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The construction of a new technological innovation system in a follower country: Wind energy in Portugal

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ABSTRACT

This article analyzes the process of construction of a new innovation system based on wind energy in a "follower" context. The technological innovation systems framework is used to analyze the process of technology diffusion as well as the emergence of a new wind sector in Portugal, where this renewable energy technology showed a spectacular development in the past decade. This framework highlights the main processes or functions that occur in the diffusion of a new technology. The evidence obtained demonstrates that the fulfillment of these functions, which were mostly studied in the context of pioneer countries, is still pertinent to explain the formation of a wind energy system in this follower country. Yet the type of resources and the nature of the activities needed to adopt the technology in the latter often differ. This case provides new insights into the importance of functions that enhance the follower's capacity to assimilate the new technology (e.g. local knowledge development, experimentation), thus creating the conditions for a fast move as soon as innovations become sufficiently mature in the core.

1. Introduction

The diffusion of mature low carbon technologies, like wind power, and their adoption in regions where energy demand is expected to rise the most in the next decades is an important issue for global sustainability (BP, 2014; IPCC, 2013; IEA, 2013a). In this matter, the transfer of wind energy technology from "core" markets to fast followers, such as Portugal, provides an interesting case study.

Portugal has no oil or natural gas resources and a historical dependence on energy imports. However, in 2014, nearly 60% of electricity was generated out of endogenous renewable energy sources (RES) (DGEG, 2014). This was only possible due to the spectacular progress of wind energy, which has become the second most important RES after hydropower within a decade. It produced 22.2% of total electricity consumption in 2012, the second highest share among OECD countries, which was only surpassed by Denmark (Eurostat, 2015). The development of wind power benefited from the implementation of a mix of "demand pull" and "supply push" policies. A very generous feed-in tariff was introduced in the early 2000s, resulting in a strong increase in the demand for wind farm connections. Thus, in 2005 the government decided to organize public tenders and to tie the attribution of capacity rights to local production of core technologies (e.g. turbines and blades) (Martins et al., 2011). This triggered the formation of an industrial cluster, which harnessed local engineering and industrial competences. The result was an increase in the share of national inputs from 20% to 100%, and also in exports that reached more than 60% of the output in 2011 (ENEOP, 2013; Público, 2011). Lessons can therefore be derived for countries that are considering the adoption of renewable energy technologies (e.g. wind power) with the objective of reducing emissions and boosting their economy.

This paper draws on the literature that addresses the emergence and growth of new technologies. It combines contributions from the technological innovation systems theory (Bergek et al., 2008a; Hekkert et al., 2007) with those from the empirical historical scaling dynamics analysis (Wilson, 2009; Grubler, 2012). The Technological Innovation Systems (TIS) approach focuses on the emergence of novel technologies and the institutional and organizational changes that are needed for technology development (Markard et al., 2012), thus providing the conceptual instruments to understand how these processes unfold. The empirical research on the spatial diffusion of several energy

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technologies, focusing on the effect of scaling in growth dynamics, has identified some international patterns of diffusion (Wilson, 2009; Wilson and Grubler, 2011). It namely uncovered an acceleration of growth as the technology penetrates into new regions (Wilson, 2012; Grubler, 1998). This was mostly explained by the fact that subsequent markets adopt a more mature technology, taking advantage of the knowledge derived from its development and market deployment in the initial markets (here referred as "Core"). Wind power was found to be a good example of the acceleration of international adoption (Bento, 2013; Wilson, 2012). It is the most mature renewable energy technology (excepting hydropower) and the one that has effectively achieved a wide diffusion (IEA, 2013a; GWEC, 2013; EWEA, 2013). The diffusion of wind energy therefore emerges as a relevant empirical setting to examine the mechanisms underlying the formation of a new innovation system in subsequent countries (here referred as "followers").

However, despite the variety of studies about the development of wind power, some of them based on international comparisons, its spatial diffusion is still largely underexplored. In fact, most authors have compared developments across pioneer countries (e.g. Garud and Karnøe, 2003; Karnøe and Garud, 2012; Kamp et al, 2004; Bergek and Jacobsson, 2003; Hendry and Harborne, 2011), but there is still a gap in the study of the organization of the innovation in other regions.[1] The objective of this paper is to address this gap. The extant theoretical and empirical literature permits the raising of two hypotheses. Firstly, that reinforcing the innovation capacity in follower countries may accelerate the formation of a local innovation system and consequently the spatial diffusion of new technologies. Secondly, that the process of construction of the innovation system is likely to differ between pioneer and follower countries, because the conditions are diverse and thus, the nature of the functions, actors and relationships also differ.

