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Analysis

Investigating policy and R&D effects on environmental innovation: A meta-analysis

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ABSTRACT

In the last decades, a wide research effort has been devoted at the analysis of the determinants of environmental innovation (EI). Whereas agreement seemed to emerge around a cluster of determinants, mainly "Technology push", "Market pull", "Policy push–pull" and "firm specific factors", empirical analyses have failed to provide strong confirmation on the relevance of some core variables. After a qualitative discussion of this literature, we empirically assess it by exploiting meta-regression-analysis techniques to test the effectiveness of two determinants: policy and R&D. Our findings are clear: as for the first, we show that only certain types of policy have proven to affect EI, in particular regulatory stringency. As for R&D, we show that the use of estimation methods is not neutral to the outcome of the primary studies.

1. Introduction

Environmental innovation (henceforth, EI) is crucial to decouple environmental pressure and economic growth. In the ten-year growth strategy "Europe 2020", the EU has stressed the importance of this type of innovation to combine European competitiveness and sustainability.

A consistent research effort has thus been devoted at the investigation of those elements that facilitate the diffusion of EI among firms, i.e. the determinants of EI. With respect to standard innovations, EIs have been described as "special innovations" (Rennings, 2000), whose understanding and investigation require particular attention. A strand of literature, bridging together economics of innovation and environmental economics, has emerged and provided crucial evidences on the specificities of EI.

Drawing on this literature, we argue that it fails to unequivocally outline the role played by two core determinants, namely policy intervention and R&D. In this contribution, we analyse the reasons behind such ambiguous results with respect to these two determinants. We thus implement at first a qualitative literature review, followed by a meta-regression analysis on properly selected articles in the field.

Our findings support our hypothesis that the results found in previous empirical studies are not neutral to the choice made by researchers for two main reasons: a conceptual one and a technical one. Such findings have important policy and methodological implications that we discuss further.

The remainder of the paper is structured as follows: Section 2 contains a definition of EI and briefly describes what drives EI by means of a qualitative literature review. Section 3 specifies the methodological approach. Section 4 presents regressions results and discusses them. Section 5 concludes.

2. What Drives Environmental Innovation?

2.1. Theoretical Background and Qualitative Review

Following the Measuring Eco-Innovation (MEI) project, by EI we mean "the production, assimilation or exploitation of a product,

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production process, service or management or business methods that is novel to the firm [or organization] and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives" (Kemp and Pearson, 2007:10). This includes innovations that are not necessarily *new to the world* but are at least *new to the organization* adopting them, as the Oslo Manual on innovation suggests (OECD, 2005), so that not only new environmental technologies, but also any new/improved product or process or service has to be accounted for. Furthermore, this includes also "unintended" innovations when they result in environmental improvements as well.

Almost neglected but important is the distinction between the terms environmental innovation and eco-innovation. Eco-innovation was initially conceived of as a sub-class of EI, in which the associated change in economic activities is such that it improves both the *economic* and *environmental* performance (Ekins, 2010; Huppes et al., 2008), while for EI in general the focus is on its environmental (rather than economic) effects.

In this analysis we will refer to the general term EI, given that in most of the empirical contributions under scrutiny, innovations are not necessarily required to bring about economic improvements as well. In other words, most of the empirical literature has focused on the general category of EI rather than on the more specific eco-innovation one. This choice is mainly related to the nature of the data this literature exploits: both of the studies based on innovation surveys and those based on patent data mainly focus on the environmental nature of the innovation and not on the economic gains that may derive (or not derive) from them. For this reason, we will only refer to the broader category of EI rather than eco-innovations.

Clearly, EI might cover different (and eventually multiple) environmental domains, which are inherently different (Ghisetti and Rennings, 2014; Rennings and Rammer, 2009; Rexhäuser and Rammer, 2014). The Community innovation Survey (2006–2008), an EU wide firm-based survey on innovation that specifically raised questions on EI, differentiated among a set of 9 typologies of EI depending on the domain covered, as reported in Table 1 in which it also underlined whether the environmental benefits arise during the production process (EIPROC) or after use (EIPROD).

A necessary step for any analysis dealing with EI is to understand its determinants, i.e. those elements that spur its adoption or generation by firms. This is a crucial element as it can help policymakers and managers to promote the adoption and the diffusion of EI.

The more "standard" innovation studies literature has outlined a set of determinants that affect firms' adoption of technological innovations: "science-push" or "technology-push", i.e. innovations driven by advancements in science and R&D; "demand-pull", i.e. driven by market conditions; "policy push", i.e. driven by policies that for instance set new standards; and finally, a combination of these factors (Carter and Williams, 1959; Kleinknecht and Verspagen, 1990).

