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Heterogeneous policies, heterogeneous technologies: The case of renewable energy☆

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ABSTRACT

This paper investigates empirically the effect of market regulation and renewable energy policies on innovation activity in different renewable energy technologies. For the EU countries and the years 1980 to 2007, we built a unique dataset containing information on patent production in eight different technologies, proxies of market regulation and technology-specific renewable energy policies. Our main finding is that, compared to privatisation and unbundling, reducing entry barriers is a more significant driver of renewable energy innovation, but that its effect varies across technologies and is stronger in technologies characterised by potential entry of small, independent power producers. In addition, the inducement effect of renewable energy policies is heterogeneous and more pronounced for wind, which is the only technology that is mature and has high technological potential. Finally, ratification of the Kyoto protocol, which determined a more stable and less uncertain policy framework, amplifies the inducement effect of both energy policy and market liberalisation.

1. Introduction

Innovation commonly is regarded as the best way to sustain current standards of living while overcoming severe environmental concerns. This is especially relevant in the case of energy, where increasing resource scarcity calls for the rapid development of alternative energy sources, notably Renewable Energy (RE). Although RE cannot currently compete with fossil fuels in terms of production costs, impressive technological progress is paving the way to promising new sources such as biomass and solar energy, among others. Countries have also developed areas of specialisation in specific types of RE sources. For example, Denmark has established a strong technological advantage in wind technologies, whereas Sweden and Germany have specialised in bioenergy, Germany and Spain in solar, and Norway and Austria in hydropower.

In addressing the issue of how technological advantages have emerged for RE, the economic literature emphasises the key role of public policies in fostering environmental innovation. Moving from these premises, assessing the effects of targeted environmental policies and/or energy prices on environmental innovations has been the main goal of most empirical research (Jaffe et al., 2003). The seminal contribution of Johnstone et al. (2010) (henceforth JHP) emphasises how guaranteed price schemes and investment incentives appear to play a major role in the early phases of technological development, whereas for relatively more mature technologies, i.e. wind, obligations and quantity-based instruments appear to be more effective policy tools. More recently, Nesta et al. (2014) found a significant effect of energy market liberalisation on innovation in RE technologies (RETs). This result implies that, given the characteristics of the energy market, in which the core competences of the incumbent are generally tied to fossil fuel plants whereas the production of RE is mainly decentralised in small-sized units, the entry of non-utility generators made possible by market liberalisation has increased the incentives to innovate for specialised suppliers of electric equipment, such as wind turbines or solar cells.

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However, much less attention has been paid to the heterogeneous effects that equal policy or equal market stimulus exerts on different RETs. A first step in this direction is the study by Lee and Lee (2013), who proposed a taxonomy of RETs according to a set of indicators derived from the innovation literature, and use it to study the similarities and differences across technologies.[1] This taxonomy identifies six types of innovation patterns depending on market structure and degree of technological maturity and potential. For instance, Lee and Lee show that, with the exception of solar Photovoltaic (PV) and geothermal energy, the market structure of innovators in RETs tends to be level (innovators are close competitors, with similar shares of patents granted), which means, among other things, that late entrants can still gain technological leadership of the market (Lee and Lee, 2013). This result suggests that the aggregate effect of deregulation found in Nesta et al. (2014) could be heterogeneous across technologies. They show also that RETs differ in terms of their technological potential, measured here as growth in number of patents, which can influence the magnitude of the inducement effect exerted by policy on different technologies and, consequently, its overall profitability.

This paper extends the previous research in three directions. First, building on the results of Lee and Lee (2013), we exploit their taxonomy to study how the market and policy effects identified in the literature differ across the eight different RETs. This analysis is important, first, because it disentangles the heterogeneous factors underlying aggregate innovation dynamics in RE and, second, because it helps in designing customised policy interventions for each specific technologies. In particular, we expect a different degree of technological maturity and technological potential to influence the inducement effect of renewable energy policies (REPs). We expect also that the increase in competition due to deregulation is expected to have a positive effect on the innovation performance of 'level' manufacturing industries[2] where firms tend to innovate to escape competition and a negative effect on 'un-level' industries where stronger competition reduces the post-innovation rents of laggard firms and decreases innovation (Aghion et al., 2005; Sanyal and Ghosh, 2013). Moreover, we expect the effect of lower entry barriers to be stronger in those renewable technologies that, by nature, are more suited to small-scale generation and, consequently, are characterised by the entry of small independent power producers following liberalisation, such as in the cases of wind and solar energy (Jacobsson and Bergek, 2004; Lehtonen and Nye, 2009).