When investigating the processes taking place in follower countries, a further distinction can be made between countries that only import the technology and those that also develop a national industry of equipment production. In the first case, the diffusion process deals essentially with the deployment of foreign technology at the local level. An example is the recent development of solar photovoltaics (PV) in Italy that relied mainly in technology produced abroad. In the second case, the process goes beyond the simple adoption of foreign technology, also entailing the creation of a supply chain, or even an entire system that supports the diffusion and use of the technology. The extreme example is the development of solar PV in China that was initially directed to exports, but more recently started to encompass the local deployment of the technology.[2] Depending on the situation, the contents of key innovative activities (or system functions) are likely to be different. A greater effort in terms of knowledge development and resource (financial, human, etc.) mobilization is to be expected when building an integrated innovation system, as compared with a situation of simple technology adoption. Moreover, the development of a new innovation system typically involves a wider variety of actors and networks and has a stronger impact on the country's socio-economic structure. The development of wind energy in Portugal is clearly the case of the emergence of a "wind system" of adoption and production, and thus this paper is more concerned with understanding the processes involved in the emergence and growth of such complex systems.

Therefore, this research focuses on the diffusion of wind energy in a fast follower country in order to answer the following question: Which were the main drivers of the spatial transfer of wind energy technology and its adoption in the case of Portugal? The patterns of international diffusion are investigated with a focus on system formation and industry up-scaling, in order to understand the adoption behavior in a new region. The paper is organized as follows. Section 2 presents the conceptual framework. Section 3 describes the methodology and data sources. Section 4 examines the formation of a technology innovation system in a follower country, using the case of Portugal. The paper ends with the discussion of the main findings. It is argued that a better understanding of the mechanisms at work in the process of innovation system formation in follower countries offers insights on the determinants of technology adoption and system building, and thereby contributes to our knowledge of the process of spatial diffusion of sustainable technologies.

2. The process of formation of new energy technology innovation systems

The paper draws on two main streams of literature that aim to understand the emergence and growth of new technology systems. The first is the technological innovation systems approach (Bergek et al., 2008a; Hekkert et al., 2007), which comes from the "technological systems" (Carlsson and Stankiewicz, 1991) tradition and is part of the more theoretical field of the socio-technical transition studies (Markard et al., 2012). The second is the recent historical scaling dynamics analysis (Wilson, 2009, 2012), which comes from the tradition of applied systems analysis (Grubler, 1998; Grubler et al., 2012). The next two sub-sections expand more on each of these streams of literature.

2.1. Technological innovation systems

The Technological Innovation Systems (TIS) approach focuses on the emergence of novel technologies and the institutional and organizational changes that are needed for technology development (Markard et al., 2012). Innovation is understood as an interactive process involving a network of actors, who act within a particular context of institutions and policies that influence technology development, adoption behavior and performance, and who bring new products, processes and organization structures into economic use (Carlsson and Stankiewicz, 1991; Bergek et al., 2008a; Jacobsson and Bergek, 2012). This definition highlights the three structural elements of the new innovation system: actors, networks and institutions (Bergek et al., 2008a; Jacobsson and Bergek, 2004). Actors include firms and other organizations (e.g. universities, industry associations) along the value chain. Networks are the result of links established between disparate components to perform a particular task (e.g., learning, knowledge creation and diffusion, standardization, market formation). Institutions consist of formal rules (e.g., laws and property rights) and informal norms (e.g. tradition and culture) that structure political, economic and social interactions (North, 1990, 1991). Institutions have three roles: reducing uncertainty by providing information; managing conflicts and promoting cooperation; and providing incentives for innovation (Edquist and Johnson, 1997).

The emergence of a technological innovation system faces several challenges, as actors need to get the technology ready and aligned with the relevant institutions (Jacobsson, 2008). The TIS literature focuses on the processes required for the new system to start, grow and gain momentum. Bergek et al. (2008a) distinguish between a formative and a growth phase. The formative phase is when "… constituent elements of the new TIS begin to be put into place, involving entry of some firms and other organizations, the beginning of an institutional alignment and formation of networks." (p. 419), while in the growth phase "… the focus shifts to system expansion and large-scale technology diffusion through the formation of bridging markets and subsequently mass markets…" (p. 420). The formative phase is therefore central in the emergence of the TIS. New technologies often face high uncertainties and financial needs in combination with low institutional support and small (if any) markets (Kemp et al, 1998). The early stage is crucial in the building up of the supportive structure that allows the innovation system to move into the next stage and to develop in a

[1] With a few exceptions, such as: McDowall et al. (2013), Sovacool (2010) and Kristinsson and Rao (2008).

[2] The authors are thankful to an anonymous reviewer for pointing out the example of solar PV.