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International research networks: Determinants of country embeddedness

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ABSTRACT

Research activities are increasingly global so that embeddedness in international knowledge networks is decisive for inventive and innovative performance. We analyze determinants of countries' embeddedness in the global photovoltaics knowledge network for the period 1980–2015 and argue that positions in this network are determined by the structure and functionality of national research systems and by instruments within the policy-mix for renewable energies. We show that cohesion and connectedness of the national research system positively affect international embeddedness, whereas centralized systems are detrimental to embeddedness. This indicates that a diffusion oriented research system allows better access to international knowledge flows. Policy instruments, especially demand side instruments, show a positive effect on embeddedness.

1. Introduction

The generation and diffusion of knowledge is a collective process and an increasingly global phenomenon. Collaboration among scientists and researchers steadily increased during the last decades and has led to more valuable output than individual research (Wuchty et al., 2007; Adams, 2013). While geographically proximate partners are typically preferred, it is especially collaboration with distant partners which allows access to diverse sets of knowledge with positive effects on performance (Bathelt et al., 2004; Cantner and Rake, 2014; Herstad et al., 2014). Collaboration with international partners leads to embeddedness in the global knowledge network. Here, embeddedness "refers to the process by which social relations shape economic action" (Uzzi, 1996, p. 674), and "research on embeddedness [...] advances our understanding of how social structure affects economic life" (Uzzi, 1997, p. 48). Being embedded in a network can therefore be understood as the position within a network in terms of connections to other actors (Wanzenböck et al., 2014, 2015). As such, embeddedness in the global knowledge network provides better access to knowledge, with positive effects on inventive and innovative performance, (Powell et al., 1999) and should therefore be considered as a policy objective.

With the rising importance of international research communities, countries strive to be integrated in global knowledge networks to access external knowledge and thereby secure technological and economic progress (Adams, 2012). While the importance of access to international knowledge flows has been emphasized for a long time (Bush, 1945), only in the past decades has policy put an emphasis on fostering access to and integration into global knowledge networks. Prominent examples include the establishment of an European Research Area, support of scientist mobility (via several programs, e.g. Marie Skłodowska-Curie, Fulbright, Erasmus+), and distinct national strategies or policies to engage in international collaboration.[1] Such programs as well as other factors substantially increased international collaboration and country embeddedness during the last decades, which seems to have enhanced the quality of national research (Wagner et al., 2015).

In this paper, we analyze the determinants of countries' embeddedness in the global photovoltaics (PV) knowledge network. We argue that the position of a country in this network is determined by two driving forces: First, by the structure and functionality of its innovation system (Nelson, 1993; Lundvall, 1992; Carlsson and Stankiewicz, 1991), and second, by active policy intervention to support R&D activities. With respect to the innovation system, we focus particularly on the interaction structure as a determinant of knowledge diffusion within the research system (OECD, 1997; Cowan and Jonard, 2004; Schilling and Phelps, 2007; Cantner and Graf, 2011; Herstad et al., 2014). This argument is related to the links between micro, meso, and macro levels of economic analysis (Dopfer et al., 2004). Here, the structure of national networks, i.e. the functionality of the research system and its set-up, determines international collaboration and

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[1] See Park and Leydesdorff (2010) and Kwon et al. (2012).

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embeddedness. With respect to policy intervention, we account for a variety of instruments that constitute the policy mix for renewable energies (Flanagan et al., 2011; Rogge and Reichardt, 2016). As such, we explore whether policy can create an environment conducive to international collaboration and increased embeddedness within the international research network.

Our empirical study is based on co-authorship information on scientific publications. This allows us to exploit the multimodal structure in publication data and link the national research network structure to country positions within the international research network. Scientific publications are an established tool for the measurement of knowledge generation or to track characteristics of the innovation process and collaboration intensity (Katz and Martin, 1997; Glänzel and Schubert, 2005). We focus on PV because it is a highly dynamic technology that has received strong governmental support and tackles a global problem by mitigating climate change. There is a large and growing literature on the effects of policies on innovation and diffusion in PV (e.g. Watanabe et al., 2000; Johnstone et al., 2010; Peters et al., 2012; Polzin et al., 2015; Cantner et al., 2016). However, we are not aware of studies on the influence of different policy measures on the embeddedness in international research networks in PV or in any other field.[2] We derive hypotheses about the effect of national network structures and policy interventions on countries' embeddedness and test them by OLS-panel regressions for all countries with scientific publications in the period from 1980 until 2015.

