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Summary

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Keywords: Complementarity, Innovation, Climate Change, Sector Performance

JEL Classification: O, Q

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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. 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 CIS and WIOD meso level 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 significant factor to increase environmental productivity, neither for the entire economy nor for manufacturing or narrower ETS sectors. The only case where a complementarity arises is for Northern EU manufacturing sectors that integrate eco innovations with product and process innovations to support environmental productivity. 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; this is probably insufficient when we look at long-term economic and environmental goals.

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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 model shows (York e 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 nationals 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 Mazzanti, 2013; 2012; Marin and Mazzanti, 2013; Costantini and Crespi, 2008).
Environmental innovations are a relevant part of the innovative dynamics that should support the integration of competitiveness and sustainability (Cainelli et al., 2012; Kemp and Pontoglio, 2011; De Marchi, 2012; Horbach, 2008). 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; Johnstone et al., 2010; Hafner et al., 2011; Dechelezpretre et al., 2011).
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 analysed 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 (Mohnen and Roller, 2005; Mancinelli and Mazzanti, 2009; Hall et al., 2012). 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 (1989,1995) we wish to first analyse 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 as a key indicator (value added on CO2). We investigate whether innovation complementarities are evident for the economy as a whole, as well as for sub sector groups, specifically manufacturing, ETS 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 Dechezlepretre (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, a part from few exceptions (Crespi, 2013), the literature about the effects of environmental innovations on economic performance has expanded along the Porter hypothesis (Mohnen and von Leuwenenen, 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 studies and its effects on environmental productivity, we merge data from the EU Community Innovation Survey - at the sectoral level (available at EUROSTAT website[1]) - with data on sectoral CO2 emissions (2009 and 2010)

[1] Community Innovation Survey (CIS) are a series of surveys produced by the national statistical offices of the 27 European Union member states, also covering the European Free Trade Association countries and the EU candidate

available from the WIOD[2]. We thus merge and exploit new EU sector datasets that cover sector, environmental innovation adoption and emission performances to investigate whether innovation – possibly induced by polices – 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 discusses the complementarity theory that we adopt and presents main research hypotheses; section 3 comments on the data; section 4 presents various econometric analyses; section 5 concludes.

2. Environmental productivity and complementarity among innovations: concepts and methods.

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.

Since Mohnen and Roller's (2005) seminal applied work devoted to testing empirical evidence for complementarities in national innovation policies, a great deal of economic literature has revolved around empirical analysis in order to test complementarities in firms' innovation practices[3]. Firms' innovation activity is a complex outcome deriving from the influence of many factors that are interrelated through complementary relationships which might give rise to systemic effects.

Remaining within the innovation sphere, we believe that deepening the empirical analysis of complementarity among different firms' innovation practices is particularly relevant when environmental innovations are involved, especially in the increasing need to adopt integrated and more complex green strategies and not only "end of pipe" technologies.

This consideration strictly descends from the definition of Environmental Innovation itself. In the MEI (Measuring EI) research project (Kemp and Pearson, 2007), EI is defined as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) compared to relevant alternatives"[4] (Kemp, 2010, p.2).

The definition of EI is not limited to specific technologies; it also includes new organisational methods, products, services and knowledge-oriented innovations[5].

The importance of adopting integrated strategies for innovation is particularly relevant in complex firms' technologies such as those pertaining to CO_2 abatement, compared to cuts in emissions such as SOx – NOx (Cainelli et al., 2013; Marin and Mazzanti, 2013). The latter might occur through end of pipe technologies while CO_2 abatement depends upon a radical change in the energy – technological framework. Various

countries. The CIS (2006-2008) collects data on environmental innovation for the first time. Though it is a cross section dataset, it captures a 3 years' time span of EI and is the first CIS survey that has included EI at EU level ever. Community Innovation statistics based data are the main data source for measuring innovation in Europe and are used in academic research as in Horbach et al. (2012) among others who exploit data for Germany.

[2] World Input Output Dataset, stemming from the WIOD FP7 project. It is a sector based economic environmental accounting dataset.

[3] Among others, see Bocquet et al. (2007), Cozzarin and Percival (2006, 2008), Gomez and Vargas (2009), Schmiedeberg (2008).

[4] Results of the MEI project can be found at http://www.merit.unu.edu/MEI/.

[5] The importance of deepening analysis of the relationship between EI and other innovation practices has already been stressed in Antonioli, Mancinelli, Mazzanti (2013).

internal and external drivers (Horbach et al., 2012) are relevant in triggering decarbonisation. The costly process of business decarbonisation might be mitigated by the occurrence of complementarity, which, for example, generates increasing returns to scale.
We are particularly interested in analysing the relationship between firms' environmental performance and different innovation practices, including environmental, process, product and organizational innovations. More specifically, the agent of our analysis is not the firm, but the sector, for two reasons: The first resides in the availability of data (which is sectorial); the second is that the meso level is the level in which we can fully understand how specific innovation, environmental and economic performances behave and interact (Costantini and Mazzanti, 2013).

In the present specific case, we assume that there is a finite set of economic sectors, indexed by $j = 1,..,J$. In each sector there are a large number of atomistic identical firms; we can therefore assume that each sector features one representative firm.
We consider the environmental performance of sector *j* (EP_j) as the sector's objective function and we focus on two innovation practices that can affect the sector's *EP* function. One of the two innovation practices is Environmental Innovation (*EI*) and the other one is either the product, or process or organizational innovation itself (*PI*)[6].

