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Analysis

Innovation complementarity and environmental productivity effects: Reality or delusion? Evidence from the EU

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ABSTRACT

Innovation is a key element behind the achievement of desired environmental and economic performances. Regarding CO_2, mitigation strategies would require cuts in emissions of around 80–90% with respect to 1990 by 2050 in the EU. We investigate whether complementarity, namely integration, between the adoption of environmental innovation measures and other technological and organizational innovations is a factor that has supported reduction in CO_2 emissions per value added, that is environmental productivity. We merge new EU innovation and WIOD data to assess the innovation effects on sector CO_2 performances at a wide EU level. We find that jointly adopting different innovations is not a widespread factor behind increases in environmental productivity. Nevertheless, even though complementarity is not a low hanging fruit, a case where 'innovation complementarity' arises is for manufacturing sectors that integrate eco-innovations with product innovations. One example of this integrated action is a strategy that pursues energy efficiency with product value enhancement. We believe that the lack of integrated innovation adoption behind environmental productivity performance is a signal of the current weaknesses economies face in tackling climate change and green economy challenges. Incremental rather than more radical strategies have predominated so far. The latter have been confined to industrial 'niches', in terms of the number of involved firms. This is probably insufficient when we look at long-term economic and environmental goals.

1. Introduction

The fulfillment of EU strategy goals on emissions and greenhouse targets chiefly depends upon the economic and technological evolution of its industrial sectors. Technological development and composition effects are pillars of sustainability in production since they both counterbalance the growth scale effect as the IPAT (Impact-Population-Affluence-Technology) model shows (York et al., 2003). Long run sustainability targets need to undergo radical changes in the EU economy. The sector's evolution is pivotal to the 'greening' of the economy, since, as the neo Schumpeterian tradition emphasizes, innovation is idiosyncratic at a sector level. Sector and national systems of innovation must both be recognized (Breschi et al., 2000). Various analyses have recently focused on economic and environmental dynamics at a sector level, by placing innovation at the center of their reasoning (Costantini and Crespi, 2008; Costantini and Mazzanti, 2012, 2013; Marin and Mazzanti, 2013).

Environmental innovations are a relevant part of the innovative dynamics that should support the integration of competitiveness and sustainability (Cainelli et al., 2012; De Marchi, 2012; Horbach, 2008; Kemp and Pontoglio, 2011). We here focus on innovation rather than invention given the importance of diffusion and adoption of innovation practices throughout the economy (Costantini and Mazzanti, 2013). Patent data and invention based analyses are nevertheless an important part of the related literature, which we do not address here for reasons of conciseness and space (Costantini and Crespi, 2013; Dechezlepretre et al., 2011; Hafner et al., 2012; Johnstone et al., 2010).

Definitions of eco-innovation (Kemp, 2000) highlight the ecological attributes of new individual processes, products and methods from a technical and ecological perspective (Kemp, 2010). Along these lines, the drivers of EI have been analyzed both inside and outside a firm's boundary, within the institutional and economic features of the territory (Horbach et al., 2012).

Relevant to this paper, various streams of literature within the innovation framework have placed attention on the role of complementarity among innovation practices (Hall et al., 2012; Mancinelli and Mazzanti, 2009; Mohnen and Roller, 2005). Nevertheless, despite some advancement even in the framework of environmental innovation, the complementarity hypothesis has been seldom analyzed, if at all, as a factor behind the achievement of desired economic and environmental performances (Antonioli et al., 2013). Complementarity is a key strategic element of a firm's organizational capabilities. It is also a somewhat irreproducible 'not patented' asset which nevertheless delivers appropriable rents (Dosi et al., 2006).

Building on the theoretical framework of Topkis (1998) and following the approaches of Milgrom and Roberts (1990, 1995), we wish to

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first analyze if there is complementarity between different kinds of innovation (i.e., product innovation, process innovation, environmental innovation) behind the reduction of CO_2 emissions, with a focus on environmental productivity (value added on CO2) as a key indicator. We investigate whether innovation complementarities are evident for the economy as a whole, as well as for sub sector groups, specifically manufacturing, ETS (Emission Trading System) sectors and geographically divided groups (North/South EU, to test whether the innovation gaps present in southern countries might be relevant in environmental terms). We aim to assess if regulated sectors, namely ETS sectors, adopt a greater level of environmental innovation to comply with regulation and are able to use complementarities among different kinds of innovation, following the hypothesis of Porter and Van der Linde (1995). Calel and Dechezleprêtre (2012) have stated that the EU-ETS has actually had effects on the increase in the introduction of environmental innovation, in this case low-carbon innovation; however, in phase one of EU-ETS, process innovation is found to be more likely to occur with respect to product innovation. There is a high level of uncertainty nevertheless on ETS-related inducement of innovation (Borghesi et al., 2012; Cainelli and Mazzanti, 2013).

