Journal of Cleaner Production 155 (2017) 141–154

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Eco-innovation, sustainable supply chains and environmental performance in European industries[1]

Valeria Costantini [a], Francesco Crespi [a, c, *], Giovanni Marin [b], Elena Paglialunga [a]

[a] *Roma Tre University, Rome, Italy*
[b] *IRCRES-CNR, Milan, Italy*
[c] *BRICK, Collegio Carlo Alberto, Turin, Italy*

ARTICLE INFO

Article history:
Received 12 December 2015
Received in revised form
2 September 2016
Accepted 6 September 2016
Available online 8 September 2016

Keywords:
Eco-innovation
Environmental performance
Inter-sectoral linkages
International spillovers
Value chain
Sustainable production
Governance systems

ABSTRACT

The introduction and adoption of green technologies are considered the most cost effective way to reduce environmental pressure without compromising economic competitiveness. The scientific literature has emphasized the crucial role played by diffusion pathways of green technologies along the supply value chain, but empirical quantitative findings on the effectiveness of green technologies in improving environmental performance are scarce. The objective of this paper is to highlight the role of inter-sectoral linkages in shaping the influence played by eco-innovations on sectoral environmental performance. Empirical findings show that both the direct and indirect effects of eco-innovations help reducing environmental stress and that the strength of these impacts varies across the value chain depending on the technology adopted and the type of pollutant under scrutiny. The main implications we can deduce are that, first both corporate and policy governance strategies should specifically address the goal of maximizing environmental gains that can be achieved through the development and adoption of clean technologies along the supply chain, and second both strategies should be coordinated in order to minimize the costs for reducing environmental pressures.

1. Introduction

Over the last decade, the policy and scientific communities have devoted increasing attention to the role played by technological innovation in achieving the challenging environmental goals that are currently being debated on the international agenda. The European Union (EU) in particular has been fuelling the debate on green technologies due to continuous improvements in its long term climate and energy strategy. In the specific discussion on mitigation costs in the climate change issue, the development of green technologies has been used as the main argument against the considerable concerns regarding the economic costs of being compliant with stringent regulations. To this end, first, environmental regulation is acknowledged as being capable of stimulating the development and diffusion of new cleaner technologies which represent a major engine for reducing the polluting pressure of human activity. Second, the promotion of eco-innovation (EI) may lead to a win-win situation in which the generation and spread of technologies for improving environmental performance (EP) produce knowledge spillovers that positively affect the international competitiveness of high-tech sectors (EC, 2014; Porter and van der Linde, 1995).

While previous literature closely investigated the inducement effects on EI determined by environmental policies (Cleff and Rennings, 1999; Costantini et al., 2015; Horbach, 2008; Jaffe et al., 2002; among others) and the relevance of regulation-induced EI in driving economic competitiveness (see, for instance, Ambec et al., 2013; Costantini and Crespi, 2008), less attention has been devoted to investigating the actual impact of EI on EP and the mechanisms through which such an effect may take place.

The present paper focuses on the latter issue by arguing that, when studying the environmental impact of the spread of environmental technologies, the role of inter-sectoral linkages in production systems also has to be properly accounted for. On the one hand, inter-sectoral linkages contribute to the process of technology diffusion and foster knowledge spillovers and positive externalities that a firm can gain, for example, due to the innovation

* Corresponding author. BRICK, Collegio Carlo Alberto, Turin, Italy.
E-mail address: francesco.crespi@uniroma3.it (F. Crespi).

[1] We gratefully acknowledge the support by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 649186 – ISI-Growth. The comments and suggestions by three anonymous referees are also acknowledged. The usual disclaimers apply.

http://dx.doi.org/10.1016/j.jclepro.2016.09.038
0959-6526/

activities of the supplying industries (Verspagen, 1997; Wolff and Nadiri, 1993). Considering the nature of vertical relationships between firms, the transmission channels through which spillovers can be transferred include all the improvements embodied in the machineries and the inputs purchased from the supplier (Griliches, 1979; Los and Verspagen, 2002) as well as all those related to user-producer interactions (Isaksson et al., 2016). On the other hand, the role of inter-sectoral linkages is not confined to the technological sphere, but can be relevant in enhancing environmental performance as the literature on sustainable supply chains has clearly emphasized. In particular, it has been shown that firms are increasingly trying to incorporate sustainable issues in their corporate strategies (Lozano, 2008; Lozano et al., 2015), with specific attention devoted to the governance choices regarding sustainable supply chains as a crucial factor for achieving environmental goals (Martínez-Jurado and Moyano-Fuentes, 2014; Vezzoli et al., 2015; von Geibler, 2013). Moreover, technological and environmental spillover effects associated with inter-sectoral linkages can be generated both domestically and across countries. In this respect, the growing integration between firms from different countries influences the characteristics and governance of production and distribution systems in such a way that participation in global value chains (GVC) represents not only an opportunity to increase firms' technological and economic performance (Gereffi, 1999; Gereffi and Kaplinsky, 2001; Giuliani et al., 2005; Saliola and Zanfei, 2009), but also a source for enhancing production sustainability by taking advantage of the differentiated and co-evolving environmental constraints and standards across countries, institutions, sectors and agents (Closs et al., 2011; Manning et al., 2012).

