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Green Technologies and Environmental Productivity: A Cross-sectoral Analysis of Direct and Indirect Effects in Italian Regions

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ABSTRACT

This paper provides empirical investigation of the effects of environmental innovations (EIs) on environmental performances, as proxied by the environmental productivity (EP) measure. We focus on sectoral environmental productivity of Italian Regions by exploiting the Regional Accounting Matrix including Environmental Accounts (Regional NAMEA). Patent applications have been extracted by the Patstat Database and assigned to the environmental domain by adopting different international classifications of green technologies: the latest release of the OECD ENV-TECH indicators, and the union of this with the previously established WIPO Green Inventory. Econometric results outline that regions-sectors characterized by higher levels of green technologies (GTs) are those facing better environmental performance. These positive effects directly stem from the introduction of GT in the same sector, as well as from the introduction of GT in vertically related sectors.

1. Introduction

The analysis of the relationship between environmental regulatory frameworks and environmental innovations (EIs) has gained momentum in the last decades, due to the increasing attention towards the reduction of pollutant emissions to increase environmental quality and the need to boost economic performances (Carrión-Flores and Innes, 2010; Carrión-Flores et al., 2013). The Porter hypothesis in its "strong" interpretation is a key reference, as it suggests that the implementation of strict and properly designed environmental regulation has twofold effect, i.e. triggering innovation efforts and stimulating productivity growth that offsets the costs of compliance (Ambec et al., 2013; Porter and van der Linde, 1995).

In this direction, most of the literature has focused on the importance of policy intervention as a determinant of EI (Acemoglu et al., 2012; Fischer and Newell, 2008; Nesta et al., 2014; Popp et al., 2009; Popp, 2002, Popp, 2006 and Popp, 2010) grounded on the assumption that stimulating the generation and/or adoption of these technologies engenders positive effects on economic and environmental performance. This latter, however, has received only limited attention in empirical analyses. Carrión-Flores and Innes (2010) used sectoral environmental performances as a proxy for industry pollution targets to show that the relationship between green policy and innovation is bidirectional. More recent analyses have begun to explicitly estimate the determinants and the effects of environmental performances (Gilli et al., 2014; Costantini et al., 2013b; Cainelli et al., 2013; Ghisetti and Quatraro, 2013; Mazzanti and Zoboli, 2009).

This paper investigates the effects of EIs on pollutant emissions so as to provide a direct and explicit account of a link which is too often hypothesized to be positive rather than proven. Some papers suggest on the contrary that in principle the link might be negative, when a "rebound effect" occurs and it turns technological efficiency gains into changes in actor's behaviours that cancel those gains (van den Bergh et al., 2011; van der Ploeg, 2011). The lack of unambiguous results call for further in this field. This is also confirmed by the recent paper by Barbieri et al. (2016), which highlights the need to overcome a research gap in the literature on EI to enlarge the so far scant understanding of their environmental effects. In this direction, we aim at providing empirical grounds to the desirability of policies aiming at promoting EIs by testing whether they actually improve environmental performance

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or not. We measure environmental performance through an indicator of environmental productivity (EP), as put forth by Repetto (1990), and exploit patent data in green technologies (GTs) as a proxy for EI. We thus investigate the impact of GTs on EP. In so doing, we first test for the existence of a direct effect of GTs on EP. Secondly, we test for the relevance of sectoral spillovers across vertically related sectors, as the generation of GTs is also likely to be stimulated by user-producer dynamics based on the derived demand of polluting agents for cleaner technologies. To test for this link, we implement a synthetic measure of vertical relatedness across sectors based on input-output tables. What we test is whether GTs generated by vertically related sectors affect EP as well.

The cross-sectoral analysis is carried out on a panel of Italian regions observed over the time span 2002–2005, and is based on the matching between regional National Accounting Matrix with Environmental Accounts (henceforth NAMEA) data, patent data and regional economic accounts. The Italian case has recently been the object of increasing attention, due to both the availability of emissions levels data at the regional and sectoral level, and to strong regional heterogeneities in environmental performances attention (e.g. Costantini et al., 2013b; Ghisetti and Quatraro, 2013; Marin and Mazzanti, 2013; Mazzanti and Zoboli, 2009). The economic literature on sectoral emission patterns and "delinking" also supports the appropriateness of a sector-based analysis because of the relevant specific patterns emerged in previous literature (Marin and Mazzanti, 2013; Marin et al., 2012; Mazzanti and Zoboli, 2009; Mazzanti et al., 2008). This paper is closely related to the one published on this Journal by Costantini et al. (2013b). However a number of differences between the two can be found. First, by investigating the determinants of environmental performances we provide a finer grained analysis digging into the differential role of green vs. non-green technologies. Second, our strategy to assign patents to sectors is based on the matching between firm-level data with the Patstat database, instead of the sector-IPC correspondence table (Schmoch et al., 2003). Third, we provide a direct assessment of the impact of GTs on EP through the value chain, by developing a synthetic indicator accounting for the different levels of vertical relatedness amongst sectors. Fourth, we account for spatial dependence in the dependent and the explanatory variables by implementing the Spatial Durbin Model.

