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A taxonomy of green innovators: Empirical evidence from South Korea

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ABSTRACT

This paper presents a new taxonomy of green innovators. Using firm-level data from the Korea Innovation Survey, this paper investigates different types of eco-innovations, how these relate to each other, and what their main determinants are. The empirical methodology builds on a combination of factor, cluster, and multinomial logit analysis. The taxonomy identifies four groups of green innovators: (1) carbon dioxide reducing; (2) waste-reducing; (3) recycling innovators; (4) and pollution-reducing. Research and development (R&D) policies emerge as relevant factors for enhancing innovation in waste-reducing firms, whereas environmental taxes and regulations are found to be more important drivers of technological change for pollution-reducing firms. The contribution of this paper is twofold. First, it points out the firm-specific characteristics and policy instruments that are more relevant for different types of green innovation. Second, it provides new firm-level evidence for South Korea, thus expanding the geographical scope of econometric research on green innovation, which has so far largely focused only on European countries.

1. Introduction

"Green innovation" or eco-innovation, (hereby used interchangeably) can be defined as the production and adoption of new technologies that lead to "a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) compared to relevant alternatives" (Kemp and Pearson, 2007: 7).[1] Academic research on green innovation has flourished rapidly in recent years, and investigates the factors that can sustain and foster a green transformation of the economy.

One recent strand of research has focused on the firm-level of analysis, studying how business firms' technological activities aimed at developing new environmentally friendly products and processes are shaped by environmental policies, research and development (R&D) policies, and demand dynamics, as well as by firm-level characteristics. This econometric research has been facilitated by the increasing availability of innovation survey data (like the Community Innovation Surveys in Europe), which enable the empirical measurement of various types of green innovation and analysis of their determinants (see Horbach, 2008; Veugelers, 2012; Li, 2014; Borghesi et al., 2015; Cainelli et al., 2015; Horbach, 2016).

Recent papers summarizing this strand of literature (see del Río et al., 2016; Hojnik and Ruzzier, 2016), point out two directions for future research. First, most studies have investigated the determinants of green innovation as such. However, green innovation is arguably a broad and complex phenomenon, encompassing diverse innovations directed towards renewable energy, new materials, carbon dioxide and pollution reduction, and recycling technologies. These are markedly different technological trajectories, requiring distinct managerial capabilities and supporting policies. Thus, an important question is: how do the various types of green innovation differ from each other, and what are their main drivers? It is important to open up the black box of green innovation, distinguish between different types, and investigate how the drivers and enabling factors differ.

Second, it is necessary to expand the geographical scope of this empirical research, most of which has been focused on European countries (Germany in particular). Empirical evidence on green innovation for non-European economies is still limited. One region of great relevance here is East Asia, where many nations have experienced rapid industrialization and have now reached the point where the 'grow first, clean up later' strategy can no longer be applied. Concepts such as green innovation, green growth, the circular economy, closed-loop value chains and the 3Rs (reduce, reuse, and recycle) have already entered the policy agendas of many

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[1] The terms "eco-innovation" and "green innovation", as well as "environmental innovation", are typically used interchangeably, although some small nuances in scope exist as discussed in Schiederig et al. (2011).

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East Asian countries (see Tseng et al., 2013).[2] What are the main patterns and determinants of green innovation in East Asia, and how do these differ from the empirical patterns identified for European countries? This question calls for further empirical evidence. South Korea, with its successful history of industrialization and recent implementation of a national green growth strategy, stands out as a particularly relevant case.

These two gaps in extant research motivate the present work. The paper presents an empirical analysis of nearly 4000 manufacturing firms in South Korea, using data from the Korea Innovation Survey 2010. This survey dataset, which has not yet been exploited in scholarly research in this field, is highly relevant, because it includes a range of questions on firms' green innovation activity. This makes it possible to distinguish nine different types of eco-innovation, study how these are linked to each other, and relate these to underlying determinants such as environmental and R&D policies, market demand, and company-level capabilities and strategies.

Specifically, the following research question is asked: *how do green innovators differ from each other, and what are the main factors enhancing firms focusing on different types of green innovation?* The objective is to present a new taxonomy of green innovators. A taxonomy of green innovators means a classification of firms doing eco-innovations into different groups (or clusters) based on empirical evidence. Such a taxonomy is important because it makes it possible to identify distinct groups of firms that focus predominantly on one (or few) type(s) of green innovation, and that have different characteristics and driving factors. Taxonomic exercises based on innovation survey data are common in innovation literature (see Pavitt, 1984; Castellacci, 2008); hence, it is interesting to extend this type of approach to the field of eco-innovation.