Building on this framework of analysis, this paper offers an empirical analysis at the sectoral level based on 27 EU countries in the period 1995–2009 and highlights the role of inter-sectoral linkages in influencing the capacity of eco-innovation to shape sectoral environmental performance, considering both direct and indirect effects. In so doing, we will not only show that at each production stage eco-innovation activities contribute to reducing environmental damage in the sector where it is generated (*direct impact*), but also that they contribute to the improvement of the environmental performance of purchasing sectors via spillover effects activated by inter-sectoral market transactions along the value chain (*indirect impact*). Moreover, both the effects associated with domestic and cross-country inter-sectoral relationships will be considered in the analysis.

The remainder of the paper is organized as follows. Sections 2 and 3 describe, respectively, the background and the methods used for both the construction of the database and the empirical analysis. Section 4 provides a discussion of the empirical results and Section 5 summarizes the main results and discusses their implications in terms of firm level and policy level governance choices regarding sustainable value chains.

2. Background literature and research hypotheses

A large stream of studies analyses the determinants of EI, distinguishing between the influence of public intervention and regulation, market-driven demand and internal strategies driven by environmental management systems (Carrión-Flores et al., 2013; Fischer and Newell, 2008; Kammerer, 2009; Popp, 2006, 2010; Rehfeld et al., 2007; Reinhardt, 1998; Wagner, 2007). On the contrary, the policy and scientific debate has taken almost for granted that the diffusion of eco-innovation is capable of significantly improving environmental performance, whereas less empirical studies have addressed the issue of the effectiveness of eco-innovation in achieving environmental goals. Among them, for example, Lee and Min (2015) examine the impact of green research and development (R&D) investments on environmental and financial performance in Japanese manufacturing firms and show that R&D specifically devoted to supporting EI reduces carbon emissions and increases firms' financial performance. In parallel, Yin et al. (2015) test whether and how institutional and technical factors affect the relationship between economic growth and environmental quality and show that technical progress (measured by R&D expenditures) limits CO2 emission dynamics. Further analyses focusing on the drivers of CO2 emissions account for a number of factors that are likely to determine the emissions level, including innovation. To this end, Cole et al. (2005, 2013) specifically analyse the UK and Japan manufacturing sectors at the firm level and find that environmental innovation, proxied by R&D expenditures, turns out to be a key determinant in the decline of CO2 emissions.

Other contributions focus on the role played by catching up with best available environmental technologies and practices (BAT) in achieving higher EP. Within this line of research, Kortelainen (2008) develops a dynamic framework to analyse eco-efficiency in terms of an environmental performance index (EPI) based on Data Envelopment Analysis (DEA) by applying frontier efficiency techniques. Based on 20 EU countries from 1990 to 2003, an EPI is calculated and the overall changes in EP are further distinguished between changes in the relative eco-efficiency (representing the catching-up effect with BAT) and a shift in the frontier due to environmental technical change, where the latter results to be the main driver of EP improvement. By applying the DEA approach together with directional distance functions,[2] Picazo-Tadeo et al. (2014) confirm that environmental technical change is the most important component in fostering intertemporal EP. Similarly, Beltràn-Esteve and Picazo-Tadeo (2015), when conducting an analysis of the transport industry in 38 countries for the period 1995–2009, draw the same conclusions when considering specific environmental pressures (with some differences between low and high-income countries).

Building on this first set of contributions, we can formulate our first research hypothesis to be tested in the empirical analysis conducted at the sectoral level for EU27 countries.

HP1. *Eco-innovations developed by industrial sectors have a positive direct impact on within sector environmental performance.*

However, the actual strength of new environmental technologies in shaping the reduction of the environmental negative externalities of economic production cannot be fully appreciated without including the role of interconnections between firms, sectors and countries in the analysis. In this respect, the scientific literature is increasingly interested in the acknowledgement of the strategic relevance of the links between sustainability issues and supply chains, leading to the conceptualisation of green supply chains, sustainable value chains and green innovation value chains (Lee and Kim, 2011; Lee et al., 2014; Olson, 2013, 2014; Zhu and Sarkis, 2006). Such analyses show that corporate sustainability strategies go beyond corporate boundaries, by considering the environmental impact of each phase of production from the use of raw materials to manufacturing, distribution, final use and disposal according to a life cycle assessment (LCA) exercise (Kovács, 2008;

[2] The directional distance function, also referred to as *environmental productivity* (Huppes and Ishikawa, 2005), is used to model economic production process with two outputs: the goods or services primarily produced and the associated undesired emissions. It measures the extent to which it is possible to increase the former output (for example, in term of value added) and, at the same time, reduce the polluting emissions while remaining within the feasible combination given the technological possibilities (Picazo-Tadeo et al., 2014).