Second, our analysis extends JHP by testing the role of market liberalisation and employing a dynamic specification which accounts for the accumulated stock of knowledge. At the same time, we extend Nesta et al. (2014) analysis by allowing for differences in the effects of REPs across technologies and considering the effects of disaggregated policy instruments (Renewable Energy Certificates (RECs), feed-in tariffs, public Research and Development (R&D) expenditure and single index summarising remaining REPs — see Section 3.2 for more details). We also split the single Product Market Regulation (PMR) index used by Nesta et al. (2014) into its three sub-components, namely, ownership, entry barriers and vertical integration, and we test them separately. Energy market liberalisation is a long and complex process, involving myriad aspects that can exert opposite effects on the development of RE (e.g. Pollitt, 2012). These effects can be captured best using these three sub-indexes rather than a single indicator. In particular, we expect that the increased competition derived from lowering entry barriers and granting to independent power producers free access to the grid, thus, favouring the development of decentralised energy production, should act as a positive incentive for innovation especially in wind and solar thermal energy. In contrast, privatisation and unbundling should favour the emergence of large players and, thus, could have an ambiguous effect on innovation in RETs since large players usually are tied to large-scale plants using coal, nuclear or gas as the primary energy input.

Third, endogeneity is an unresolved issue. Nesta et al. (2014) show empirically that historical successful innovation in clean energy increases the power of green lobbies towards policy makers. Since here we consider different REPs rather than a single REP index, finding good instruments for each endogenous policy is difficult. We hence rely on a different strategy and indirectly address the issue of policy endogeneity using the ratification of the Kyoto protocol as an exogenous shock for national-level policies in a difference-in-difference setting. To ensure that Kyoto effect has been incorporated into the national policy framework, we consider only countries that are members of the European Union, where ratification is enforced by all states. Although this strategy cannot provide a definitive quantification of the policy effect, it allows us to assess whether the results are qualitatively robust.

To address the issues discussed above, we constructed a cross-country dataset covering eight RE technologies (geothermal, hydroelectric, marine, wind, solar thermal, solar PV, biofuel and waste) and 19 European countries covering the period 1980–2007. The paper is organised as follows: Section 2 defines the main determinants of RE innovations; Section 3 describes the data used in the analysis; Section 4 presents the empirical strategy; and Section 5 discusses the main results. Section 6 concludes the paper.

2. Heterogeneous determinants of renewable energy innovations

Establishing comparative advantage in a given RE technology depends on a host of factors. Sub-section 2.1 is concerned with the effect of environmental policy, Sub-section 2.2 describes the role of market structure and liberalisation and Sub-section 2.3 exploits Lee and Lee's (2013) taxonomy to discuss the rationale behind the expected heterogeneous effect of policy and market factors on RE innovation.

2.1. Environmental policies and innovation

Early theoretical studies on the impact of environmental policies on firms' competitiveness emphasise the static trade-off between firm competitiveness and compliance with environmental regulation (for a review, see Jaffe and Stavins, 1995). This idea was criticised in the seminal study by Porter and van der Linde (1995), which considering the dynamic effect of regulation on the incentive to innovate, predicts a different effect of environmental regulation on firm competitiveness. In particular, the so-called Porter hypothesis, in its 'weak' version (as defined by Jaffe and Palmer, 1997), argues that environmental regulation fosters innovation, while no expectations can be formulated *ex-ante* on the effect of regulation on firm competitiveness.[3]

The implications of these studies are of particular interest in the context of a growing, but still limited sector such as renewables, where, in the absence of a public intervention, production costs are generally higher compared to fossil fuel energy sources. In this case, the inducement effect of environmental policy is expected to act through several channels. First, both quota systems and demand subsidies, which increase the market for RE, are expected to stimulate innovation thanks to the higher expected return from R&D investments (Popp et al., 2009). Second, since innovative activities in RE sectors are characterised by a high degree of uncertainty in all phases of product life cycle, any policies able to reduce this uncertainty can be expected to spur innovation. More specifically, in the early phase of technological development, manufacturer producers may under-invest in emerging RETs if they are

[1] This taxonomy has been created by applying a cluster analysis to energy-technology patents filed at the USPTO over the years 1991–2010.

[2] In line with Aghion et al. (2005), by level we mean an industry in which innovators are close competitors which hold similar market share.

[3] This effect operates through several channels. First, regulation reduces uncertainty in environmental pollution activities; second, it signals to firms potential technological improvements and potential resources inefficiencies; third, it induces cost-saving innovation in order to minimise compliance costs. The Porter hypothesis has been the focus of several studies; a good review is Ambec et al. (2013).