The empirical analysis of the South Korean firm-level data employs a combination of factor, cluster, and multinomial logit analysis. This methodological approach is useful and it has been applied in previous research in innovation studies to deal with survey datasets that contain a large number of variables that are highly correlated to each other (see Castellacci, 2009). By employing a combination of factor and cluster analysis, this paper intends to reduce these variables to a smaller number of factors, and use the latter to identify different clusters (groups of firms), each of which predominantly focuses on one type of green innovation.

The paper thus points out a new taxonomy with four groups of eco-innovating firms that follow distinct technological trajectories: (1) carbon dioxide reducing; (2) waste-reducing; (3) recycling innovators; (4) pollution-reducing firms. The analysis of the determinants of innovation in these four groups of firms shows that R&D policies are more relevant factors enhancing innovations in waste-reducing firms, whereas environmental taxes and regulations emerge as more important drivers of technological change for pollution-reducing firms.

In short, the contribution of the paper is twofold. First, by identifying distinct groups of green innovators characterized by different strategies and driving factors, it opens the black box of the eco-innovation concept, and shows the firm-specific characteristics and the policy instruments that are more relevant for each type of green innovation. Second, by providing new firm-level evidence for South Korea, the paper contributes to expanding the geographical scope of econometric research on green innovation, which has so far largely focused only on European countries.

[2] For recent surveys of these topics, and the circular economy in particular, see Ghisellini et al. (2016) and Lieder and Rashid (2016).

2. Literature review

The innovation literature on the determinants of green innovation (or eco-innovation) has developed rapidly during the past decade (Horbach, 2008; Jakobsen and Clausen, 2016).[3] Within the specific strand of research relevant to this paper, quantitative (econometric) analyses of the drivers of green innovation have been conducted using innovation survey data—in particular the Community Innovation Survey (CIS) in Europe (which had in 2008 added an additional module with interesting questions on eco-innovation activities conducted by firms).

del Río et al. (2016) and Hojnik and Ruzzier (2016) recently surveyed this emerging strand of literature and found that the econometric research has not yet achieved consensus on the effect of different drivers of eco-innovations, their relative importance, and how they differ for distinct types of eco-innovations and for different countries. This section briefly reviews the debate discussed by key studies in this literature, particularly those investigating the determinants of distinct *subtypes* of green innovation using innovation survey datasets.

One important issue in the study of green innovation is the *double externality problem*, as noted by Rennings (2000), Rennings et al. (2006) and Jaffe et al. (2005). In fact, green innovations bring together two distinct types of *market failure*: the first concerns the standard positive externality in the creation of new knowledge, which leads to a market failure and hence provides the rationale for R&D and innovation policy support; and the second refers to the negative externality related to pollution and environmental degradation, which provides the rationale for the introduction of environmental taxes and regulations. The latter has typically been the focus of environmental policy, whereas the former has provided the foundation of public intervention through innovation and R&D policy (Castellacci and Lie, 2015). Because of this double externality, green innovations necessitate both environmental taxes and (or) regulations, on the one hand, and innovation policy support, on the other. This explains why the literature in this field has emphasized determinants such as public regulation and types of policy-mix.

Veugelers (2012) employed innovation survey data for Flemish firms (a subset of the Belgium data) to investigate how different policy instruments relate to green innovation. The main finding is that market demand and voluntary agreements are important for all types of green innovations, whereas policy instruments like environmental regulations and taxes (environmental policy) and financial incentives and support mechanisms like R&D subsidies and tax incentives (R&D and innovation policy), matter relatively less. Further, Veugelers finds environmental policy to be relatively more important for green *process* innovations (and for carbon dioxide-reducing technologies in particular), whereas R&D and innovation policy support matter more for energy-reducing innovations. On the other hand, Borghesi et al. (2015), using Italian survey data, find environmental policy to be more important than innovation policy support for both subtypes of eco-innovation, whereas R&D and innovation policy are not relevant for spurring energy-reducing and carbon dioxide-reducing innovations. Further, the paper does not find significant support for market demand as an important driver of green innovation.

[3] Some of the commonly used theoretical approaches in this field include institutional and neo-institutional theory (e.g. Lin and Sheu, 2012; Zhu et al., 2012; Li, 2014), resource-based theory (e.g. Chen, 2008), stakeholder theory (e.g. Banerjee et al., 2003; Tang and Tang, 2012), green (or sustainable) value-chain management (see e.g. Seuring, 2013; Seuring and Müller, 2008), and the more general business and management literature (for a recent survey see Bossle et al., 2016).

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