knowledge elements (Guan and Liu, 2016). Second, collaborations enable the newly created knowledge to become available to all actors involved and, thus, enhance knowledge sharing (Ahuja, 2000). Third, most knowledge is subject to economies of scale and scope, especially for explicit knowledge which, once created, can be deployed in additional applications at lower marginal cost (Grant, 1997). Therefore, the number of direct ties in an organization's collaboration network is