This attempt is somewhat original given that literature on complementarity has mainly focused on the drivers of innovation rather than its effects. Secondly, as regards performances, apart from few exceptions (Crespi, 2013), the literature about the effects of environmental innovations on economic performance has expanded along the Porter hypothesis (Mohnen and Van Leeuwen, 2013). We here take a specific and original direction by analyzing the recent effects of innovations and their complementarity on environmental productivity, which we here define as economic value on CO_2 (Repetto, 1990). We focus on the EU economy.

To investigate these issues that revolve around the notion of complementarity within innovation practices and its effects on environmental productivity, we merge data from the EU Community Innovation Survey – at the sectoral level (available at EUROSTAT website) – with data on sectoral CO_2 emissions (2009 and 2010) available from the WIOD[1]. We thus merge and exploit new EU sector datasets that cover sector, environmental innovation adoption and emission performances to investigate whether innovation determines better environmental performances. Various econometric techniques are implemented to assess this relationship, taking into account the specific features of ETS sectors, the complementarity among various innovations and the dynamic contents of the innovation–emission relationship at meso level. We first assess the effect of innovations taken alone and their 'integrated' effect with a view to complementarity.

The paper is structured as follows: Section 2 presents a review of the empirical literature about complementarity; Section 3 discusses the complementarity conceptual framework that we adopt and presents main research hypotheses; Section 4 presents the empirical analysis about complementarity, discussing various econometric analyses; Section 5 concludes.

2. Measuring Complementarity: the Relevant Literature

A relationship of complementarity between two activities implemented by a firm exists when the 'doing more' of 'one of them' increases the attractiveness of 'doing more' on the part of the other. Systemic effects arise, "with the whole being more than the sum of the parts" (Roberts, 2006, p. 37). This has obvious implications on firms' strategies, since a firm's efforts should be targeted toward all the complementary activities. In fact, the change of just some choice variables may result ineffective if other complementary variables remain unchanged.

Economic literature essentially distinguishes three methods of measuring complementarity (Galia and Legros, 2004a,b; Mohnen and Roller, 2005). The first examines whether the correlation between two variables is positive and conditioned by other (exogenous) elements. In other words, one establishes whether or not empirical evidence supports the hypothesis of a relationship of complementarity between two variables, while controlling for other parameters, but with a substantial difference compared to simple correlations which do not provide any information about potential complementarity (Arora and Gambardella, 1990; Ichniowski et al., 1997). The "advantage" of this method can be found in the fact that it does not specify an objective reference variable in the analysis of complementarity (e.g. productivity). Rather, it focuses on the variables being examined for complementarity, which can be defined as the "dependents" in the model (Galia and Legros, 2004b). The other two approaches in contrast treat variables which are potentially part of a relationship of complementarity as explanatory variables in an empirical model where the dependent variable is usually a performance variable (productivity, profitability, innovation).

The second approach (*the reduced form approach*) analyzed by Arora (1996) is based on the notion that if an activity of the firm has an effect on any given objective variable, it will not be correlated to another activity unless these activities are complementary. Analysis of complementarity is essentially founded on an analysis of interaction/correlation between two factors, in relation to any chosen dependent variable in the empirical model. The limit here is on the focus placed on only two potentially complementary variables, as Arora (1996) and Athey and Stern (1998) have highlighted. These limits lead us to the third approach, which we can consider as more general in nature.

Defined in literature as the *productivity approach*, the third approach resembles the last and is based on the identification of an objective variable defined as dependent in the regression model, with an explanatory vector which could contain discrete or continuous variables of interest, their interactions of complementarity defined in different terms, and other external control factors. Especially when dealing with discrete variables, this approach reveals to be flexible, general, and relatively simple, even when more than two activities of the firm are being analyzed. Inside this third, most prevalent approach, developments in empirical multivariate analysis can be broken down into two basic trends in application. The first and most diffuse technique verifies complementarity by testing the significance of interaction variables created from factors of research interest, controlling for exogenous factors and possibly omitted variables[2]. The second technique, on the other hand, requires either structurally discrete variables, or variables empirically proven to be discrete, or a dichotomization of continuous variables. Discrete variables of interest allow for the identification of a finite series of combinations, which, in other words, indicate different states of the world. These states of the world are either attributable to cases of complementarity (presence or absence of all factors) or to cases of substitutability (other states, with at least one factor missing). The goal is to examine whether the impact on the performance of cases of complementarity surpasses, or at least is equal to, the effect of substitutable states. The added value of the second analytical practice is in its higher degree of flexibility, even if it lies within a statistical context of increased complexity as regards testing for complementarity, since it involves examination of the vectors of two, three or even more elements of interest.

All three approaches outlined above can be attributed to conceptual schemes that are modular in nature, where the organization or system analyzed can be broken down into explanatory factors and exogenous elements/parameters.

Concerning the framework of discrete analyses within the more recently developed *productivity approach*, we cite the contributions of Galia and Legros (2004a), Mohnen and Roller (2005), and Carree et al. (2011) as the most representative.

[1] World Input Output Dataset, stemming from the WIOD EU project funded under the Seventh Framework Programme FP7. It is a sector based economic environmental accounting dataset.

[2] For a close examination of problems related to the estimation of these reduced forms, see the contributions of Arora (1996) and Carree et al. (2011).