In line with Huang et al. (2013) or Du et al. (2014), we observe a steady increase in collaboration within the global PV research network. While a small group of countries remains central throughout all years, some countries catch up, whereas others lose relative positions in the network. With respect to the determinants of embeddedness, we find positive effects of overall cohesion and connectedness of the national research system. Among a subsample of OECD countries, the effect is not as pronounced because they all have well established and internationally embedded research systems (see also, Choi, 2012). Countries with a decentralized research network are internationally more embedded, indicating that diffusion oriented national research systems are more open towards external knowledge flows. With respect to the instruments of the policy mix, demand side instruments seem to be important for research and collaboration in PV, as has been shown elsewhere for inventive activity (Johnstone et al., 2010; Peters et al., 2012; Cantner et al., 2016). In particular, public procurement, proxied by the cumulative number of satellites, shows up as a robust predictor of embeddedness. This result fits well with the more general argument that governmental demand can increase research activity (Geroski, 1990; Edler and Georghiou, 2007; Aschhoff and Sofka, 2009; Guerzoni and Raiteri, 2015). With respect to direct R&D subsidies, we find ambiguous results; they only seem to encourage collaboration with already well embedded actors. The general commitment to mitigate climate change induces higher connectivity only for a subsample of OECD countries.

Our research contributes to the literature in several ways. We propose a novel approach to measure the functionality of a research system and show its influence on system performance, i.e. the relationship between meso structure and macro performance. We also provide insights on how the determinants depend on the operationalization of embeddedness. Furthermore, our results show that instruments of innovation policy not only increase research activities, but have effects on international collaboration and embeddedness. Lastly, we add public procurement to the already established instrument mix for renewable energies.

In the following section, we review the related literature and derive hypotheses. In Section 3, we describe the publication data and the international as well as the national collaboration networks. In Section 4, we present the econometric study where we estimate the effects of the national network structure and different policies on the embeddedness of countries. We discuss our results and conclude in Section 5.

2. Literature review and hypotheses

2.1. Networks of scientific collaboration

Knowledge generation is a cumulative and interactive process in which the relations between actors are key for knowledge exchange and diffusion (Dosi, 1988; Powell et al., 1996; Ahuja, 2000). The continuous increase in collaboration during the last decades has – amongst others – been attributed to an increasing specialization and division of labor because of the cumulative and dispersed nature of knowledge (Jones, 2009). There is vast empirical evidence that collaborative research leads to more valuable output than individual research (e.g. Adams et al., 2005; Wuchty et al., 2007; Adams, 2013). However, researchers who collaborate, as documented, e.g., by co-authorship, do not just add their individual expertise for a joint output but also exchange information and learn from each other (Breschi and Lissoni, 2004).

Not only has the tendency and intensity of collaboration and team size increased in science, but also the share of international collaborations and the geographical distance between co-authors (Wagner et al., 2015). By drawing on 21 million publications across all fields of science, Waltman et al. (2011) show that the average collaboration distance per publication has increased from 334 kilometers in 1980 to 1553 in 2009. For Europe, Hoekman et al. (2010) find a diminishing effect of geographical proximity on co-publishing, with territorial borders becoming less relevant. The reasons for these trends are manifold. The decline in travel cost, improvements in communication technologies, the rise of English as the common language in science, governmental programs, division of labor and specialization, joint research infrastructures, but also cultural traditions and norms have been put forward (Luukkonen et al., 1992; Wagner and Leydesdorff, 2005b; Waltman et al., 2011). The globalization of science is also driven by an increase in migrant scientists who typically have larger international research networks (Scellato et al., 2015). Wagner and Leydesdorff (2005b) systematize these factors into internal and external to the science system but postulate that international collaboration is an emergent feature of the science system due to preferential attachment. Even though there are differences in the levels of international collaboration, the trend towards increased internationalization can be observed in all disciplines (Wagner, 2005; Wagner et al., 2017).

The aggregate structure of collaboration is analyzed in what we refer to as knowledge networks. Co-authorship networks, where authors are treated as nodes connected by joint publications, are a prime example for such knowledge networks (Glänzel and Schubert, 2005). In one research stream, knowledge networks are analyzed to identify universal structures, such as small world properties, or to test hypotheses regarding processes of network formation, such as preferential attachment or homophily (Newman, 2001; Barabasi et al., 2002; Wagner and Leydesdorff, 2005b). Besides their structural properties, networks are also of interest because they provide information about the position of individual nodes among a group of actors. Central positions might indicate importance or power in a network by controlling information flows between otherwise unrelated actors (Freeman, 1979). Some positions within the knowledge network might give an advantage for accessing novel, external knowledge. Given that external knowledge is a highly valuable input for processes of research and innovation, a second research stream is concerned with the questions regarding the influence of network positions on performance. Based on various types of knowledge networks, this field of research produced substantial empirical evidence showing that direct but also indirect connections matter for research and innovation performance. For

[2] Several bibliometric studies focus on PV publications from different perspectives (Dong et al., 2012; Huang et al., 2013; Du et al., 2014; Cho et al., 2015; Popp, 2016, 2017) but not with respect to the determinants of international collaboration or embeddedness.