(1) $$EP_j = EP_j(EI, PI, \theta_j) \qquad \forall j$$

The problem with sector *j* resides in choosing a combination of innovation practices, $(EI, PI) \in I$, which maximize its *EI* function. θ_j represents the sector's exogenous parameters (such as sector-specific environmental policies, or sector's geographical locations).
We are particularly interested in analysing whether a relationship of complementarity exists between *EI* and *PI*.
Since innovation practices are typically investigated in discrete settings (e.g. adopting or not, adopting at an intensity higher than the average, etc..), we study complementarity between these forms of actions through the properties of supermodular functions. Following Topkis (1995, 1998), Milgrom and Roberts (1990, 1995), and Milgrom and Shannon (1994), we state that the two variables x' and x'' in a *lattice*[7] X are complements if a real-valued function $F(x', x'')$ on the *lattice* X is supermodular in its arguments, that is, if and only if:

(2) $$F(x' \vee x'') + F(x' \wedge x'') \geq F(x') + F(x'') \qquad \forall x', x'' \in X.$$

Or, expressed differently:

(3) $$F(x' \vee x'') - F(x') \geq F(x'') - F(x' \wedge x'') \qquad \forall x', x'' \in X,$$

[6] The relationship of complementarity may involve more than two variables simultaneously through a chain reaction that starts from a complementarity relationship between two variables and in turn involves a complementarity relationship between one of the two variables and a third variable and so on.

[7] More specifically, "a *lattice* $(X, \geq)$ is a set X, with a partial order $\geq$, such that for any $x', x'' \in X$ the set X also contains a smallest element under the order that is larger than both x' and x'' ($x' \vee x''$) and the largest element under the order that is smaller than both ($x' \wedge x''$)" (Milgrom and Roberts, 1995, p. 181).

That is, the change in F from x' (or x'') to the maximum $(x' \vee x'')$ is greater than the change in F from the minimum $x' \wedge x''$ to x'' (or x'): raising one of the variables raises the value of increase in the second variable as well[8].

This technical approach has the benefit of focussing on a purely economic analysis, without the need to dwell on more mathematical issues, such as particular functional forms that ensure the existence of interior optima. For example, no divisibility or concavity assumptions are needed, so that increasing returns are easily encompassed.

In our specific case, complementarity between the two different innovation practices may be analysed by testing whether $EP_j = EP_j(EI, PI, \theta_j)$ is supermodular in *EI* and *PI*. Since each sector is characterized by specific exogenous parameters (θ_j), even if the maximization problem is the same for all the sectors, the *EP* function may result supermodular in *EI* and *PI* for some sectors but not for others.

In our empirical analysis, the sector's environmental performance that we want to test is related to an index of environmental productivity. More specifically, in agreement with Repetto's (1990) definition of a "single factor measure of environmental productivity" (Repetto, 1990, p. 36)[9], we consider each sector's value added per unit of CO_2 emissions. Obviously, the less the sector's CO_2 emission is with respect to its value added, the better its environmental performance, and the higher its environmental productivity (EP_j). Environmental innovations (*EI*) that reduce environmental damages of course contribute to environmental productivity. What we want to verify is if *EI* is complementary to other innovation practices (either product, process, or organizational) when the sector's objective function is its environmental productivity.

Our aim is to derive a set of inequalities (such as those explicated in equations (2) and (3)), that are tested in the empirical analysis.

If a sector chooses not to adopt either of the two practices in its *EP* maximizing problem, namely $EI = 0, PI = 0$, the element of the set *I* is $EI \wedge PI = \{00\}$. If a sector chooses to adopt both practices, we have $EI = 1, PI = 1$ and the element of the set *I* is $EI \vee PI = \{11\}$. Including mixed cases as well, we have four elements in set *I* that form a lattice: $I = \{\{00\}, \{01\}, \{10\}, \{11\}\}$.

From the above we can assert that *EI* and *PI* are complements and hence that the function EP_j is supermodular, if and only if:

(4) $$EP_j(11, \theta_j) + EP_j(00, \theta_j) \geq EP_j(10, \theta_j) + EP_j(01, \theta_j),$$

or:

(5) $$EP_j(11, \theta_j) - EP_j(00, \theta_j) \geq \left[EP_j(10, \theta_j) - EP_j(00, \theta_j)\right] + \left[EP_j(01, \theta_j) - EP_j(00, \theta_j)\right]$$

That is to say, the changes in the Environmental Productivity of sector *j* that are brought about when both Environmental Innovation and process/product/organizational innovations increase together are more than the changes resulting from the sum of the separate increases of the two kinds of innovations. Specifically,

8 From equations (1) and (2) it is evident that complementarity is symmetric: increasing x' raises the value of increases in *x''*. Likewise, increasing *x''* raises the value of increases in *x'*.

9 For extensive discussion on environmental productivity measures and their conceptual background we refer to Mazzanti and Zoboli (2009). Here we simply remark that the IPAT framework and its 'statistical' counterpart (STIRPAT) are a general conceptual umbrella (York *et al.*, 2003) to study the economic and innovation determinants of environmental performances.

increases in *EP* due to an increase of both *EI* and *PI* from $\{00\}$ to $\{11\}$ are greater (or at least equal) than the sum of increases in *EP* due to separate increases of *EI* and *PI* from $\{00\}$ to $\{10\}$ $(\{01\})$.

To sum up, complementarity between the two decision variables (*EI* and *PI)* exists if the EP_j function is shown to be supermodular in these two variables and this happens when either inequality (4) or inequality (5), or other derived inequalities are satisfied.

As mentioned above, different sectors' exogenous parameters (θ_j) may imply different degrees of complementarity between the two innovation practices (EI_j and PI_j).

In our specific analysis, we are particularly interested in verifying whether the different sector and geographical specificity and also the strength of environmental regulations to which sectors are exposed may play a role in the exploitation of complementarity relationships between environmental innovations and other innovation practices[10]. We will then narrow the analysis to some sub sectors of the economy and geographical areas. As regards policy, we assess whether a joint implementation of EI/PI strategies can improve environmental productivity especially when situations of more stringent environmental regulations are present. We will focus on ETS sectors in some specific analyses[11]. More stringent environmental standards may indeed foster firms' adoption of training and organisational innovation, which in turn could lead to further environmental innovation. The conceptual framework refers somewhat to the Porter idea of competitive firm advantages that reside in the firm value chain, within which 'strategy is manifested in the way activities are *configured* and *linked together'* (Porter, 2010).

