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Smart innovation policy: How network position and project composition affect the diversity of an emerging technology

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ABSTRACT

Technological diversity is important to achieve long-term technological progress as diversity fosters recombinant innovation and renders undesirable lock-ins less likely. Many government policies influence the diversity of a technology, in particular by subsidizing collaborative innovation projects. This study investigates the influence of network position and the composition of innovation projects on the creation diversity of an emerging technology at a system level. We first conceptualize technological diversity and formulate hypotheses using a combination of innovation system and social network arguments. Empirically, we study the Dutch innovation system in relation to biogas energy technology.

Our results show that the more projects are related to each other through shared actors, the less likely they are to contribute to technological diversity. This supports the arguments that diffusion of knowledge and sharing knowledge bases lead to less diversity. With regard to composition, we found that including more partners in a project is negatively related to diversity, while a greater diversity of actors in a project contributes to technological diversity.

Overall, we conclude that a combination of innovation system and social network arguments provides a credible micro-level explanation for how the diversity of an emerging technology is created within an innovation system. These insights can be used to design "smart" innovation policy instruments that influence the level of technological diversity.

1. Introduction

The creation of technological diversity is considered pivotal in the development of emerging technologies (Dosi, 1982; Faber and Frenken, 2009; Rigby and Essletzbichler, 1997). Diversity aids in preventing a technological lock-in of a suboptimal alternative, it increases the chances of making recombinant innovations and it adds to the resilience of the technology against unexpected environmental changes.

Policymakers can influence technological diversity as part of their innovation agenda. Many policy programs stimulate research collaboration between actors in the innovation system, such as between large firms, small- and medium-sized enterprises, and knowledge institutes. The outcomes of these collaborations are knowledge and technological configurations that contribute to technological diversity, even if the increase in diversity is not among the policy's objectives. In addition, policymakers can also promote selection, for example by subsidizing the exploitation of a particular alternative, such as feed-in tariffs (Perez and Ramos-Real, 2009), or by establishing technology-specific regulations (Negro et al., 2012; Rennings and Rammer, 2011). As such, governments have several tools at their disposal to influence the technological diversity. Surprisingly, we still have little knowledge about how these different policy tools influence the level of diversity, as insights into the underlying driving mechanisms are currently lacking.

The question of what mechanisms explain diversity creation also remains unresolved in the innovation studies literature. The field of evolutionary economics provides a number of studies that describe the diversity of different technologies over time, such as airplanes (Frenken and Leydesdorff, 2000), steam engines (Frenken and Nuvolari, 2004), communication standards (Fontana et al., 2009) and tanks (Castaldi et al., 2009). These studies give case-related explanations for their observations, yet systematic mechanisms that explain diversity creation are lacking.

A related, but largely unconnected, strand of evolutionary literature that might explain the creation of diversity is that of innovation systems (Edquist, 1997; Hekkert et al., 2007), and the delineation

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to technological innovation systems in particular (Carlsson and Stankiewicz, 1991; Hekkert et al., 2007).[1] This approach highlights the collective nature of innovation and claims that new technologies are jointly developed by different types of actors that collaborate in networks under an institutional regime that is partly shaped by innovation policy (Carlsson and Jacobsson, 1997; Carlsson and Stankiewicz, 1991). This literature highlights so-called systemic problems that negatively influence the pace of innovation within an innovation system (Wieczorek and Hekkert, 2012). Network failures are specifically highlighted as a systemic problem. Networks can be too weak, which inhibits knowledge sharing, and too strong, which is seen as a cause for lock-in and detrimental for innovation (Klein Woolthuis et al., 2005; Weber and Rohracher, 2012; Wieczorek and Hekkert, 2012). However, except for the distinction between weak and strong networks the focus on systemic problems does not give any guidance as to what types of network lead to better innovation outcomes. Recently some scholars have taken up the challenge to analyze network structures as part of an innovation system analysis (e.g. Van Alphen et al., 2010; Binz et al., 2014; Ter Wal and Boschma, 2009; Yokura et al., 2013). But also in these studies, as in the studies on systemic problems, the link between networks and technological diversity is completely absent. This disconnection is striking as the literatures on innovation systems and technological trajectories both originate from evolutionary economics (Boschma et al., 2002; Nelson and Nelson, 2002).

