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Analysis

Forms of knowledge and eco-innovation modes: Evidence from Spanish manufacturing firms

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ABSTRACT

The paper investigates the knowledge drivers of firms' eco-innovations (EI) by retaining the diverse nature of their target. Different internal and external knowledge sources are examined and the evidence of EI-modes is searched for with respect to a sample of Spanish manufacturing firms covering the 2007–2009 and 2010–2012 periods. An "attenuated" Science, Technology, EI-mode prevails internally, with R&D more pivotal than either embodied or disembodied non-R&D knowledge, depending on the EI strategy. Externally, synthetic knowledge matters more than the analytical one, suggesting instead a Doing, Using, Interacting EI-mode. Hence, a dichotomic combination of the two modes emerges across the firm's boundaries. However, remarkable differences are in place, depending on whether EIs target efficiency or non-efficiency related environmental improvements. Our evidence also shows that internal and external knowledge turn out difficult to combine, both within and across modes.

1. Introduction

The socio-economic relevance of environmental innovations - hereafter EIs[1] - is nowadays undisputed (EC, 2010; Porter and van der Linde, 1995). The analysis of their drivers has accordingly become of paramount importance in academic research. In particular, a 'hybrid approach' (Rennings, 2000; Cleff and Rennings, 1999), in which environmental/ecological economics and innovation studies are integrated, has flourished. Within this approach, the analysis of "standard" innovation drivers is extended to EIs and combined with that of the "regulatory push/pull effect" of environmental policy (e.g. Cañón-de-Francia et al., 2007; Wagner, 2007; Horbach, 2008; Kesidou and Demirel, 2012; Horbach et al., 2012).

Only recently, some focus has been placed on the different types of knowledge, competencies and resources that firms acquire/develop to become eco-innovators (e.g. De Marchi, 2012; De Marchi and Grandinetti, 2013; Ketata et al., 2014; Ghisetti et al., 2015; Cainelli et al., 2015). In particular, an approach to these EI drivers has been privileged, which looks at the different significance and importance of an identified number of determinants – e.g. R&D and cooperation – between "generic" eco-innovators and non-eco-innovators. In spite of the interesting insights obtained with this analysis, some important questions have been marginalised and require a novel perspective to be adopted, as we propose in this paper.

First of all, the standard analysis does not consider that eco-innovators may distinguish from standard innovators also in the management of their portfolio of knowledge drivers. In particular, by relying on some knowledge sources rather/more than on others, both internally and externally, eco-innovators may follow different "eco-innovation modes", with respect to standard innovators (Evangelista and Vezzani, 2010). Referring to a popular distinction in innovation studies (Jensen et al., 2007), eco-innovators might show specific ways of following a Science, Technology, and Innovation (STI) mode, in brief a STEI mode, rather than a Doing, Using, and Interacting (DUI) mode (Jensen et al., 2007), that is a DUIEI mode, and of combining them across the firm's boundaries (e.g. Parrilli and Elola, 2012; Fitjar and Rodríguez-Pose,

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[1] A standard definition of EI is provided by Kemp and Pontoglio (2007, p. 10) as "the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to [firms] and which results, through-out its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives".

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2013; Gonzalez-Pernıa et al., 2015). The neglect of this issue is quite unfortunate, as its analysis could help the operationalisation of environmental policy/managerial action, as well as the academic debate on the radicalness of EIs, which also depends on their innovation modes (Jensen et al., 2007; Carrillo-Hermosilla et al., 2010). In order to address this important aspect, we thus propose a "systemic" approach to EI drivers: rather than looking at their differential impact with respect to standard innovations individually, we consider the different knowledge assets side by side in defining the firm's knowledge portfolio for EIs.

A second neglected aspect in the extant literature pertains to the heterogeneity of the EI strategies that firms can follow, for example, by adopting cleaner production technologies rather than end-of-pipe ones. So far, a basic comparative approach has limited the focus to their different techno-economic drivers and/or institutional/policy factors (e.g. Cleff and Rennings, 1999; Demirel and Kesidou, 2011; Horbach et al., 2012, 2013; Triguero et al., 2013). Little attention has instead been paid to the different knowledge needs and combinations entailed by specific EIs with respect to generic ones, losing sight of specific modes of eco-innovating within the same green realm. This is another important aspect to consider for an accurate policy and managerial action on EIs. Whenever theoretical and/or empirical arguments allow us to do so, we thus originally specify our arguments about general EI-modes by distinguishing at least two more refined classes of EIs: efficiency related, like material and/or energy saving technologies, and non-efficiency related, like end-of-pipe solutions and new green products.

In order to implement this new approach, we put forward some research hypotheses about the significance and relative importance that different forms of internally generated and externally acquired knowledge have for the firm's EI strategies, in general and in the two EI domains that we retain. We then test these hypotheses through an empirical investigation that makes use of longitudinal data coming from the Spanish Technological Innovation Panel (PITEC). In particular, with respect to previous studies on the same dataset (Cainelli et al., 2015), we use a wider methodological framework on two more recent non-overlapping waves of it (2012–2010 and 2009–2007).

