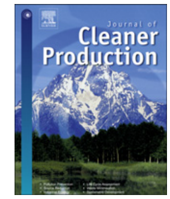
Journal of Cleaner Production 19 (2011) 1170–1179

Contents lists available at ScienceDirect

Journal of Cleaner Production

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



Analysing the determinants of environmental technology investments. A panel-data study of Spanish industrial sectors

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ARTICLE INFO

Article history:
Received 10 November 2008
Received in revised form
1 May 2010
Accepted 2 May 2010
Available online 8 May 2010

Keywords:
Clean technologies
Environmental regulation
Drivers and barriers

ABSTRACT

The aim of this paper is to empirically assess the determinants of environmental technology investments in the Spanish industrial sectors with the help of panel data econometric techniques. The paper confirms the relevance of the stringency of environmental regulation to explain overall investment patterns in environmental technologies. These investments are also positively related to human and physical capital intensity and R&D intensity, and negatively related to the export intensity of sectors. Furthermore, the study shows that the determinants for investments are likely to differ between environmental technology types (i.e., end-of-pipe versus cleaner technologies).

1. Introduction

The aim of this paper is to analyse the factors affecting investments in environmental technologies in the Spanish industrial sector and their influence on different environmental technology types (end-of-pipe or cleaner technologies).[2] The paper tries to contribute to the understanding of the factors influencing innovation and diffusion of environmental technologies with the help of panel data econometric techniques.

With respect to the existing literature, this paper has several aspects making it an original contribution:

– It is based on an integrated theoretical framework which considers three sets of determinants for environmental technology investments (internal and external factors and techno-economic characteristics of the technologies). Other approaches only provide a partial consideration of those factors or rely on an ad-hoc approach.
– Very few studies have used econometric modelling to analyse the factors affecting different technology types. Even less have used panel data econometric techniques.
– Very few studies have used investment expenditures on environmental technologies as the dependent variable.
– We combine a focus on environmental technologies with the focus on sectors. Other studies have analysed this issue at the level of firms.
– This paper is the first one carried out in Spain using this methodology and data. Indeed, it is one of the few papers on environmental technological change in this country (together with del Río, 2005; del Brío et al., 2002; Aragón Correa, 1998).

The paper is structured as follows. The next section provides the analytical framework of the study, the hypotheses and the links to the existing literature. The empirical study is provided in Section 3. The paper closes with some concluding remarks.

2. Theoretical framework and links to the existing literature

2.1. The existing literature

The relatively recent empirical literature on the determinants (drivers and barriers) for the uptake of environmental technologies can be classified into qualitative (case studies) and quantitative studies (econometric modelling).[3] Quantitative studies are less able to capture the relevance of the local institutional and socioeconomic context and certain qualitative aspects of environmental regulation (including the "stringency of environmental regulation",

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[1] Tel.: +34 926 29 53 00.
[2] End-of-pipe (EOP) technologies are devices added at the end of the production process which do not modify it and transform emissions into easier-to-handle substances and cleaner technologies involve reductions in the consumption of materials or energy at the source.

[3] Del Río (2007) provides a detailed overview of this literature (both qualitative and quantitative studies). See also Montalvo (2008) and Volleberg (2007).

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doi:10.1016/j.jclepro.2010.05.001

the style of regulation and the choice of different policy instruments) but they are considered more rigorous, objective and prone to generalisations.

Microeconometric methods have proven useful and relevant in this regard and, particularly, multinomial models (logit and probit) have been applied (see Steger, 1996, among others). However, they share a number of problems. They use cross-section data on a specific moment of time only. In addition, an endogeneity problem and, thus, a bias in the estimation of the coefficients may result (Mazzanti and Zoboli, 2006).

In contrast, panel data mitigate some of these problems. They allow us to analyse how the innovation/adoption of environmental technologies changes as a response to changes in explanatory variables. Certainly, a major problem to carry out an econometric analysis based on panel data is data availability. Due to the few possibilities to get survey-related panel data on eco-innovation, the literature on this topic is limited (Horbach and Rennings, 2007) and mostly refer to firm-level data.[4] To our knowledge, only two papers have focused on sectors as the unit of analysis: Brunnermeier and Cohen (2003) and Cole et al. (2005). Our study is in line with these later studies and provides a cross-sector analysis of environmental technology investments.

