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Demand-pull and technology-push public support for eco-innovation: The case of the biofuels sector☆

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ABSTRACT

The purpose of this paper is to explore the differentiated impact of demand-pull and technology-push policies in shaping technological patterns in the biofuels sector. The empirical analysis is based on a novel and original database (BioPat) containing patents in the field of biofuels selected using appropriate keywords and classified according to the technological content of the invention. Our results generally show that technological capabilities and environmental regulation spur innovative activities in the biofuels sector. Both demand-pull and technology-push factors are found to be important drivers of innovation in the biofuels sector. However, technology exploitation activities in first generation technologies are found to be mainly driven by quantity and price-based demand-pull policies. On the contrary, the pace of technology exploration efforts in advanced generation biofuels is shown to react positively to price-based demand-pull incentives but also to technology-push policy. The clear diversity in the impact of different public support instruments provides new insights which fuel discussion on the optimal policy mix debate and offers new elements for the design of future policy strategies.

1. Introduction

Analysis of environmental innovation is gaining growing interest in the current academic and political debate (Berkhout, 2011; Borghesi et al., 2013; Kemp and Oltra, 2011; Markard et al., 2012; OECD, 2011). Different analytical perspectives have been adopted to investigate the dynamics, characteristics and determinants of eco-innovation and their impact on economic systems and societies as a whole (Arundel and Kemp, 2011; Arundel et al., 2011; Beise and Rennings, 2005; Costantini and Mazzanti, 2012; Jaffe and Palmer, 1997; van den Bergh et al., 2007; Wagner, 2007). In particular, there is a growing consensus on the potential pivotal role played by environmental and innovation public policies which are increasingly jointly investigated in order to understand how to foster the rate of introduction and diffusion of new environmental technologies and ensure the conditions for promoting economic development while protecting the environment (Corradini et al., 2014; Del Río, 2009; Mowery et al., 2010; Newell, 2010).

Relevant policy instruments are conventionally classified in the two broad categories of demand-pull and technology-push instruments (e.g., Horbach et al., 2012; Peters et al., 2012; Rennings,

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2000). Both kinds of instruments have been found to be important in spurring innovation in environmental technologies. However, only recently scholars have focused on the differentiated impact of these instruments on the diverse types of innovative activities such as those related to the introduction of incremental or radical innovations (Nemet, 2009), suggesting that demand-pull policies may benefit mature technologies to a larger extent than less mature technologies (Hoppmann et al., 2013). Moreover, the existing empirical literature usually does not differentiate between different types of demand-pull policies, i.e., price or quantity-based instruments which may have a different ability to spur innovation activities, especially when technologies at different stages of maturity are considered.

With regard to these issues, this paper aims to make two main contributions. First, it provides an econometric analysis of the differentiated effects of demand-pull and technology-push instruments on innovation performances by accounting for technology maturity, exploiting a panel database on a large country sample and a relevant longitudinal structure. Second, it investigates the impact produced by different types of demand-pull policies on innovation activities, taking into account the different stages of development of alternative technologies.

For these purposes, the choice of the biofuels sector appears to be appropriate as it is characterized by a strong pace of technological change and rapid evolution in terms of the emergence of different technological trajectories. A remarkable characteristic of the biofuels sector is in fact represented by the existence of different technology groups at different development stages, i.e., technology generations (Suurs and Hekkert, 2009a, 2009b). According to Janda et al. (2012), biofuels can be classified as conventional biofuels (first generation) which are based on conventional technologies mainly adopted by farmers' organizations, and advanced biofuels (second, third and fourth generations) originating from science-based technologies.

Moreover, since biofuels represent an alternative to fossil fuels with a high pro-environment potential related to greenhouse gas (GHG) emission reductions in the transport sector, a number of specific policies from both demand and supply sides have been implemented worldwide in this sector to create a stable investment environment and allow the commercialization and diffusion of biofuel technologies (Panoutsou et al., 2013).