In the management literature, the analysis of innovation networks is much more common. In these studies, social networks are used to explain the innovative performance of firms (e.g. Ahuja, 2000; Powell et al., 1996). These studies highlight that strategic network positions of actors induce new combinations of knowledge or resources that lead to new innovation (Ozman, 2009). These studies can intellectually fuel innovation systems research to enable better understanding of the networking element. However, these network studies also suffer from a number of limitations to adequately explain the creation of technological diversity. First, these studies try to explain the technological diversification of a firm (e.g. Cecere and Ozman, 2014; Leten et al., 2007), but they do not look at how this changes the diversity of the technology in the network or innovation system as a whole. Second, there is a strong focus on firms and firm networks, which does not do justice to the innovation systems premise that new inventions and technologies are the outcome of collaboration between *different* actor types (Phelps, 2010). Third, to the best of our knowledge, social network studies in management have not focused on the influence of innovation policy on the innovative performance of networks. Policies can change the conditions under which networks are formed, but it is unknown whether the arguments that are used in network literature are applicable to networks that are supported by policies in an uncertain environment.

Thus, both strands of scientific literature by themselves are insufficient to explain technological diversity. However, by incorporating insights from social network studies into an innovation systems framework, we are able to formulate testable hypotheses that may explain the policy-induced creation of technological diversity within innovation systems. In this article we study the contribution of policy-induced projects to technological diversity within the innovation system. In light of the studies mentioned above, we are specifically interested in how different characteristics of the project in terms of position in the network and the composition of project partners impact technological diversity. This leads to the following research question:

What is the influence of an innovation project's network position and partner composition on the creation of diversity of an emerging technology?

To answer this question, we first conceptualize technological diversity creation and formulate hypotheses related to the characteristics of the innovation project that are tested empirically on the Dutch innovation system in relation to the emerging technology of biogas energy generation. Biogas is a mixture of carbon dioxide and methane, predominantly produced from organic waste material in an oxygen-free environment (Negro et al., 2007; Raven, 2004). As this technology converts organic waste to sustainable energy, it has been intensively stimulated by the Dutch government during the past few decades through various policy schemes. Using government data on biogas energy innovation projects, we are able to map quantitatively the development of the innovation network and the change in technological diversity in the innovation system due to each innovation project.

Our main result is that the projects that contribute most to technological diversity are not too strongly embedded in a network, and consist of a set of actors that are limited in number, but diverse in types. In addition, we show that other concepts are less adequate in explaining technological diversity creation than our hypothesized concepts.

The first contribution of this paper is the integration of the literatures on technological trajectories, technological innovation systems and social networks. By using a social network approach, we are able to provide a systematic explanation for changes in technological diversity in a technological innovation system. Moreover, the combination of theories allows researchers to assess the performance of the technological innovation system in terms of technological diversity, which adds to the existing focus on technological diffusion (Bergek et al., 2008; Hekkert et al., 2007).

Second, we contribute to the social network literature by examining technological diversity created by collaborative policy-induced projects as a dependent variable. Thereby, we show that the network arguments that are commonly used to explain the innovation success of firms also apply to other dependent variables, actors and policy contexts.

Finally, our findings are of importance to policymakers as we demonstrate that subsidizing research projects alone is not enough to influence diversity. Network position and project composition are of great importance to this end. These insights can be applied to emerging technologies whose characteristics remain unobserved. By smartly subsidizing projects, governments can direct the diversity of an emerging technology to a desired optimal level (Van den Bergh, 2008).

2. Theory

In this section we first discuss the concept of technological diversity and how we view it at the level of innovation projects as our dependent variable. Next, we formulate our hypotheses and discuss three related concepts: resource variety, sector diversity and geographical proximity.

[1] Innovation systems have been approached from a variety of angles. The oldest approach is the national innovation system (Edquist, 1997; Faber and Hesen, 2004; Freeman, 1987, 1995), but the concept has been applied on a sectorial (Malerba, 2002), regional (Cooke, 2001; Cooke et al., 1997) and technological level (Carlsson and Stankiewicz, 1991; Hekkert et al., 2007; Nelson, 1994). Given that we are interested in explaining technological diversity at a system level, we focus in this paper on technological innovation systems.