On the other hand, we wonder if sectors less exposed to environmental regulations and hence, following the PH, less stimulated to adopt EIs, could find it the externalisation of some innovation practices more convenient. This kind of behaviour could even lead to a crowding out effect in relation to some of the innovation strategies under scrutiny and hence to substitutability[12] among them.

Building upon the aforementioned discussion, we can thus set out two main research hypotheses:

[H1]. Complementarity between environmental innovations aimed at abating CO_2 and product, process, and organisational innovation is crucial to increasing environmental productivity, namely value added per emitted CO_2.

[H2]. Manufacturing and narrower ETS sectors such as ceramics, metallurgy and paper cardboard might present more evident signs of innovation complementarity than non-ETS sectors, since they are pressed to find more radical solutions in order to remain both competitive and sustainable by regulatory tools that put a price on carbon.

These H1 and H2 have also been tested by focussing on different geographical areas of the EU. The main reason is that northern EU is an area where carbon pricing and climate change policies are historically more stringent (Johnstone et al., 2010; Mazzanti and Musolesi, 2013). Geography additionally introduces policy issues in the analysis.

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[10] A few examples of stringent environmental standards are: the EU 2003 Directive on emission trading; the 2008 Directive IPPC on emission abatement and environmental technology together with its 2010 revision; the EU Waste Packaging Directives of 1994 and 2003.

[11] The EU Emission Trading System (ETS), which followed a proposal for a Directive that had been discussed since 2001, was launched by the related 2003 EU ETS Directive. It is currently the major EU policy aimed towards achieving Kyoto and EU 2020 targets. It allocates tradable CO_2 permits to firms in sectors such as metallurgy, ceramics, paper and cardboard, chemical, coke and refinery, as far as manufacturing is concerned. The innovation effects of (the EU) ETS (Ellerman et al., 2010), though having been extensively analysed and compared to other environmental policies at the theoretical level, so far have not found consolidated empirical testing.

[12] A substitutability relationship exists if: $EP_j(11,\theta_j) - EP_j(00,\theta_j) \leq [EP_j(10,\theta_j) - EP_j(00,\theta_j)] + [EP_j(01,\theta_j) - EP_j(00,\theta_j)]$, that is, the changes in the sector's environmental productivity when both forms of innovation practices (*EI* and *PI*) are increased together are less than the changes resulting from the sum of the separate increases of the two kinds of practice.

3. The data

The data used in this analysis comes from three different sources; the first of these is data on innovation practices (eco-innovation[13], organizational innovation, product and process innovation) as well as data on ICT adoption are from the sixth Community Innovation Survey (CIS)[14], whose sectoral level is available on EUROSTAT website. The Community Innovation Survey is a series of surveys produced by the national statistical offices of the 27 European Union member states, also covering the European Free Trade Association countries and the EU candidate countries. The surveys have been implemented since 1993, on a biannual basis and are designed to obtain information on the innovation activities of enterprises, including various aspects of the innovation process, such as innovation effects, cost and sources of information used. Data is collected at the micro level, using a standardized questionnaire developed in cooperation with the EU Member States to ensure comparability across countries. The sixth CIS (2006-2008) collects data on environmental innovation for the first time[15]. Though it is a cross section dataset, it captures a 3-year time span of EI and is the first CIS survey ever to include EI at the EU level . Community Innovation statistics-based data is the main data source for measuring innovation in Europe and is used in academic research as in Horbach et al. (2012) and Borghesi et al. (2012), and Veugelers (2012), which exploit data for Germany, Italy, Belgium, respectively.
The second source of data is the World Input Output Database (WIOD), which results from a European Commission funded project as part of the seventh Framework Programme and was developed to analyse the effects of globalization on socio-economic variables and trade, in a wide range of countries (the 27 EU Member States and other 13 major countries in the world, from 1995 to 2009). The WIOD is made up of four different accounts (World Tables, National Tables, Socio Economic Accounts and Environmental Accounts). For the purpose of this work, we used the *Socio-Economic and Environmental Accounts*, both providing a wide range of economic variables such as value added, employment and CO2 emissions.
Table 1 below shows summary statistics and gives a description of the variables considered in this analysis. Building on the concept of environmental productivity (Repetto, 1990) the dependent variables VA/CO2_09 and VA/CO2_10 are obtained as the ratio between sectorial value added and sectorial CO2 emission in 2009 and 2010 respectively. We note that VA/CO2 is higher in 2010. This means, taking into account the GDP collapse in 2009, that the GDP increase in 2010 was lower overall than the related CO2 emission increase (with respect to 2009).
Innovation practice indicators, originally presented by Eurostat as the share of firms introducing innovation per sector have been dichotomized to obtain an innovation adoption indicator; to compute the binary variable, we compared the country's sectorial value to the average CIS sample sectorial value[16]: if the country value is above the CIS sample average, adoption indicator value is 1 and 0 otherwise; however, since the average is sensible to outliers, to test if our empirical analysis was robust, we computed the innovation indicator also using the median value and the third quartile value (i.e., 25% more innovative firms) for dichotomization. Notwithstanding this, we did not obtain substantially different results.
We also created four sectorial dummies beyond the innovation adoption indicators, namely *manuf*, *utility*, *other* and *ETS*, and two geographical dummies (*EU_NC* for northern Europe; *EU_SUD* for southern Europe) in order to control for differences within the European area.

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[13] We only consider CO2 abatement innovation for the purpose of this work. In the CIS-VI eco-innovation module, a first set of questions asks respondents if they have introduced an innovation with one or more environmental benefits (ECO). Six types of environmental benefits are listed that can occur during the enterprise's use of the innovation(ECOOWN): lower use of materials (ECOMAT), lower energy use (ECOEN), lower CO2 emissions (ECOCO), less use of pollutants (ECOPOL), less soil, water, air or noise pollution (ECOSUB), recycling (ECOREC).