Previous analyses on the effects of policies on the rate and direction of technological change in environmental sectors have proved to be difficult due to considerable measurement problems related to both eco-innovation and policy dimensions (Del Río 2009; Kemp 2010; Kemp and Pontoglio, 2011; Lanoie et al., 2011). In this respect, the paper specifically addresses measurement issues on both innovation and policy sides by carefully selecting information from relevant patent documents and collecting detailed information on different classes of policy instruments.

The rest of the paper is structured as follows. Section 2 describes the background of the analysis with specific reference to the relevant literature and identifies the research hypotheses to be empirically tested. Section 3 highlights the main characteristics of the sector under scrutiny. Section 4 presents the econometric approach and the dataset, while Section 5 provides empirical results. Section 6 offers some conclusive remarks.

2. Literature background

According to Arundel and Kemp (2011) and Arundel et al. (2011), eco-innovation consists of new or modified processes, techniques, systems and products for avoiding or reducing environmental damage. A large body of literature has contributed to finding out which main forces support eco-innovation, by means of theoretical and empirical models.[1] Such analyses suggest that both technology-push and demand-pull forces are important in shaping the rates of introduction and diffusion of new environmental technologies and that the role played by public policies in this context is particularly significant (Del Río 2009; Horbach, 2008; Kuhlmann et al., 2010; Nemet, 2009).

On the technology-push side, previous evidence has shown that the quality of the stock of knowledge and the level of technological capabilities acquired through research and development (R&D) activities are found to be very important for the production and diffusion of eco-innovation both at the micro and macro levels (Johnstone et al., 2012; Löschel, 2002; Popp et al., 2009, 2011a, 2011b). In parallel, since innovation processes need investments, market incentives are important when creating favorable investment conditions for firms (Schmookler, 1966). In this respect, the extent of market demand and the level of prices have been considered important incentives to eco-innovation (Beise and Rennings, 2005; Johnstone et al., 2010; Newell et al., 1999, 2006; Popp, 2002).

Public policies can act on both the demand and the supply sides to create favorable conditions for eco-innovation (Johnstone et al., 2012; Nemet, 2009), with environmental policies and subsidies to R&D recognized as the most important drivers of eco-innovation.[2] Stringent environmental regulation may induce flows of innovations that facilitate being compliant with the environmental targets by changing relative prices and the relative profitability of alternative technologies (Jaffe and Palmer, 1997; Newell, 2010; Porter and van der Linde, 1995). Moreover, environmental policies can create or enlarge the potential market for specific eco-innovations through the adoption of niche strategies (Kemp et al., 1998; Nill and Kemp, 2009). For instance, in the case of renewable energy technologies, demand-pull instruments aim to restore competitive conditions between fossil fuels and renewable energy sources which cannot reach their optimum performance without policy intervention that favors technological and organizational learning through their diffusion.

On the supply/technology side, the role of public policy in shaping the pace of innovation in environmental technologies is also important (Costantini and Crespi, 2013). A large body of literature has identified substantial market failure in the identification of the correct amount of resources that markets are able to allocate in the generation of technological and scientific knowledge (Arrow, 1962; Nelson, 1959). Moreover, the broader perspective adopted by the innovation systems literature has expanded the range of legitimate justification and scope for public intervention in this field to different types of system failures (Borrás and Edquist, 2013; Edquist, 2005; Fagerberg et al., 2005; Metcalfe, 1995; Nelson, 1993). Following these arguments, significant amounts of public funds are spent on programs that increase the quality of scientific and technological capabilities in innovation systems also through the funding of innovative activities by private firms (OECD, 2013).

Hence, in line with this reasoning, we test the following hypothesis:

HP1. Demand-pull and technology-push policies are relevant drivers of eco-innovation.

The policy instruments designed to enlarge the markets for new environmental technologies can be distinguished between

[1] Even though we are aware of strong differences in definitions, for the sake of simplicity, we will use the terms environmental innovation, eco-innovation, environmental-friendly and green technologies interchangeably in this paper.

[2] In this paper, we use the terms demand-pull policies and deployment policies interchangeably, indicating all instruments that aim to foster market expansion for eco-innovation. We also use the terms technology-push, supply-push or supply side as synonyms since only the effects of technology-push instruments have been considered in the present analysis.