Interesting results emerge about the prevalence of a "hybrid" mode of eco-innovating, combining the resort to STEI internally with DUIEI externally. Furthermore, such a mode presents important elements of heterogeneity across different EI strategies. For example, in the case of efficiency related EI strategies that purse a reduction in the use of energy, the hybridisation is somehow unbalanced towards the DUIEI mode: an expectedly more important role of internal (non-R&D based) embodied knowledge is actually accompanied by a less expected more relevant weight of synthetic external knowledge. On the other hand, a problematic combination of internal and external knowledge emerges in general, and with respect to all the specific kinds of EIs that we consider.

The rest of the paper is organised as follows. Section 2 illustrates the background literature and our research hypotheses. Section 3 presents the empirical application and Section 4 its results. Section 5 concludes.

2. Background literature and hypotheses

While recognising to knowledge a central role,[2] previous works on EIs drivers have adopted an approach that has limited its focus to "filtering" the validity in the green realm of a number of results obtained by "standard" innovation studies. For example, R&D has been shown to be of greater relevance in the comparison, because of both an alleged superior novelty of EIs with respect to standard innovations (Cainelli et al., 2015) and an entailed higher need of absorptive capacity (Ketata et al., 2014; Ghisetti et al., 2015). A different role between eco- and non-eco innovators has also been found for innovation cooperation (De Marchi, 2012; Cainelli et al., 2015), and for the breadth and depth of external knowledge search (Ghisetti et al., 2015; Ketata et al., 2014), pointing to a higher multidimensionality and systemic nature of EIs (Carrillo-Hermosilla et al. (2010).

On the other hand, it is hard to find a richer kind of analysis that relates the set of requirements entailed by EIs - and their relative importance - to the knowledge portfolio of the eco-innovators, in a sort of "systemic" approach. In particular, no account has been explicitly given so far to whether EIs develop upon specific kinds of learning mechanisms and knowledge-bases, in terms of characteristics like degrees of tacitness, complexity, independence and the like (Malerba and Orsenigo, 1993).

A useful starting point to recover these knowledge aspects is searching for environmental "innovation modes", meant as "firms' [eco-]innovative behaviours [synthetised] into a manageable and interpretable set of typologies of [eco-]innovation practices, strategies and performances." (Evangelista and Vezzani, 2010, p. 1257; our own amendments in squared brackets). While the search for these modes can be generally carried out by combining a wide set of innovation indicators (for a review of this literature see Filippetti, 2011), the focus of the present paper makes more focal the reference to two already crystallised modes of innovating, called "Science, Technology, Innovation" (STI) mode, and "Doing, Using, Interacting Mode" (DUI) (Jensen et al., 2007).

In a nutshell, the two modes differ for their different use of internal and external knowledge. As for STI, in terms of internal knowledge, this is marked by the prevalent use of *R&D based knowledge*, which is generally codified and explicit, as well as potentially global in its reach (Campbell and Güttel, 2005). In external terms, the STI mode mainly relies on knowledge sourced by interacting with epistemic communities of actors (e.g. scholars and inventors) and/or institutions (e.g. universities and labs), organised around specific disciplines. This is mainly, though not exclusively, an *analytical* kind of *knowledge* (Moodysson et al., 2008), which typically leads to a declarative kind of knowledge (Lundvall and Johnson, 1994).

Coming to the DUI mode, internally, it relies on a kind of knowledge that emerges from non-deliberated research efforts (i.e., learning-by) at odds with R&D, and which we could therefore call *non-R&D based knowledge*: typically, this is tacit, implicit and local, but also marked by a certain variety in turn. On the one hand, it can be *embodied* in the firms' investment in physical capital, as well as *embedded* in the human capital they build up with their training investments (Madhavan and Grover, 1998). On the other hand, it can be *disembodied* (as the R&D based one is), but only indirectly related to R&D, if not even unrelated to it, and rather connected to other activities representing important "complementary assets" for innovation to take place, like marketing investments (Rothwell, 1977; Teece, 1986). In external terms, the DUI mode is fuelled by the firm's interaction with its business suppliers, customers, if not even competitors (Lundvall, 1992), yielding a procedural knowledge, which is *synthetic*, as it amounts to the novel combination (i.e. synthesis) of different pieces of existing knowledge (Asheim and Coenen, 2005; Lundvall and Johnson, 1994).

With this STI/DUI distinction in mind, one way to identify the modes in which firms orient their innovative activities towards environmental objectives – in brief, their "EI-modes" – is addressing the use of different forms of internal and external knowledge for the sake of eco-innovating.

We begin our argumentation by focusing on internal knowledge. In this respect, EIs have been found to be more multifaceted than their non-environmental counterparts, requiring firms to master diverse knowledge pertaining to 'design', 'users' involvement', 'product-

[2] Following the resource-based view of the firm (Wernerfelt, 1984; Barney, 1991), its "natural" extension (Hart, 1995; Hart and Dowell, 2010) and its recent refinements in terms of capabilities theories (Cohen and Levinthal, 1990; Teece et al., 1997), EIs have been linked to specific learning processes (e.g. Ketata et al., 2014), which firms undertake by combining the generation of internal knowledge with the absorption of external one (De Marchi, 2012; De Marchi and Grandinetti, 2013; Cainelli et al., 2015; Ghisetti et al., 2015).