[14] http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis. Data is available at http://epp.eurostat.ec.europa.eu/portal/page/portal/science_technology_innovation/data/database.

[15] Information taken from the Eurostat website (http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis).

[16] The CIS sectorial average for each country is adjusted by omitting the country sectorial value when making the comparison. For example, for the manufacturing sector in Italy we compared the Italian manufacturing value to the CIS manufacturing value computed without Italy.

[table 1 here]

In order to test for complementarity, we used the dichotomised innovation practice indicators to create four states of the world for each joint adoption of innovation. For example, concerning the introduction of both eco-innovation and organisational innovation (see Tab. 2 below) we obtained an index for joint adoption (*EI/IO (11)*), two indexes for the adoption of only one of the practices (*EI/OI (10)* stands for EI adoption only; *EI/IO (10)* stands for organizational innovation adoption only) and, finally we obtained the index *EI/OI (00)* when none of the practices were introduced.
The following tables from 2 to 4 show the distribution of the states of the world for the adoption of EI and organisational innovation, and product and process innovation respectively.

[tables 2-3-4 here]

4. Econometric evidence: complementarity analyses

The empirical model we rely upon is a cross section framed regression wherein the dependent variable ‘environmental productivity’ (VA/CO_2 in 2009 or 2010) is diachronic with respect to lagged innovation adoption (2006-2008). This rules out the simultaneity between innovation and productivity which might generate flaws at empirical level.

The regression we test is:

$$(6) \quad VA/CO_{2t} = \beta_0 + \beta_1 vaemp_{2008} + \beta_2 ICT_{2008} + \\ + \beta_3 EIPI_{11\,2008} + \beta_4 EIPI_{10\,2008} + \beta_5 EIPI_{01\,2008} + \beta_6 EIPI_{00\,2008} + \varepsilon_t$$

Where t refers to 2009 and 2010 respectively while PI represents innovation practices other than ecoinnovation (i.e., product innovation or process innovation or organisational innovation, respectively). Labour productivity (vaemp) and ICT are picked in 2008, while innovation practices from CIS-VI cover the three years between 2006 and 2008 (see Tab. 1 for a short description of the variables).
The inclusion of labour productivity as a main covariate follows Mazzanti and Zoboli (2009) and aims at capturing sector heterogeneity and general heterogeneity in economic conditions. ICT investments are included to further control for a ‘new economy’ factor that can absorb relevant cross section heterogeneity. The four factors finally introduce the states of the world for which EI and other ‘innovations’ are both present (11), neither are adopted (00), or they are adopted in isolation of each other (10, 01). We use OLS as an estimation procedure and we correct for heteroskedasticity in usual fashion. The parsimonious regression aims to mitigate collinearity (see the appendix for correlations). Since labour productivity and ICT are not correlated – this recalls the ‘Solow productivity paradox’ – we can insert both as main factors. Heterogeneity is further controlled by geographical dummies such as EU North, South, East and West. For the sake of brevity in tables 5-15 we present the set of complementarity tests. Full regressions are available upon request[17].

[17] Beyond complementarity evidence we comment on, we find that labour productivity is strongly significant and positive in its effects in many cases, except for ETS sectors in Northern Europe. In particular we highlight the case of ETS sectors where labor productivity is significant for the joint adoption of EI and all the other innovation practices; the same happens to Northern European countries. All regressions are available upon request. Data are available for replication.

Tables 5-15 below summarise the main evidence we find with respect to the existence of complementarity between EI and techno-organisational innovation adoption. The null hypothesis we test (we recall H1 and H2) is the absence of pair-wise complementarity between innovation adoption to reduce CO2, and other types of techno-organisational innovation[18].
Tables 5-7 present tests for the EU as a whole. Though in two cases the Wald tests present higher values (all sectors and the case of EI/process innovation; manufacturing and the case of EI/product innovations) the null nevertheless cannot be rejected. Complementarity (and substitutability, in case of significant negative inequality) does not characterise the adoption of EI and other techno-organisational innovations in the EU. Evidence is clear and does not support the idea that complementarity is behind CO2 cuts by sectors. ETS sectors are also not using radical innovation strategies to cut CO_2, as recent analyses suggest from other empirical perspectives (Borghesi et al., 2012; Rogge et al., 2011, Rogge and Hoffman, 2010). Tables 8-10 add some sort of sensitivity analysis by using an alternative method to construct the set of binary variables that are needed to set the complementarity test (namely to create the states of the world)[19]. The highest value we find is for the pair EI-product innovation (the ETS sectors in 2010). Nevertheless, the test value does not reach a minimum threshold of 10% significance. The pair EI-product innovation is of interest, because it possibly represents the most radical and effective strategic movement towards environmental productivity increases, given that on the one hand EI are primarily aimed at cutting CO_2, while product innovation generally delivers the highest output in terms of value added creation (e.g. investing in new special steel production of high international market value while rearranging environmental technology for this production to abate emissions, an example that is coherent with anecdotal evidence for Scandinavian countries, for example)[20].

