



## Analysis

# Beyond inducement in climate change: Does environmental performance spur environmental technologies? A regional analysis of cross-sectoral differences



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## ABSTRACT

This paper contributes to the debate on the inducement of environmental innovations by analyzing the extent to which endogenous inducement mechanisms spur the generation of greener technologies in contexts characterized by weak exogenous inducement pressures. In the presence of a fragile environmental regulatory framework, inducement can indeed be endogenous and environmental innovations may be spurred by firms' reactions to their direct or related environmental performance. Cross-sector analysis focuses on a panel of Italian regions, over the time span 2003–2007, and is conducted by implementing zero-inflated regression models for count data variables. The empirical results suggest that in a context characterized by a weak regulatory framework, such as the Italian one, environmental performance has significant and complementary within- and between-sector effects on the generation of green technologies.

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## 1. Introduction

The economic analysis of environmental issues has received increasing attention over the last decades. Within the wide body of literature on the subject, the dynamics of the creation of environmental innovations has recently become a key topic, due also to the identification of these new technologies as a means of restoring the competitiveness of advanced countries which has been harmed by the economic crisis. Their emergence is indeed supposed to bring about new jobs and new perspectives for economic growth.

In this respect, an investigation of the determinants of green innovations may provide useful input to policymakers when designing targeted measures aiming, on the one hand, at reducing the environmental impact of production activities and, on the other, at fostering technology-based competitiveness.

Most of the literature analyzing determinants of environmental innovation has been grounded on the induced innovation approach according to which stringent environmental regulation may exert an incentive to firms to introduce innovations, for instance, allowing the polluting standards exogenously set up by policymakers to be met (Ambec et al., 2013; Brunnermeier and Cohen, 2003; Rennings and Rammer, 2011; Rennings and Rexhäuser, 2011).

This paper aims at contributing to this strand of literature by adopting a different and yet complementary perspective on the inducement mechanism. We investigate the extent to which, in a context with a weak environmental regulatory framework, an inducement of environmental technologies can still be at stake. In such a framework, inducement could indeed be *endogenous* rather than *exogenous*. Instead of investigating the direct relationship between an inducing factor (mainly an environmental policy) and the generation of green technologies, as previous literature has done, we posit that it is important to understand if and to which extent such *endogenous* mechanisms are set in motion as a response to environmental performance. In articulating this hypothesis, we provide an interpretation of how those *endogenous* mechanisms work by appreciating the distinction between direct inducement and that exerted by related sectors. To

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understand the latter, we need to stress the differences and complementarities between the adoption of greener technologies and their generation processes. For the latter, we argue that inducement mechanisms are likely to work through user–producer dynamics based on the derived demand of polluting agents for cleaner technologies rather than through their direct innovating efforts. We put particular emphasis on the importance of vertical linkages and the role of *derived demand* in stimulating the generation of green technologies since environmental innovations may be endogenously pulled by the derived demand of vertically related sectors featuring bad environmental performance. To test for this, we implement a synthetic measure of vertical relatedness across sectors based on input–output tables.

Cross-sectoral analysis is carried out on a panel of Italian regions observed over the time span 2003–2007, and is based on matching of the regional National Accounting Matrix with Environmental Accounts (henceforth NAMEA) data, patent data and regional economic accounts. The econometric results, obtained by implementing a zero-inflated binomial model for count data variables, identify interesting and persistent patterns of inducement for different classes of emissions. Environmental performance of vertically related sectors, proxied by emission intensities in terms of value added, exerts a positive impact on the generation of green technologies. This would support the hypothesis that sectors with higher levels of green innovativeness are stimulated to generate green knowledge by the demand coming from vertically related sectors with bad environmental performance.

The rest of the paper is organized as follows. Section 2 articulates an induced innovation framework to the analysis of the determinants of the creation of green knowledge at the sectoral and regional level and constructs the working hypothesis. Section 3 outlines the empirical context of the analysis while Section 4 presents the data, methodology and variables. In Section 5, we show the results of the econometric analyses and the main robustness checks we implemented. We provide conclusions and points for discussion in Section 6.

## 2. Induced Technological Change and Derived Demand for Environmental Innovations

The inducement hypothesis in climate change has been largely investigated in the domain of environmental economics. This hypothesis identifies environmental regulation as a driver for environmental innovations, resting upon the traditional Hicksian argument that “A change in the relative prices of factors of production is itself a spur to invention, and to invention of particular kind – directed to economizing the use of the factor which has become relatively expensive”<sup>1</sup> (Hicks, 1932: 124–125). This strand of literature points to the moderating role played by regulation on the generation of green technologies. A stringent policy is treated as an additional cost that increases total production costs by changing the relative factor prices. This induces firms to engage in innovation activities aimed at reducing the increased cost, e.g. by developing emission-saving technologies.<sup>2</sup> The incentives

<sup>1</sup> Habakkuk (1962) provided support to this hypothesis showing how, in American and British historic evidence through the nineteenth century, labor scarcity pushed firms to generate and introduce labor-saving technologies. The formal analysis provided by Kennedy (1964) and Samuelson (1965) consists in the construction of an innovation possibility frontier, with the typical shape of a production possibility frontier, along which the trade-off between labor-saving and capital-saving innovations can be traced. The relative costs of capital and labor shape the isorevenue that enables identification of an optimum direction of technological change (Binswanger and Ruttan, 1978). The approach has been criticized for the lack of microeconomic foundations by Salter and Reddaway (1966), but remains one of the cornerstones of the economics of innovation. Ruttan (1997, 2001) has shown that technological change is characterized by a strong directionality that can be represented in terms of changes in the output elasticity of production factors.

