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The open eco-innovation mode. An empirical investigation of eleven European countries

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ABSTRACT

This paper deals with the open innovation mode in the environmental realm and investigates the effects that knowledge sourcing has on the environmental innovations (EIs) of firms. Using the Community Innovation Survey (CIS) 2006–2008, we refer to the firm's probability of both introducing an EI and extending the number of EI-typologies adopted. We estimate the impact of the 'depth' and 'breadth' of knowledge sourcing. In addition, we test for the moderating role of the firm's absorptive capacity. Knowledge sourcing has a positive impact on both types of EI-performance. However, a broad sourcing strategy reveals a threshold above which the propensity to introduce an EI diminishes. Cognitive constraints in processing knowledge inputs that are too diverse may explain this result. Absorptive capacity generally helps firms to turn broadly sourced external knowledge into EI. However, internal innovation capabilities and knowledge socialization mechanisms seem to diminish the EI impact of knowledge sourced through deep external interactions. The possibility of mismatches between the management of internal and external knowledge, and of problems in distributing the decision-makers' attention between the two, may explain this result.

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1. Introduction

The economic importance of environmental innovations (EIs) is today undisputed in both the business and policy realms (e.g., Wagner, 2006; Ambec et al., 2013). At the intersection of these two realms, EIs have an important 'win–win' effect whereby firms combine competitiveness and environmental sustainability (Porter and van der Linde, 1995; Porter, 2010).

However, this twofold effect comes at the price of a double market-failure – in the generation of new knowledge and in its impact on the environment – which makes environmental regulations a pivotal factor in driving EI. In environmental economics, this EI factor initially received most of the attention, but it did so with a "mechanistic stimulus-response approach" that underscored the role of external market conditions and internal techno-organizational capabilities as innovation drivers (Cleff and Rennings, 1999, p. 200). As a consequence a 'hybrid approach' to the determinants of EI has been developed in which innovation theory is integrated with the analysis of the so-called 'regulatory push/pull effect' of environmental policy (Rennings, 2000). This approach is the theoretical signpost of the present paper. More precisely, we further extend the evolutionary theory underpinning the hybrid approach in order to address a gap with respect to the knowledge base underlying EI. As Horbach et al. (2013, p. 528) have recently recognized, "[the] issue of sources of information and knowledge used in eco-innovative activities is rarely treated in the eco-innovation literature". One of the few stylized facts to have emerged, albeit still in a non-systematic way (e.g., Florida, 1996; Oltra and Saint Jean, 2005a,b; Rennings and Rammer, 2009), is that EIs require knowledge inputs from different and heterogeneous sources, possibly more so than other innovations (Horbach et al., 2013). With the notable exception of the so-called 'eco-industries', firms that strive for EI need to go beyond their core competences (Teece et al., 1997). Accordingly, external knowledge becomes an idiosyncratic EI driver to consider.

For this reason, attention has recently turned to the channels through which eco-innovative firms can access and benefit from external knowledge sources. A large part of the extant literature

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has focused on those kinds of flows that, owing to the public good nature of EI (Corradini et al., 2011, 2014), occur via spillovers, both within and across sectors and regions (e.g., Mazzanti and Zoboli, 2005; Cainelli et al., 2012; Costantini et al., 2013; Ghisetti and Quatraro, 2013). At a more micro-level, interesting insights have also been obtained by the literature on the firm's management of innovation cooperation (e.g., De Marchi, 2012; De Marchi and Grandinetti, 2013).

In spite of important specifications, these channels have been found to increase firms' EI. They thus point to an additional sphere of environmental policy action encompassing, among other things, network/cluster policies and technology/knowledge transfer initiatives. However, to the best of our knowledge, no evidence has yet been obtained on how EI-oriented firms search for external knowledge and then implement it internally. We believe that this is important information from which policies directed to smart and sustainable growth could greatly benefit. The identification of 'EI-friendly' modes of knowledge sourcing and absorption could help policy-makers devise the proper tools with which to extend the benefits of the open innovation mode to the environmental realm. In particular, an extra twofold positive impact could ensue from the eventual emergence of what could be called an 'open eco-innovation mode' (OEIM). On the one hand, openness to external knowledge sources could help firms attenuate the internal constraints (e.g., the lack of capabilities and intangible inputs to the generation/adoption of green-knowledge) that often prevent them from gaining a competitive advantage based on EI. On the other hand, the same kind of openness could also help firms win in terms of sustainability by increasing their connectedness with (and response to) environmentally responsible partners and their social embeddedness in green-oriented innovation systems. Evidence of these benefits would press for extension of the innovation side of the so-called 'environmental policy mix' (Jänicke and Lindemann, 2010; Schmidt et al., 2012; Costantini and Crespi, 2013). Specifically, following a system – rather than a market-failure approach, the aim of such an extension should be to include measures that support the firm's interactions, capabilities and learning (e.g., Metcalfe, 2005; Malerba, 2009), also in line with an increasingly relevant evolutionary framing of environmental policy (Nill and Kemp, 2009).