Tables 11-13 sketch the evidence for Northern countries alone (we include The Netherlands, Belgium, Germany, France, Sweden and Finland on the basis of data availability[21]). It is well-known that innovative and environmental performances of the EU North are on average different (see Figures 1-2. Updated evidence and comments on EU heterogeneity in terms of EI innovation adoption are found in Gilli et al., 2013). Historically speaking, some northern EU countries promptly reacted to the second oil shocks by innovation and energy mix reshuffling. This socio-economic and policy 'reaction' has brought about different CO_2 trends between areas (Mazzanti and Musolesi, 2013). Thus, complementarity in relation to innovations might also be a factor that presents different features in various parts of the EU. We find, in fact, that the only cases where complementarity shows up, that is when the null of no complementarity is rejected,

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[18] Wald tests are frequently used to test if a given set of parameters is statistically significant. In our case we test the following specification:

$$\beta_{EI\_PI\_11} + \beta_{EI\_PI\_00} = \beta_{EI\_PI\_10} + \beta_{EI\_PI\_01}$$

that is, if the sum of coefficients related to the joint adoption of EI and one of the other innovation practices (PI) and the adoption of none of them is statistically different from the sum that relates to the estimated coefficients of the introduction of EI only and PI only. Rearranging the null hypothesis is:

$$H_0:\ \beta_{EI\_PI\_11} - \beta_{EI\_PI\_10} - \beta_{EI\_PI\_01} + \beta_{EI\_PI\_00} = 0$$

If the null is rejected, the difference between the sum of the coefficients is statistically significant thus complementarity between EI and other innovation practices is present; on the contrary if the null is not rejected, coefficients are not statistically different from each other, thus no complementarity characterizes the analysed innovations.
To assess if the coefficients imply supermodularity or submodularity we need to determine the sign of the linear combination among the coefficients; if this is positive the function is supermodular or submodular if negative.

[19] Results are robust to the variation of the method we adopt to 'dichotomise' the innovation variable in order to set the 4 states of the world. 4 main options are considered: mean, median, first quartile and a specific mean, where we take the difference between country sectorial values and the EU sector average value calculated without that country.
[20] In this paper we are not explicitly covering the role of policies behind innovation adoption and emissions cuts. We capture policy heterogeneity by country dummies and geographically/sector oriented analysis. The inclusion of specific policy factors is scope for further research.
[21] We exploit the EUROSTAT CIS. As examples, Spain and the UK as well did not implement the EI part of the CIS5 questionnaire, which was not compulsory.

is for the pairs EI-product innovation (both 2009 and 2010) in manufacturing (first quartile dichotomisation generates similar outcomes), and EI-process innovations in 2009.

We highlight two facts: First, even in the depth of recession, technology complementarity supported relatively better integrated economic-environmental performances. Then, at the dawn of the timid economic restart in 2010, complementarity between EI and product innovations – of potential high value given its cuts to emissions and generation of spaces of high value added export in international markets – characterises the EU North.

The core manufacturing heart of Europe thus beats in a more innovative way. Heavy but competitive sectors in the North respond with higher environmental and economic performances. We cannot assess whether this is a pillar of future EU sustainability. It depends upon whether technology is able to compensate for scale effects. We stress that within the technological domain, how innovations are tied to each other and 'organised' in their integrated design might matter. We note that it can affect European socio economic sustainability if economic dynamics – which correlate to environmental performances to a large extent – diverged 'too much' between EU south and EU north. This is possibly the key problem of EU integration at the moment. The path to a greener economy, which is engraved in current EU policies and targets, is a chance to mitigate divergences. We point out the risk that the path towards a greener economy might widen divergences further on[22].

The somewhat gloomy outcome we present, if one thinks of the potential core role of innovation (complementarity) in achieving goals of sustainability and competitiveness, is nevertheless coherent with related evidence on innovation dynamics taking place in the EU before and after the down turn. First, recent studies by the EEA (2013b) shows that the EU's decrease in emissions has been driven more by a changing composition of the economy than by the role of technology. If on the one hand Eco Innovations characterise around 45% of EU firms as the EU Horizon plan declares; complementarity among various (EI) innovation practices is confined to very specific elements and pairs according to Regional evidence on the other (Antonioli et al., 2013).

Secondly, within the debate that analyses the links between the crisis and its innovation and economic effects, Filippetti and Archibugi (2011) use the EU Innovation scoreboard dataset to analyse the effect of the crisis on EU innovation performances, finding that the downturn has strongly negatively affected caching up in eastern areas, and concluding: "We have also seen that the countries that were relatively less affected are those with a stronger National systems of innovation. Switzerland, Sweden, Finland, Germany and Austria will emerge from this crisis with a relatively stronger innovative capacity, while the United Kingdom and France, and to a larger extent, the Southern European countries, are likely to lose additional relative positions. Within a perspective of increasing integration, this calls for a stronger and cooperative innovation policy at the European level not only in good times but especially in bad times" (p.189)[23]. National systems of innovation emerge as relevant, namely the northern EU model that has its roots in a strong support to (green) innovations and a huge surplus in its current accounts (Costantini and Mazzanti, 2012). This is a winning model if we look at the economic-environmental performances of northern EU countries. We note that it has also created divergent gaps between southern and northern areas. Whether it is true that southern countries own a large share of responsibility for not having increased their investments in innovation and strengthened their environmental policy commitment in the last 15 years, this divergence of economic (and environmental) performances runs the risk of tearing the different parts of the EU apart. More investments in innovation and strengthening of environmental policy in the south, and more (public) investments in the north to support aggregate demand would help rebalance the macroeconomic economic-environmental equilibrium of the EU.

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[22] Tables 14-15 further illustrate how the values of the tests for southern Europe (Cyprus, Malta, Italy and Portugal) are dramatically different, which denotes a general lower degree of complementarity of firms and sectors in the laggard countries (in terms of economic, environmental and innovation dynamics).
All above-mentioned results are confirmed when using the median instead of the mean to create the set of binary variables (evidence as well as the dataset for replication available upon request).

[23] Linking our evidence to the commented paper, one should be pessimistic about the future scenario. In fact, our innovation impacts relate to the pre-crisis innovation diffusion. If that diffusion further benefits the northern EU after the downturn, given different 'innovation' and institutional reactions, we should expect additional divergences in the value added/CO_2 performance in the current decade. In absence of new data, for the time being even if one only considers factors at an anecdotal level , this scenario seems likely to happen (EEA, 2013a).