The econometric results identify robust patterns of relationship between EI and EP for different classes of emissions. GTs, both those within sector and those of vertically related sectors, exert a positive impact on EP. This would support the hypothesis that improvements in EP are driven by higher propensity to innovate in GTs both within sectors and in vertically related sectors.

The rest of the paper is organized as follows. Section 2 articulates a framework relating EP, EI and GTs at the sectoral and regional level and constructs the working hypotheses. Section 3 outlines the empirical strategy, while Section 4 shows the results of the econometric analyses, and the main robustness checks we implemented. We provide the conclusions and articulate a discussion into Section 5.

2. Regional EP and Green Technologies

A quite large body of empirical literature has investigated the relationships between innovation and productivity at different levels of analysis, moving from the seminal Zvi Griliches' (1979) contribution. Most of the analyses have been carried out at the firm or country level, with special focuses on sectoral comparisons. Regional analyses of the relationship between innovation and productivity have instead appeared only recently (Quatraro, 2009 and 2010; Dettori et al., 2012; Paci and Marrocu, 2013). These works point to the positive effects of innovation on regional productivity growth, even after controlling for region-specific factors and the impact of neighbor regions' performances.

While typically analyses of innovation and productivity use the traditional measure of total factor productivity as a dependent variable, the literature in the field of environmental economics has recently begun to consider a peculiar productivity index, i.e. the environmental productivity (EP), which was originally proposed by Repetto (1990) (Jaffe et al., 1995; Yaisawarng and Klein, 1994; Huppes and Ishikawa, 2005).[1] In this perspective, value added is rescaled by non-marketed inputs and outputs (e.g. air emissions or natural resources). EP represents therefore a measure of environmental performance allowing to appreciating changes in pollutant emissions at different levels of the analysis (Huppes and Ishikawa, 2005). The measurement of EP in empirical works has recently received valuable contributions. Beltrán-Esteve and Picazo-Tadeo (2015) assessed EP trends in the transport industry on 38 countries by employing Data Envelopment Analysis techniques and directional distance functions and by computing Luenberger productivity indicators for decomposing the changes in EP and deriving relevant policy implications. Picazo-Tadeo et al. (2014) proposed an approach to assess intertemporal EP as the outcome of changes in eco-efficiency and environmental technical change, Kortelainen (2008) proposes the construction of an EP index through frontier efficiency techniques and a Malmquist index approach.

Previous empirical studies have focused on the analysis of the determinants of environmental performances, usually measured by the ratio between air emissions and value added, which is nothing but the inverted measure of EP. Due to the difficulty to obtain firm-level data on emissions, these previous contributions have been mostly carried out at the national, sectoral or regional levels and exploited data from environmental hybrid economic-environmental accounting matrixes. When the empirical setting is firm-level, the lack of data on firms' (or plants') emissions have been often overcome by exploiting sectoral data to construct sectoral emission intensity as exogenous variables.

Firm-level analyses have shown for example the existence of a non-linear relationship between environmental and economic performances, both in the Italian and the Mexican contexts (Cainelli et al., 2013; Sanchez-Vargas et al., 2013). Costantini et al. (2013b), carried out a regional and sectoral analysis to test whether environmental performances are affected by both internal innovations (measured by environmental patents) and technological and environmental spillovers from neighbor regions in the Italian context. Ghisetti and Quatraro (2013) focused on the Italian case as well, and found that regional and sectoral environmental performances are likely to trigger EI, as measured by patents in green technologies, also in vertically related sectors. Gilli et al. (2014) adopted instead a measure of environmental productivity (EP) and investigate the role of complementarities of different typologies of innovation in shaping EP at the EU level, by using regionalized data from the "Community Innovation Survey".

The analysis of the effects and determinants of EP emerge as a complement to the analysis of the relationship between differential regulatory frameworks and EI (Brunnermeier and Cohen, 2003; Del Río González, 2009; Popp, 2002, Popp, 2006, Popp, 2010; Porter and van der Linde, 1995). The main rationale behind government intervention to stimulate the generation and/or the adoption of these technologies lies indeed in their expected positive effects on emissions abatement, which should overall improve industrial activities' sustainability. In this perspective, our analysis of the impact of EI on EP aims at providing empirical foundations to those policy instruments aimed at supporting the generation and/or adoption of EIs.

More recently, Costantini et al. (2016) have stressed the importance to account for inter-sectoral linkages when assessing the effects of EI on

[1] Following Kortelainen (2008) it is worth stressing that some authors have defined environmental productivity as a ratio of the environmental sensitive total factor productivity (TFP) index to the traditional total factor productivity index (see e.g. Ball et al., 2004; Managi et al., 2005 and Managi, 2006), which clearly is a different measure.