This paper's analysis of the search by firms for external knowledge is its first element of originality. A second element is its investigation of this phenomenon with respect to a sample of firms in eleven European countries, while previous research has mainly focused on one country at a time, or on a small set of similar countries (e.g., Ziegler and Rennings, 2004; Kesidou and Demirel, 2012). A third original aspect of the paper is its use of an econometric strategy that enables investigation of the impact of external knowledge on two different EI processes: the firm's introduction of an EI, and the enlargement of its EI-portfolio (i.e., the number of EI-typologies).

The rest of this paper is structured as follows. Section 2 reviews the background literature and puts forward our research hypotheses. Section 3 sets out the empirical application through which we test those hypotheses. Section 4 discusses the main results, and Section 5 concludes.

2. Theoretical background

After intense effort (e.g., Rennings, 2000; Kemp and Pearson, 2007; Kemp, 2010), a consensus has emerged on the definition of an EI as: "the production, assimilation or exploitation of a product, 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 Pontoglio, 2007, p. 10). This definition is very composite and not confined to the technological sphere: it also encompasses organizational and service-based aspects and covers an array of environmental impacts along the entire environmental pipeline.

In considering the innovation process in Schumpeterian terms, such a pipeline would in principle span from the invention (Johnstone et al., 2010a, 2012) to the diffusion (e.g., Popp, 2010; Verdolini and Galeotti, 2011) phases of techno-organizational outcomes with a green impact. However, in line with much of the literature on the topic, in this paper we focus on the adoption of EIs, for two main reasons. Firstly, the reference to adoption overcomes the problem that not all inventions enter the market and, accordingly, not all the green technologies invented (e.g., patents) can directly influence the firm's environmental performance. Secondly, EI-adoption refers more directly to the firm's 'green capabilities' than to simple exposure to (and benefit from) the diffusion of an environmental technology.

Given the multi-faceted nature of EI (Markard et al., 2012), the ongoing search for its determinants (Del Río González, 2009; Berkhout, 2011) has led to results that pertain to different literature streams. At the crossroads between environmental economics and innovation studies, a relatively new body of literature has emerged and focuses on the most typical drivers of EI, classified as 'market-pull', 'technology-push' and above all 'regulation' effects (Nemet, 2009; Horbach et al., 2012). In regard to the first effect, EIs have been shown to be pulled by turnover expectations and new demand for eco-products (Rehfeld et al., 2007), past economic performance (Horbach, 2008), and customer benefits (Kammerer, 2009). As far as the 'technology-push' effect is concerned, EIs have been related to firms' R&D, knowledge capital endowment (Horbach, 2008), organizational practices and management schemes, such as Environmental Management Schemes (EMS) (Ziegler and Rennings, 2004; Rennings et al., 2006; Wagner, 2007; Rehfeld et al., 2007; Ziegler and Nogareda, 2009). As for the 'regulation' effects, the extant literature has stressed the central role of environmental standards and policies in spurring the adoption of EI and in creating lead markets for eco-innovators (Beise and Rennings, 2005).

Both survey-based studies (Frondel et al., 2008; Del Río González, 2009; Horbach et al., 2012; Rennings and Rammer, 2011; Rennings and Rexhäuser, 2011) and patent-based empirical investigations (Lanjouw and Mody, 1996; Jaffe and Palmer, 1997; Brunnermeier and Cohen, 2003; Johnstone et al., 2010a,b, 2012; Popp, 2010) have emphasized the extremely important effect of regulation on EI. It has been argued that environmental regulations stimulate a mechanism similar to the Hicksian inducement effect (Hicks, 1932) on EI (Porter and van der Linde, 1995). Evidence has been also obtained concerning the economic impact of policy-induced EI (e.g., Costantini and Mazzanti, 2012), the inducement effect of weak regulatory pressures (Ghisetti and Quatraro, 2013), and the net effects exerted by mixed policies[1] (Jänicke and Lindemann, 2010; Schmidt et al., 2012; Costantini and Crespi, 2013) and neighboring countries' policies (Peters et al., 2012) on the direction of environmentally related technological change.[2]

In comparison to the above effects, the extant literature has instead paid little attention to the EI drivers that work through the

[1] The transition toward sustainability depends not only on the presence of a regulatory framework (that may induce innovations) but also on the existence of proper coordination between existing environmental and technological policies (Costantini and Crespi, 2013).

[2] Besides the above effects, EI determinants have also been found, in the form of controls, among specific firms' characteristics such as: size, location, sector and age (e.g., Ziegler and Rennings, 2004; Rennings et al., 2006; Wagner, 2007; Rehfeld et al., 2007; Horbach, 2008; Mazzanti and Zoboli, 2009).

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