Since the seminal contribution by Rennings (2000), the literature stresses that EI is a "special" type of innovation because of its "double externality" nature. EI reduces negative environmental externalities (first externality) but it is subject to externalities arising from knowledge spillovers, which could potentially lead to sub-optimal investments for its adoption (second externality).

Table 1
Typologies of EI.

Description	Type of EI
Reduced material use per unit of output	EIPROC
Reduced energy use per unit of output	EIPROC
Reduced CO_2 'footprint' (total CO_2 production)	EIPROC
Replaced materials with less polluting or hazardous substitutes	EIPROC
Reduced soil, water, noise, or air pollution	EIPROC
Recycled waste, water, or materials	EIPROC
End-user benefits, reduced energy use	EIPROD
End-user benefits, reduced air, water, soil or noise pollution	EIPROD
End-user benefits, improved recycling of product after use	EIPROD

Furthermore, EI is characterized by the "policy push/pull effect": it is strongly policy-driven, but, at the same time, policies might act both on the supply (push) and on the demand side (pull) (Cleff and Rennings, 1999; Rennings and Rammer, 2009).

Lastly, EI is strongly dependent on social and institutional innovation, as many issues in the sustainable use of resources and in the reduction of negative environmental externalities are not primarily technological (Rennings, 2000).

Given these specificities, an ad hoc literature on the specific determinants of EI has emerged, drawing upon "standard" studies on innovations' determinants but taking into account that EIs are not only technological, but also organizational, social, and institutional innovations (Horbach, 2008).

This strand of literature acknowledges that EI is stimulated both by "market-pull" and by "technology-push" factors, but a policy (regulatory) push/pull effect is its key driver (Cleff and Rennings, 1999), mainly because of the public good nature of EI and the "double externality" issue. Empirical studies have focused on a cluster of determinants which is coherent with those already outlined for technological innovations, i.e. "market-pull", "technology-push", "firm specific factors", and "policy" determinants (Horbach et al., 2012); the main difference lying in their differential interplay with respect to EI (De Marchi, 2012; Ghisetti et al., 2015).

Turnover expectations, new demand for eco-products (Rehfeld et al., 2007), past economic performances (Horbach, 2008) and customer benefits (Kammerer, 2009) characterize the "market-pull" cluster of determinants. The "technology-push" depends on a firm's technological and organizational capabilities, such as its engagement in R&D, knowledge capital endowment (Horbach, 2008), organizational innovation and management schemes (Rennings et al., 2006; Ziegler and Nogareda, 2009; Ziegler and Rennings, 2004; Wagner, 2008; Rehfeld et al., 2007). "Firm specific factors" such as firm size, location, sector and age co-affect environmental innovativeness, and have been accounted for in the majority of the previous investigations (e.g. Mazzanti and Zoboli, 2009; Horbach, 2008; Rehfeld et al., 2007; Wagner, 2008; Rennings et al., 2006; Ziegler and Rennings, 2004).

To our knowledge, a general theoretical framework on the determinants of EI is still lacking, so that it is difficult to highlight the full set of relations and interrelations that emerge among the clusters of determinants. It is worth stressing that not only do they all affect EI, but they also mutually co-affect EI. Some of the so-called "firm specific factors", for instance being bigger or export oriented, might actually affect "technology push" determinants, for instance by increasing firm R&D activities.

Recently, "interactive" types of determinants have been considered (Ghisetti et al., 2015). Knowledge creation has a strong interactive dimension: cooperation in R&D and knowledge sources coming from outside the boundaries of a firm are themselves sources of innovation (Veugelers, 1997), if an internal "absorptive capacity" allows absorbing external knowledge (Cohen and Levinthal, 1989). This holds true not only for standard innovation, but also for EI (Frey et al., 2013), as the knowledge required for EI's adoption goes beyond already existing industrial knowledge base, thus requiring the need to explore new knowledge sources (De Marchi, 2012). Coherently, the existence of innovative oriented industrial relations and networking activities have been found to favour the adoption and diffusion of EI (Mazzanti and Zoboli, 2009).

2.2. Evidence on R&D and Policy

Given this framework, we consider Policy and R&D as the more intentional determinants, given that these are the tools that firms and governments can utilize to stimulate EI.

It is indeed surprising – and in our view worth deeper investigation – that a consistent number of empirical studies failed to find a statistically