On the other hand, few studies have analysed the determinants for the uptake of different environmental technologies (EOP versus cleaner technologies). Del Río and Tarancón (2005) and Frondel et al. (2007) are notable exceptions. The reason for this is threefold. First, it is difficult to separate investments in cleaner production technologies from other non-environmental technologies. Innovations reducing environmental impacts may not have been developed for environmental reasons only, i.e., they fulfil ecological as well as technical criteria of efficiency, operational safety and reliability (Huber, 2004). Second, the distinction of EOP and cleaner process technologies is difficult in some cases.[5] Third, data on the use of cleaner technologies have hardly ever been seriously included in official environmental statistics thus far. As argued by Kemp and Foxon (2007, p.19), we lack good statistical information about cleaner production. Statistical offices have only counted investments in EOP technologies due to methodological problems of separating cleaner production measures from investments in non-environmental technologies. However, pre-established checklists of environmental technologies (as in the database used in this paper) whereby respondents state that they have invested in a specific technology (which can be classified as EOP or cleaner production) circumvent those problems to some extent.

Finally, while many studies stress that the success of a given environmental technology exclusively depends on government policy, others show a weaker impact of environmental policy instruments (see Belis-Bergouignan et al., 2004; Blackman et al., 1998; Hemmelskamp et al., 2000). Our analysis assumes that, in addition to environmental policy, there are other determinants of environmental technologies investments.

2.2. The conceptual framework

Traditionally, the literature on the determinants of "general" technological change was framed in the context of the demand-pull versus technology-push dichotomy. Whereas some emphasised the importance of new knowledge and technological opportunities (the supply-push view), others stressed the role of consumers', firms' and the government's demand (the demand-pull view)(Hemmelskamp, 1997). Nowadays, there is a consensus that both sets of factors are important, even though their relative importance may differ from case to case (Oosterhuis, 2006).

A consensus also began to emerge that both aspects of the dichotomy were necessary, but not sufficient to explain technological change (Dosi, 1982; Mowery and Rosenberg, 1979). A systemic perspective, which stresses the interactions between supply and demand, such as the information exchanged between innovators, consumers, and other actors involved in a new technology provides a richer picture of the drivers for and barriers to innovation (Foxon, 2003). This approach emphasises the importance of systemic interactions between users, producers and technology developers. Interactions through both market mechanisms and flows of knowledge and influence, within an institutional set up, creates incentives for different types or rates of innovation (Taylor and Rubin, 2005).

Indeed, the systemic model combines two main types of interaction (Foxon, 2003; Kemp, 2007). One relates to the processes occurring within a firm. This is related to internal capabilities and organisational aspects. As stressed by the resource-based view of the firm, firm-internal characteristics, such as strategy, structure and core capabilities, are important determinants of innovation (Fagerberg et al., 2005). Firm's technological capabilities are particularly emphasised (Baumol, 2002).

The second level involves broader factors shaping the behaviour of firms: the social and cultural context, the institutional and organisational framework, infrastructures and the processes which create and distribute scientific knowledge (Kemp et al., 2000). Therefore, although interrelated, there is clearly an aspect "internal" to the firm and another related to the interactions between the firm and its external environment. In addition, the attractiveness to adopt a technology is likely to differ according to different technology types and economic and technical characteristics of the technologies (Clayton et al., 1999).[6]

Regarding the analysis of environmental technological change more specifically, it has been scattered across different academic disciplines, including evolutionary economics (Rip and Kemp, 1998; Unruh, 2000; Foxon et al., 2005, among others), induced innovation theory (Ruttan, 2000), actor-network analysis (Luiten and Blok, 2004), industrial economics (Kerr and Newell, 2001; Cole et al., 2005), organisation studies (Khanna et al., 2006), environmental economics (Jaffe et al., 2002) and the corporate environmental management literature (Welford, 1996; Steger, 1996). Each has tended to focus on a narrow range of determinants and particular levels of analysis (Bernauer et al., 2006). For example, the corporate environmental management literature focuses on management aspects which are internal to the firm (environmental strategy and commitment of top managers) to explain environmental technology innovation/adoption, whereas environmental economists typically give pre-eminence to environmental policy. These analytical approaches are not mutually incompatible and should be combined. This has already (partially) been attempted elsewhere (see, among others, Montalvo, 2008; Kemp, 1997, 2007; Taylor and Rubin, 2005; del Río, 2009; Sartorius, 2008; Rennings, 2000).

The combination of those approaches suggests that, when taking the decision to engage in environmental technological change, firms are influenced by a wide array of factors, which could tentatively be grouped into three categories (del Río, 2009).

[4] Including Jaffe and Stavins (1995), Jaffe and Palmer (1997), Cleff and Rennings (2000), Kerr and Newell (2001), Hammar and Löfgren (2006), Khanna et al. (2006), Mazzanti and Zoboli (2006), OECD (2008) and Horbach (2008).

[5] For example, an EOP technology may recover substances that can be recycled.

[6] The purchase price and the performance characteristics of the technology (compared to competing technologies) are a key factor in this regard (Kemp, 1997).