[Tables 5-15 here]

5. Conclusions

The paper adds new insight on the effects of innovation on environmental productivity by exploring original EU sector data through the lens of complementarity theory, which is a consolidated technique used to study the drivers of innovation. Complementarity among innovation practices points to relatively radical ways of tackling the challenge of cutting CO_2 and creating economic value, since it entails both an investment in diverse practices and a full reorganization of firm strategy. The hypothesis is that though the implementation of more innovations occurs at a higher cost – tangible and intangible – the consequential outcome, which is driven by increasing returns to scale and redesign of the organization, might bring about higher performances. Complementarity is an intangible asset in which to invest resources. Moreover, environmental innovations are in that 'complementarity' context which is implicitly of a more radical nature, since they are not adopted in isolation, as well-known end of pipe technologies often are. The existence of complementarity thus highlights somewhat radical ways of managing innovations. These are needed to tackle climate change mitigation, for which end of pipe solutions are rather useless.

Complementarity is not a delusion, but it is a rare fact in the real world of innovation adoption. It is rare because even if it potentially brings about value in terms of asset specificity and rent capture by creation of 'irreproducible' assets, it entails a full and costly 'techno-organizational redesign'.

We do find that complementarity is not characterising the EU economy for what concerns the 'use' of EI as a driver of CO_2 reduction. Investing in EI and other techno-organisational practices has not led to environmental productivity improvements. Evidence does not change when narrowing down on manufacturing and ETS sectors that are subject to stricter regulations. The outcome is robust to diverse specifications of the underlying variables we use to frame the 'complementarity setting'. Results are similar for what concerns environmental productivity in 2009 and 2010: innovation actions that took place before 'the crisis' (2006-2008) have not produced significant effects on economic-environmental performances.

The only case where a complementarity arises is for northern EU manufacturing sectors that seem to coherently integrate eco and product innovations to support sustainability and competitiveness. We do believe that the lack of integrated innovation adoption behind environmental productivity performance is a signal of the current weaknesses economies face in tackling green economy challenges. Incremental rather than more radical strategies have so far predominated. This is probably not sufficient when we look at long run economic and environmental goals. The specific EU case study also shows risks of further divergence in both economic and environmental performances between innovative northern countries and southern EU laggards.

Environmental and innovation policies might introduce the notion of complementarity more explicitly in funding and regulatory schemes.

Though the period under consideration has specific features in of itself and innovations could take more time to exert their effects, this is a possible proof that the mild decrease in GHG emissions the EU has experienced hugely depends upon incremental innovations, which are in addition not integrated among themselves in a significant goal-oriented way. The lack of integration documents the non-radicalness of the innovation strategy that economic sectors have pursued so far, at least on average. As additional support to this statement, only when interacting do EI and technological process innovation statistical tests on complementarity move up, though never reaching a full significance. Further research might extend the analysis to firm level assessment of innovation effects on emissions. It is also worth considering the future exploitation of new CIS waves and even more detailed sector data.

Tab. 1 Description of variables (* dependent variable)

	Observations	***Mean***	***Description***
VA/CO2_09 *	496	23.766	Environmental productivity in 2009
VA/CO2_10 *	496	21.970	Environmental productivity in 2010
EI	528	0.271	Adoption of environmental innovation for CO2 abatement
Inno_org	528	0.436	Adoption of organizational innovation
Inno_prod	528	0.101	Adoption of product innovation
Inno_proc	528	0.125	Adoption of process innovation
Emp08	431	11,325 2	Number of employees per sector
Vaemp	500	84.589	Labor productivity
ICT	379	0.172	Percentage of adoption of information and communication technology
Manuf	528	0.542	Manufacturing sector dummy
Utility	528	0.042	Utility sector dummy
Other	528	0.3333	Other services sector dummy
ETS	528	0.25	ETS sectors dummy
EU_NC	528	0.227	Northern Europe dummy (Belgium, Germany, Netherlands, Finland, Sweden and France)
EU_SUD	528	0.182	Southern Europe dummy (Cyprus, Malta, Italy and Portugal)

In order to test for complementarity, we used the dichotomised innovation practices indicators to create four states of the world for each joint adoption of innovation. For example, concerning the introduction of both ecoinnovation and organisational innovation (see Tab. 2 below) we obtained an index for the joint adoption (*EI/IO (11)*), two indexes for the adoption of only one of the practice (*EI/OI (10)* stands for EI adoption only; *EI/IO (10)* stands for organizational innovation adoption only) and finally we get the index *EI/OI (00)* when none practices were introduced.
The following tables from 2 to 4 show the distribution of the states of the world for the adoption of EI and organisational innovation and product and process innovation respectively.

Tab. 2 EI and Organisational Innovation (OI), states of the world

	EI/OI (11)	EI/OI (10)	EI/OI (01)	EI/OI (00)
Mining and quarring	3.91%	7.14%	3.61%	3.55%
Manufacturing	5.47%	4.29%	4.82%	5.67%
Food, beverage and tobacco	3.13%	8.57%	7.23%	3.55%
Textile and leather	4.69%	4.29%	4.82%	4.96%
Wood products	4.69%	5.71%	6.02%	3.55%
Paper products	6.25%	0.00%	3.61%	4.96%
Coke and petroleum	0.78%	4.29%	4.82%	2.13%
Chemical	4.69%	2.86%	6.02%	4.26%
Rubber and plastic	5.47%	2.86%	6.02%	4.26%
Non metallic mineral products	5.47%	5.71%	4.82%	4.96%
Metal and fabricated metal products	4.69%	5.71%	4.82%	5.67%
Computer and electrical equipment	4.69%	4.29%	6.02%	4.96%
Machinery and equipment	4.69%	4.29%	3.61%	6.38%
Motor vehicles and transport equipment	3.91%	2.86%	6.02%	5.67%
Other manufacturing	4.69%	5.71%	6.02%	4.26%
Waste, water and electricity	7.03%	5.71%	1.20%	4.96%
Construction	2.34%	0.00%	1.20%	3.55%
Wholesale and retail trade	3.91%	4.29%	2.41%	4.26%
Transport and storage	4.69%	8.57%	6.02%	3.55%
Accomodation and food	0.78%	1.43%	1.20%	0.71%
Information and communication	4.69%	0.00%	2.41%	4.96%
Financial activities	3.91%	8.57%	4.82%	4.26%
Real estate	0.78%	1.43%	2.41%	0.71%
Other professional activities	4.69%	1.43%	0.00%	4.26%
	100%	100%	100%	100%

