ARTICLE IN PRESS

Research Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Green patents, regulatory policies and research network policies

Andrea Fabrizi[a], Giulio Guarini[b], Valentina Meliciani[c,*]

[a] Presidenza del Consiglio dei Ministri, Rome, Italy
[b] Tuscia University, Viterbo, Italy
[c] LUISS University, Rome, Italy

ARTICLE INFO

Keywords:
Green patents
Porter hypothesis
Research networks
Policy mix

ABSTRACT

The main goal of this paper is to analyse the single and joint impact of regulation policies and research network policies on environmental innovation. Our theoretical framework combines the open eco-innovation mode approach with the Porter Hypothesis, by adapting them to the knowledge production function where green patents are the dependent variable. We focus on the factors that influence the production of green patents as a proxy of new "environmental" knowledge for a panel of European countries over time. We find that both marked-based regulation policies and participation in green European research networks (in particular with universities and public research centres) positively affect environmental innovation. Moreover, the two policy tools have a complementary effect. This suggests that the effectiveness of environmental regulation policies can be increased by combining them with appropriate innovation policies.

1. Introduction

Environmental Research and Innovation is a cornerstone of the Europe 2020 Strategy, which identifies smart, sustainable and inclusive growth as a means to help the EU develop a resource efficient, greener and more competitive economy while delivering high levels of employment, productivity and social cohesion. As a result, it is expected that at least 60% of the overall Horizon 2020 budget should be related to sustainable development.[1] Sustainable development is also a priority for European Member States, which are progressively adopting stricter market and non-market regulations for environmental policy.

Overall, innovation on the one hand and regulation on the other form the main pillars of the EU policy for sustainable development. However, we know very little on the single and joint impact of these policies on environmental innovation (EI). In particular, very few studies have investigated the relative effectiveness of different regulatory instruments (Johnstone and Labonne, 2006; Arimura et al., 2007; Lanoie et al., 2011) and, to the best of our knowledge, there exists no study which estimates the impact of participation in EU funded research networks for green innovation. Finally, the complementarity/substitutability of the two policies has been largely neglected in the literature. This paper aims to shed light on these issues by bridging two lines of research on the determinants of environmental innovation: the numerous tests of the Porter hypothesis and the role of networks.

The Porter hypothesis, in its *weak version*, states that "properly designed environmental regulation may spur innovation" (Ambec et al., 2013, p.5). According to the *narrow version* "flexible regulatory policies give firms greater incentives to innovate and thus are better than prescriptive forms of regulation" (Ambec et al., 2013, p. 6). This suggests that market instruments (e.g. pollution taxes, deposit-fund schemes, tradable permits) are preferable to non-markets instruments (standards). Finally, the *strong version* of the hypothesis affirms that "in many cases this innovation more than offsets any additional regulatory costs—in other words, environmental regulation can lead to an increase in firm competitiveness" (Ambec et al., 2013, p.6).

Empirical studies, both at the firm and at the country level, have mainly found support for the weak and narrow versions of the Porter hypothesis while the evidence for the strong version is more controversial (see the surveys of Ambec et al., 2013, Rubashkina et al., 2015 and Morales Lage et al., 2016).

The literature on the role of networks for environmental innovation is more recent and less developed than that on regulation. It draws on the idea that environmental innovations require more heterogeneous sources of knowledge with respect to other innovations (Horbach et al., 2013). Empirical analyses have supported this view: environmentally innovative firms cooperate on innovation with external partners to a greater extent than other innovative firms (De Marchi, 2012; De Marchi and Grandinetti, 2013; Cainelli et al., 2015) and the breadth of the firm's knowledge sourcing has a positive effect on environmental innovation (Ghisetti et al., 2015). All these studies use firm level data

* Corresponding author.
E-mail address: vmeliciani@luiss.it (V. Meliciani).

[1] See http://ec.europa.eu/programmes/horizon2020/en/area/environment-climate-action.

https://doi.org/10.1016/j.respol.2018.03.005
Received 17 March 2017; Received in revised form 2 March 2018; Accepted 5 March 2018
0048-7333/

Please cite this article as: Fabrizi, A., Research Policy (2018), https://doi.org/10.1016/j.respol.2018.03.005

(mainly drawn from the Community Innovation Surveys) and, with the exception of Ghisetti et al. (2015) which use data from 11 European countries, focus on single countries (Italy or Spain).

Departing from previous studies, we use data from EU Framework Programmes to measure research cooperation among EU countries in fields related to sustainable development and we relate them to the capability to introduce environmental innovation (measured by green patents[2]). Moreover, following the policy mix literature (Flanagan et al., 2011; Guerzoni and Raiteri, 2015; Rogge and Reichardt, 2016; Costantini et al., 2017), we address the issue of whether research networks and regulations are complementary policy tools for EIs. We argue that this can be the case due to the presence in the environmental domain of multiple and self-enforcing market failures (Jaffe et al., 2005; Johnstone et al., 2010a, 2010b; Lehmann, 2012), including externalities, information failures and knowledge spillovers. This has relevant policy implications since the existence of complementarities would suggest that environmental policies, to be more effective, should not merely be regulation policies, but should be conceived also as industrial and innovation policies.

