Research Policy 45 (2016) 1165–1184

Contents lists available at ScienceDirect

Research Policy

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

Inventor networks in renewable energies: The influence of the policy mix in Germany

Uwe Cantner[a,b], Holger Graf[a], Johannes Herrmann[a,*], Martin Kalthaus[a]

[a] Friedrich Schiller University Jena, Department of Economics, Carl-Zeiß-Straße 3, Jena, 07743, Germany
[b] University of Southern Denmark, Department of Marketing and Management, I2M Group, Campusvej 55, DK-5230 Odense M, Denmark

ARTICLE INFO

Article history:
Received 12 February 2015
Received in revised form 28 January 2016
Accepted 6 March 2016
Available online 21 March 2016

JEL classification:
Q42
Q55
L14
O31
O34
O38

Keywords:
Renewable energy
Inventor network
Policy mix
Systemic instrument
Technology push
Demand pull

ABSTRACT

Technological change and gains in efficiency of renewable power generation technologies are to a large extent driven by governmental support. Various policy instruments that can broadly be categorized as technology push, demand pull or systemic constitute part of the policy mix for renewable energies. Our goal is to gain insights into the influence of this policy mix on the intensity and organization of inventive activities for wind power and photovoltaics in Germany since the 1980s. We examine the effect of different instruments on the size and structure of co-inventor networks based on patent data. Our results indicate notable differences between the technologies: the network size for wind power is driven by technology push and systemic instruments, while in photovoltaics, demand pull is decisive for network growth. By and large, the instruments complement each other and form a consistent mix of policy instruments. The structure of the networks is driven by demand pull for both technologies. Systemic instruments increase interaction, especially in the wind power network, and are complementary to demand pull in fostering collaboration.

1. Introduction

During the last decades, the global capacity for electric power generation by renewable sources (excluding hydropower) increased substantially from 85 GW in 2004 to 657 GW in 2014 (REN21, 2015). In Germany, the share of renewable energies in electric power production reached 27% in 2014 (BMWi, 2015). This development is mainly driven by political support and technological progress in the specific technologies. Several studies have shown that policies and environmental regulations are important drivers of innovative activities in environmental technologies, especially in renewable energies (Johnstone et al., 2010; Grau et al., 2012; Peters et al., 2012; Wangler, 2013; Dechezleprêtre and Glachant, 2014; Costantini et al., 2015a). In particular, inventive activities, largely induced by policies for wind power (WP) and photovoltaic (PV) technologies, increased tremendously over the last decades.

Policies have been implemented in an attempt to influence the development and diffusion of renewable power generation technologies (RPGT), especially PV and WP, from different directions. Demand pull instruments affect innovative activities indirectly by creating demand for RPGT, e.g. through feed-in tariffs (FIT) or investment support, and thus increase market size. Technology-push instruments directly affect inventive and innovative activities by means of R&D subsidies or through performing public R&D in research institutes. Systemic instruments, such as cooperative R&D programs, clusters or infrastructure provisions, provide support for collaboration and knowledge transfer (Smits and Kuhlmann, 2004). The combination of these policies constitutes an instrument mix,[1] which needs to be consistent to support fully innovative activity.

With respect to technology push policies, while their influence on investments in R&D is quite clear, two important aspects of policy impact are less obvious. First, while demand pull instruments increase incentives to invest in production facilities, do they also

* Corresponding author.
E-mail address: johannes.herrmann@uni-jena.de (J. Herrmann).

[1] The terms instrument mix and policy mix are not clearly defined and sometimes are used interchangeably. Here we rely on the distinction by Rogge and Reichardt (2015), where the instrument mix is an essential part of a broader policy mix.

http://dx.doi.org/10.1016/j.respol.2016.03.005
0048-7333/

increase incentives for innovation and investment in R&D? And if so, is it an immediate effect or rather a consequence of the change in market size and structure? Regarding the second aspect, it is common knowledge that internal investments in R&D are only one input in the innovation process. External knowledge, captured through technological spillovers, increases the knowledge-base of innovative actors and therefore has a positive influence on innovation output (Cassiman and Veugelers, 2006). Several channels of technological spillovers have been identified in the economics of innovation, with personal contact through cooperation or job mobility being one of the most important (Singh, 2005; Breschi and Lissoni, 2009; Edler et al., 2011). These modes of interaction constitute a network of actors, being either organizations or individuals. Networks of knowledge exchange are widely viewed as a central driver for inventive activity and it is most likely that they are affected by different policies as well (Cantner and Graf, 2011; Phelps et al., 2012; Broekel et al., 2015). What we do not know is how the mix of policies influences the structure of these networks.