Tab. 3 EI and Product Innovation (PrI), states of the world

	EI/Prod Innov (11)	EI/Prod Innov (10)	EI/Prod Innov (01)	EI/Prod Innov (00)
Mining and quarring	0.97%	8.33%	1.61%	4.93%
Manufacturing	6.80%	3.57%	6.45%	5.63%
Food, beverage and tobacco	2.91%	7.14%	8.06%	3.52%
Textile and leather	5.83%	2.38%	1.61%	7.04%
Wood products	5.83%	4.76%	3.23%	4.93%
Paper products	3.88%	3.57%	4.84%	2.82%
Coke and petroleum	0.97%	2.38%	1.61%	2.82%
Chemical	3.88%	3.57%	6.45%	3.52%
Rubber and plastic	4.85%	4.76%	4.84%	4.93%
Non metallic mineral products	5.83%	5.95%	3.23%	4.93%
Metal and fabricated metal products	3.88%	5.95%	8.06%	4.93%
Computer and electrical equipment	3.88%	5.95%	9.68%	4.23%
Machinery and equipment	3.88%	5.95%	8.06%	4.23%
Motor vehicles and transport equipment	2.91%	3.57%	8.06%	5.63%
Other manufacturing	5.83%	4.76%	4.84%	4.93%
Waste, water and electricity	6.80%	7.14%	1.61%	4.93%
Construction	0.97%	1.19%	3.23%	2.82%
Wholesale and retail trade	2.91%	5.95%	1.61%	4.23%
Transport and storage	6.80%	4.76%	3.23%	3.52%
Accomodation and food	0.97%	1.19%	1.61%	0.70%
Information and communication	5.83%	0.00%	4.84%	4.23%
Financial activities	7.77%	3.57%	1.61%	5.63%
Real estate	0.97%	1.19%	1.61%	0.70%
Other professional activities	4.85%	2.38%	0.00%	4.23%
	100%	100%	100%	100%

Tab. 4 EI and Process innovation (PI); states of the world

	EI/Process Innov (11)	EI/Process Innov (10)	EI/Process Innov (01)	EI/Process Innov (00)
Mining and quarring	3.23%	6.00%	4.05%	3.47%
Manufacturing	6.45%	4.00%	4.05%	6.25%
Food, beverage and tobacco	5.38%	4.00%	4.05%	5.56%
Textile and leather	6.45%	3.00%	4.05%	5.56%
Wood products	4.30%	6.00%	5.41%	4.17%
Paper products	4.30%	4.00%	6.76%	3.47%
Coke and petroleum	1.08%	2.00%	2.70%	1.39%
Chemical	3.23%	5.00%	4.05%	4.86%
Rubber and plastic	5.38%	4.00%	5.41%	4.86%
Non metallic mineral products	2.15%	9.00%	8.11%	3.47%
Metal and fabricated metal products	5.38%	5.00%	9.46%	3.47%
Computer and electrical equipment	4.30%	5.00%	2.70%	6.94%
Machinery and equipment	4.30%	5.00%	2.70%	6.25%
Motor vehicles and transport equipment	4.30%	3.00%	5.41%	6.25%
Other manufacturing	4.30%	6.00%	6.76%	4.17%
Waste, water and electricity	7.53%	6.00%	2.70%	4.17%
Construction	2.15%	1.00%	0.00%	4.17%
Wholesale and retail trade	4.30%	4.00%	4.05%	3.47%
Transport and storage	6.45%	5.00%	5.41%	4.17%
Accomodation and food	1.08%	1.00%	1.35%	0.69%
Information and communication	3.23%	3.00%	5.41%	3.47%
Financial activities	5.38%	5.00%	4.05%	4.86%
Real estate	1.08%	1.00%	1.35%	0.69%
Other professional activities	4.30%	3.00%	0.00%	4.17%
	100%	100%	100%	100%

Tab. 5 Complementarity test; all sectors (mean value variable dichotomisation)

All sectors				
Innovation Practices Variables	VACO2_09		VACO2_10	
Mean value used for dicotomisation	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI Organisational Innovation	0.01	≤0	0.08	≥0
EI Process Innovation	1.70	≤0	1.72	≤0
EI Product Innovation	1.95	≤0	2.10	≤0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 6 Complementarity test; manufacturing sector (mean value variable dichotomisation)

Manufacturing				
Innovation Practices Variables	VACO2_09		VACO2_10	
Mean value used for dicotomisation	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI Organisational Innovation	0.33	≤0	0.16	≤0
EI Process Innovation	0.39	≥0	2.55	≥0
EI Product Innovation	0.78	≤0	0.39	≤0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 7 Complementarity test; ETS sector (mean value variable dichotomisation)

Innovation Practices Variables	VACO2_09		VACO2_10	
Mean value used for dicotomisation	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI Organisational Innovation	0.03	≥0	0.11	≥0
EI Process Innovation	0.74	≥0	0.56	≥0
EI Product Innovation	1.36	≤0	1.67	≤0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 8 Complementarity test; all sectors (first quartile variable dichotomisation)