The paper makes use of two novel data sources. Green research networks are constructed using EU open data from the annual reports of Framework Programmes for Research and Technological Development of the EC Directorate for Research (FPs). This data allows us to compute the total number of participations in environmental networks at the country level and also to distinguish between universities, research centres and private companies. The source of data on environmental regulation is the OECD database on Environmental policy stringency (EPS) which provides composite indexes based on a selection of environmental policy instruments, primarily related to climate and air pollution. In our analysis, we choose two mid-level indexes obtained by grouping indicators into two broad categories of market-based and non-market instruments. This allows us to test both the weak and narrow versions of the Porter hypothesis. The analysis covers 23 European countries over the period 2003–2012.

The paper is organized as follows. Section 2 reviews the relevant literature and proposes some testable hypotheses. Section 3 presents the empirical strategy. Section 4 discusses data and provides descriptive statistics. Section 5 comments on the results of the empirical analysis. The last Section contains our concluding remarks.

2. Background literature and research hypotheses

In this section, we illustrate the main theoretical and empirical contributions to the literature on environmental innovation drivers and we develop the research hypotheses that will be tested in the econometric analysis on the determinants of new green knowledge. The main engines of EIs considered in this paper are represented by technology-push mechanisms, regulation and networking activities (see Fig. 1).[3] These factors are discussed below.

2.1. Technology push drivers

EIs can be pushed by firms' R&D, knowledge capital endowment (Horbach, 2008), organizational practices and management schemes (Ziegler and Rennings, 2004; Rennings et al., 2006; Wagner, 2007; Rehfeld et al., 2007; Ziegler and Nogareda, 2009). These factors can affect both standard and environmental innovations due to their potential complementarity.

Complementarity may arise from various channels. Firstly, environmental innovations generate the so called "dual externality" (or "double externalities") according to which on the one hand they reduce the negative externality concerning pollution, and on the other hand they generate knowledge spillovers involving both green and standard innovation processes (Jaffe et al., 2003; Rennings, 2000). Secondly, EIs can involve cumulative mechanisms of learning in which they can be the origin or the effect of standard innovations (Horbach, 2008; Guarini, 2015). Thirdly, economies of scope can be generated by the interaction between standard and green technologies (Johnstone et al., 2008). Consequently, the line between standard and environmental innovation processes can be thin.

Many empirical studies test the effectiveness of technological drivers. Some analyses focus on green and general R&D and patents, with different measures of research activity such as R&D as a percentage of GDP or number of researchers. According to Ghisetti and Pontoni (2015), the majority of empirical papers find a positive impact of R&D (general and green) on environmental innovations, but the results are strictly dependent on the control variables considered and on the measurement of R&D. In this paper, following most of the literature, we focus on general R&D intensity as a technology push driver which is expected to positively affect environmental innovation.

2.2. Regulatory drivers

There is a growing literature studying and trying to estimate the impact of environmental regulation on green innovation (for recent reviews see Carraro et al., 2010; Popp et al., 2010; Ambec et al., 2013; Dechezlepretre and Sato, 2017). The rationale behind the induced innovation hypothesis, dating back to Hicks (1932), is that when regulations raise the cost of pollution relative to other production costs, firms have an incentive to develop new technologies reducing emissions. Porter and Van der Linde (1995) have further developed this idea, formulating the so-called "Porter Hypothesis" (PH). The theoretical incipit of the PH is that "the Panglossian belief that firms always make optimal choice […]" is "true only in a static optimization framework" with "perfect information" and where "profitable opportunities for innovation have already been discovered" (Porter and Van der Linde, 1995, p.99), whereas real processes of competition and technological progress are characterised by "incomplete information", "organizational inertia" and "control problems". Therefore, innovations can be supported by public intervention, because through opportune instruments and means environmental regulation can arouse the Promethean spirit of entrepreneur, that otherwise might remain dormant. Regulation can promote innovation through five main channels: "First, regulation signals companies about likely resource inefficiencies and potential technological improvements." "Second, regulation focused on information gathering can achieve major benefits by raising corporate awareness." "Third, regulation reduces the uncertainty that investments to address the environment will be valuable". "Fourth, regulation creates pressure that motivates innovation and progress". "Fifth, regulation levels the transitional playing field. During the transition period to innovation-based solutions, regulation ensures that one company cannot opportunistically gain position by avoiding environmental investments." (Porter and Van der Linde, 1995, pp. 99–100).

Thus, not every regulation is innovative *per se*, but depends on the characteristics of the specific policy. According to Porter and Van der Linde (1995) the stringency of regulation is a crucial element. Indeed, lax regulation can be complied with by the firms through light solutions that do not significantly influence the production process, such as secondary treatments or "end-of pipe" interventions, while stringent regulation affects the entire production causing a reformulation of processes and products that can generate innovations. Hence, comparing the two types of regulation, the cost of compliance with lax

[2] See Section 4 for definition of green patents and data source.

[3] Market drivers are also important and environmental policy actions are often designed to change consumer behaviours, perceptions and interact with firms' own strategies. Although this paper mainly focuses on regulation, knowledge networks and their interaction, we introduce some indicators of market conditions at macro level (such as GDP, exports) in the robustness checks, that can indirectly capture market drivers (Appendix C2 in the Supplementary material). Instead, for analyses directly focusing on market drivers at the micro level, see for instance Rehfeld et al. (2007), Horbach (2008), Kammerer (2009).