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Spatial diffusion and the formation of a technological innovation system in the receiving country: The case of wind energy in Portugal

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ABSTRACT

This paper investigates how energy technologies diffuse spatially through the examination of wind growth in Denmark (core) and Portugal (follower). The research draws on the empirical historical scaling dynamics to compare patterns of diffusion, and proposes an explanation for these patterns with the help of the technological innovation systems (TIS) theoretical framework. The analysis uncovered an acceleration of diffusion when the technology attained the new market. The mechanisms that allowed rapid adoption were found to be, among others, transnational linkages and an improved absorptive capacity. The latter benefited from past investments in knowledge development, imports of state-of-the-art technology and construction of a local industry assembling available competencies. Targeted policies (e.g. tender-based feed-in scheme) were effective to stimulate technology transfer and boost diffusion. The linkages with the global TIS and the concept of absorptive capacity improve the understanding of the processes involved in the formation of a TIS in receiving countries.

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1. Introduction

The diffusion of low carbon technologies across regions is essential to tackle climate change in the years to come (IPCC, 2014). In the last decade, the electricity sector has witnessed a spectacular investment increase in renewable energy sources, especially wind energy. The global cumulative installed capacity of wind power has reached 282 GW in 2012 (GWEC, 2013), generating 521 TWh, or 2.3% of total gross electricity consumption (BP, 2013). Even though China leads in terms of installed capacity (around 70 GW), the majority of wind plants are still located in OECD countries.

The objective of this paper is to contribute to our understanding of the process of spatial diffusion of wind energy technologies and how it can lead to the development of more sustainable energy systems. It addresses a case of diffusion from a pioneer country (Denmark) to a fast follower one (Portugal), comparing the development of wind energy in both countries and analyzing the processes that enabled fast technology development and the building-up of a wind energy system in the latter. Denmark clearly assumed the leading role in technology developments in the 1990s (see Garud and Karnøe, 2003; Karnøe and Garud, 2012; Bergek and Jacobsson, 2003; Kamp et al., 2004; Neij and Andersen, 2012), especially after the unsuccessful commercialization of early multi-megawatt wind power plants in the previous decade in the US and Germany (Gipe, 1995). A variety of knowledge and technological exchanges took place between Portugal and Denmark since the early stages, even if other countries like Germany also became suppliers of technology and know-how later in the process.

Portugal is an interesting case of study, not only given the speed of wind energy penetration, but also for the modes it assumed. On the one hand, wind energy registered a remarkable growth in the past decade, becoming the second most important renewable energy source after hydropower. In 2011, it produced 17.2% of total electricity consumption, the second highest share among OECD countries, only surpassed by Denmark (EWEA, 2013; DGEG, 2013). On the other hand, the application of a mix of demand "pull" and supply "push" policies resulted in the formation of an industrial cluster and ultimately in a national incorporation of inputs that reached 100% (with exports representing more than 60% of production, cf. Público, 2011). This case reasserts the conclusions of previous studies that pointed to the role of home markets for industry expansion in renewable energy technologies (Lund, 2009; McDowall et al., 2013). Yet, there is still limited knowledge about the process of emergence and development of wind energy in Portugal, which may offer some lessons on the factors that can lead to rapid diffusion of renewable energy technologies in follower countries.

In order to conduct this analysis, the paper draws on the literature that addresses the emergence and growth of new energy technologies, in particular recent conceptualizations that give an increasing attention to the spatial dimension of these processes. It makes use of contributions from historical scaling dynamics analysis (Wilson, 2009; Grubler, 2012) to reveal patterns that are then discussed with the help of theories and concepts from the technological innovation systems literature (Bergek et al., 2008a; Hekkert et al., 2007, 2011).

The diffusion of several energy technologies is well documented by the historical scaling dynamics analysis (Wilson, 2012, 2009; Grubler, 2012), which found strong patterns of market growth in and across regions. This approach centers on the analysis on technology scaling, i.e. technological growth that is both rapid and extensive and occurs at multiple levels: the technology unit size and the industry as a whole (Wilson, 2012). One important contribution of the historical analysis concerns the patterns of international diffusion: it uncovered an acceleration of growth rates when energy technologies move from the initial markets and start diffusing in new regions, i.e. diffusion is faster in subsequent markets (see Grubler, 2012, 1998).

The Technological Innovation Systems (TIS) literature addresses the emergence of new technologies from a systemic perspective, as a process of formation and development of a new innovation system. In contrast with the previous approach, more centered on the technology, it investigates the evolution of the structure in terms of actors, networks and institutions, as the technology evolves over time (Carlsson and Stankiewicz, 1991; Bergek et al., 2008a; Jacobsson and Bergek, 2012). More recent theoretical developments added the notion of core processes or functions of the innovation system that are decisive for the performance of the emerging TIS (Bergek et al., 2008a; Hekkert et al., 2007). Thus the TIS provides a more encompassing framework that permits to *explain* the empirical patterns identified by the historical scaling analysis, offering the theoretical