<sup>2</sup> Pindyck (1979) and Atkeson and Kehoe (1999) shed light on the question as to what extent energy and capital are complementary or substitutes by concluding that in the short run these are complements while in the long run they are substitutes. Accordingly, an increase in the price of energy (factor of production) in the long run induces technological change (Jaffe and Stavins, 1995).

are engendered outside the production system, i.e. in the institutional system and will for this reason be labeled as exogenous in this paper. The correlation between environmental regulation and technological change has been empirically investigated either by using patent data to test whether regulation affected knowledge generation<sup>3</sup> (e.g. Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997; Lanjouw and Mody, 1996; Popp, 2006) or by using survey data to test whether regulation pushes and/or pulls environmental innovations (e.g. Cainelli et al., 2012; Crespi, 2012; Frondel et al., 2008; Horbach et al., 2012; Rennings and Rammer, 2011; Rennings and Rexhäuser, 2011; for a review see Del Río, 2009). In both cases, evidence confirms that regulation exerts a positive effect on innovation.

The outcome of such inducement mechanisms cannot however be taken for granted. The public nature of innovation and the appropriability regime does indeed create a positive externality, which is translated into innovation efforts that are lower than the social optimum. Conversely, pollution is a case of negative externality, the social costs of which are spread over the entire society, so that firms pollute more than the social optimum level. Without policy intervention “firms pollute too much and innovate too little compared with the social optimum” and investments in green technologies are in the end too low as “the two market failures are mutually reinforcing” (Johnstone et al., 2010b: 9). The need for environmental regulation is also supported by the *Porter Hypothesis* (Porter and van der Linde, 1995) in its different versions,<sup>4</sup> and empirical evidences underline the positive effect of regulation over firms’ competitiveness, e.g. in terms of increased trade for environmental technologies (Costantini and Mazzanti, 2012).

Moreover, the regulatory push/pull framework may have different effects across different typologies of environmental innovations (Ghisetti and Rennings, 2013; Rennings and Rammer, 2009; Rexhäuser and Rammer, 2013) and different policy frameworks<sup>5</sup> may generate different innovative outcomes (Popp et al., 2009). What is more, the stringency, predictability, flexibility, incidence and depth of the policy instruments impact on the effort and direction of the innovations (Johnstone et al., 2010b) although the measurement of these elements is not an easy task (Kemp and Pontoglio, 2011).

In contexts characterized by weak environmental regulatory frameworks and/or barriers to policy enforcement, the inducement may come from within the economic system (*endogenous*) rather than from the institutions (*exogenous*).

A step forward in the identification of the endogenous incentive for firms to generate green technologies is represented by the literature on

<sup>3</sup> In this perspective, an increase in pollution abatement expenditures, taken as a proxy for the stringency of environmental regulation, exerts a positive effect on granted patents in environmental fields (Lanjouw and Mody, 1996) and on patent applications in environmental technologies (Brunnermeier and Cohen, 2003). Conversely, by using the same proxy for environmental regulation, Jaffe and Palmer (1997) found a positive effect only on innovation inputs, measured by R&D expenditure, while no significant effect was found on overall patents. The literature has also focused on specific environmental patents, e.g. on the effect of climate change policies on renewable energy patents (Johnstone et al., 2010a), on some specific regulations, e.g. the Clean Air Regulation on NO<sub>x</sub> and SO<sub>x</sub> (Popp, 2006) and on the role of the perception of stringent environmental policies (Johnstone et al., 2012). In all these cases, confirmation of the inducement hypothesis has been found.

<sup>4</sup> This hypothesis suggests that stringent environmental regulations, under certain circumstances, may trigger innovations which lead to innovation offsets that are going to improve firm competitiveness. According to the assumptions on the effect of regulations, the Porter Hypothesis can be split into a “narrow” a “weak” and into a “strong” version (Jaffe and Palmer, 1997). This hypothesis remains controversial in its empirical investigation (see, for instance, Lanoie et al., 2011). Without going into the details of this literature, it is important for us to highlight its content and the fact that this idea challenges the one that regulation may be detrimental on firms’ and countries’ competitiveness, thus encouraging production to be moved to countries with lower environmental standards. This is known as *pollution haven hypothesis*.

<sup>5</sup> Market-based instruments such as taxes on the emissions or tradable permits have indeed stronger impacts on innovations than direct regulation (e.g. Popp et al., 2009).

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