The aim of this research is to understand how the different instruments of the policy mix as well as the consistency of this mix influence the process of invention and innovation in WP and PV. We focus on Germany because of the strong political support for renewable energies and the high share of German inventors in these specific industries. In addition, Germany represented a good fraction of the world market for RPGTs in our observation period (1978–2012). This is especially true for PV, where Germany represented between 30 and 60 percent of the world market from 2001 to 2010 (IEA, 2010). Our approach adds three important aspects to the existing literature. First, in addition to the level of inventive activity, we put the focus on the structure of relations within the network of collaboration. Second, regarding policy instruments, we distinguish between R&D subsidies that are granted to single organizations and research grants aimed at fostering collaboration and which can, therefore, be regarded as systemic (Smits and Kuhlmann, 2004). Third, we test for the consistency of a set of instruments within a policy mix. Here, the effects of single policy instruments as well as of changes in the policy mix on networks of cooperation are studied by mapping co-inventor networks in the PV and WP industries in Germany.

We use patent applications in WP and PV by German inventors to reconstruct co-inventor networks and estimate the effects of several policies as well as their mix on the size and structure of these networks. By and large, the size of the networks is increased by technology push as well as systemic instruments, whereas demand pull policies seem especially effective in PV. The structure of the co-inventor networks is driven by systemic instruments, especially in WP. For both technologies, surprisingly, demand pull policies are very important in facilitating collaboration. The mix of these instruments shows strong consistency in most cases.

The remainder of this paper is organized as follows: in the following section, we give a short review of the literature on innovation networks and innovation policy and derive respective hypotheses. In Section 3, a short overview of relevant policy instruments in Germany is provided. Section 4 describes the data and our empirical approach. Section 5 presents our results and discusses their robustness. In the last section, we discuss our findings and conclude.

2. Policy influence on innovation, collaboration and networks

2.1. The innovation—network nexus

Inventive activity, and innovative activity in general, is an interactive process of knowledge creation and accumulation (Kline and Rosenberg, 1986) in which novelty is created by combining knowledge from a diverse set of actors (Kogut and Zander, 1992). This knowledge re-combination is especially successful in teams that are able to combine diverse sets of knowledge (Wuchty et al., 2007; Bercovitz and Feldman, 2011). Corresponding networks of knowledge transfer and learning constitute one important driver of innovation (Dosi, 1988; Powell et al., 1996; Ahuja, 2000). These networks can be studied by the use of social network analysis, which maps actors and their relations in the context of innovation and knowledge transfer.[2] Knowledge transfer can be traced through different types of networks, such as co-authorship networks (e.g. Barabasi et al., 2002; Newman, 2004; Moody, 2004; Acedo et al., 2006), co-invention (e.g. Balconi et al., 2004; Fleming and Frenken, 2007; Casper, 2013), university-industry research collaborations (e.g. Balconi et al., 2004; Ponds et al., 2010; Guan and Zhao, 2013) and industry collaborations (e.g. Ahuja, 2000; Hagedoorn, 2002; Schilling and Phelps, 2007).

The motives to engage in collaborations and to exchange knowledge are manifold (Cantner and Graf, 2011) and the objective is to increase the inventive and innovative performance. Indeed, as empirical research finds, collaboration and networking in R&D in general lead to a higher research output than individual R&D activities (e.g. Czarnitzki et al., 2007; Fornahl et al., 2011). While there are relatively few studies on the relation between network structure and its performance, theoretical as well as empirical results suggest a positive influence of increased interaction (Powell and Grodal, 2005; Fritsch and Graf, 2011; Phelps et al., 2012). The speed of information diffusion increases with the connectivity of the network and the probability of knowledge transfer between individuals decreases the longer the paths connecting them (Singh, 2005). Average innovative performance is higher in well-connected networks (Fleming et al., 2007). Analyzing these networks helps us to understand how knowledge is generated and distributed and the way in which it affects the actors in the networks.

2.2. Policy instruments fostering innovation and collaboration

2.2.1. Rationale for policy intervention

Due to the costly and uncertain nature of inventive and innovative activity, policy intervenes to enhance and increase research and development activities. Furthermore, there are several market failures that hamper inventive and innovative activity, such as knowledge externalities or technological lock-ins and path dependencies (Arthur, 1989; Griliches, 1992; Cecere et al., 2014).

Concerning cooperation in R&D, the implied knowledge transfer between the actors and the underlying network structures tends to be affected by system failures of complementarity (Do the diverse piece of knowledge and hence the actors behind fit together?), reciprocity (Is the network based exchange of knowledge governed by trust and reciprocity?) and intermediation (Are the eventual network partners aware of all potential cooperation partners?). Answering a "no" to any one of these questions leads to a rationale for policy intervention in order (i) to reduce the monetary risk of non-complementarity and/or non-reciprocity and (ii) to bear the costs of searching for appropriate partners (Carlsson and Jacobsson, 1997; Klein-Woolthuis et al., 2005; Cantner et al., 2011). In this context, various types of policies may have different influences on network formation, thereby affecting the rate of knowledge transfer and consequently influencing the speed at which technologies are developed. For example, R&D subsidies are frequently and increasingly awarded only if actors collaborate on these projects

[2] See Borgatti and Foster (2003) for a general overview of social network analysis and Cantner and Graf (2011) for an overview and application in the context of innovation networks.