All sectors				
Innovation Practices Variables	VACO2_09		VACO2_10	
IIIQ value used for dicotomisation	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI Organisational Innovation	0.38	≤0	0.31	≤0
EI Process Innovation	1.93	≤0	2.11	≤0
EI Product Innovation	1.35	≤0	1.13	≤0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 9 Complementarity test; manufacturing sector (first quartile variable dichotomisation)

Manufacturing				
Innovation Practices Variables	VACO2_09		VACO2_10	
IIIQ value used for dicotomisation	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI Organisational Innovation	1.00	≥0	0.98	≥0
EI Process Innovation	0.07	≥0	0.07	≥0
EI Product Innovation	1.45	≤0	0.92	≤0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 10 Complementarity test; ETS sectors (first quartile variable dichotomisation)

ETS					
Innovation Practices Variables		VACO2_09		VACO2_10	
IIIQ value used for dicotomisation		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.47	≤0	0.63	≤0
EI	Process Innovation	0.32	≥0	0.33	≥0
EI	Product Innovation	2.03	≥0	2.20	≥0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. “b” are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 11 Complementarity test; all sectors; northern Europe (mean value variable dichotomisation)

All sectors					
Innovation Practices Variables		VACO2_09		VACO2_10	
Mean value used for dicotomisation		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.61	≤0	0.42	≤0
EI	Process Innovation	1.59	≤0	1.58	≤0
EI	Product Innovation	1.14	≥0	1.12	≥0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 12 Complementarity test; manufacturing sector; northern Europe (mean value variable dichotomisation)

Manufacturing					
Innovation Practices Variables		VACO2_09		VACO2_10	
Mean value used for dicotomisation		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.88	≥0	0.86	≥0
EI	Process Innovation	2.81*	≥0	0.65	≥0
EI	Product Innovation	2.85*	≥0	2.81*	≥0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 13 Complementarity test; ETS sectors; northern Europe (mean value variable dichotomisation)

ETS					
Innovation Practices Variables		VACO2_09		VACO2_10	
Mean value used for dicotomisation		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.57	≥0	0.52	≥0
EI	Process Innovation	0.00	≥0	0.00	≥0
EI	Product Innovation	1.21	≥0	1.20	≥0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. "b" are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 14 Complementarity test; all sectors; southern Europe

All sectors					
Innovation Practices Variables		VACO2_09		VACO2_10	
Mean value used for dicotomisation		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.54	≥0	0.30	≥0
EI	Process Innovation	0.03	≥0	0.06	≥0
EI	Product Innovation	0.42	≥0	0.47	≥0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. “b” are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

Tab. 15 Complementarity test; manufacturing sector; southern Europe

Manufacturing					
Innovation Practices Variables		VACO2_09		VACO2_10	
Mean value used for dicotomisation		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	1.71	≥0	1.84	≥0
EI	Process Innovation	0.03	≥0	0.01	≥0
EI	Product Innovation	0.19	≤0	0.20	≤0

*** significant 1%; ** significant 5%; * significant 10%. The null is absence of complementarity. “b” are the coefficients of the regression associated with the states of the world (1 or 0 respectively presence or absence of a defined input in the functions that studies complementarity)

References

Antonioli D., Mancinelli S., Mazzanti M., (2013). Is environmental innovation embedded within high-performance organisational changes? The role of human resource management and complementarity in green business strategies. Research Policy, 42 (4), pp. 975-988

Bocquet, R., Brossard, O., Sabatier, M., (2004). Complementarities in organiztaional design and the diffusion of information technologies. Research Policy 36, 367-86.

Borghesi S. Cainelli G. Mazzanti M., (2012), The European Emission Trading Scheme and environmental innovation diffusion: Empirical analyses using Italian CIS data, *Annali di Economia - Giornale degli Economisti*, December

Breschi, S., Malerba, F., Orsenigo, L., (2000), Technological regimes and Schumpeterian patterns of innovation, *The Economic Journal*, Vol. 110, pp. 388-410.

Cainelli, G., Mazzanti M., Zoboli R., (2013). Environmental performance, manufacturing sectors and firm growth: structural factors and dynamic relationships. Environmental Economics And Policy Studies. Forthcoming

Cainelli G. Mazzanti M. Montresor S., (2012), Environmental Innovations, Internationalisation and local networks, *Industry and Innovation* 19(8), November 2012.

Calel, R., & Dechezleprêtre, A., (2012). Environmental policy and directed technological change: evidence from the European carbon market. Nota di Lavoro FEEM

Costantini V. Mazzanti M. (2013), *The Dynamics of Economic and Environmental Systems. Innovation*, Policy and Competitiveness, Springer.

Costantini V., Crespi F., (2008), Environmental regulation and the export dynamics of energy technologies, *Ecological Economics*, 66 (2-3), pp. 447-460.

Costantini V. Mazzanti M. (2012), On the green side of trade competitiveness? *Research Policy*, February, vol.41.

Costantini, V., Crespi, F., (2013), Public policies for a sustainable energy sector: regulation, diversity and fostering of innovation, *Journal of Evolutionary Economics*, DOI 10.1007/s00191-010-0211-3, April.

Cozzarin, B.P, Percival, J.C., (2006). Complementarities between organisational strategies and innovation. Economics of Innovation and New Technology 15, 195-217.

Cozzarin, B.P, Percival, J.C., (2008). Complementarities Affecting the Returns to Innovation. Industry & Innovation 15, 371-392.

Dosi, G., Malerba, F., Ramello, G., Silva, F., (2006), Information, appropriability, and the generation of innovative knowledge four decades after Arrow and Nelson: an introduction, *Industrial and Corporate Change*, Vol. 15 (6), pp. 891-901.

De Marchi V. (2012), Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms, Research Policy, 41(3), 614–623

EEA (2013a), Why did greenhouse gas emissions decrese in the EU in 2011?, report from the Greenhouse gas inventory, EEA, Copenhagen.

EEA (2013b), Towards a green economy in Europe. EU environmental policy targets and objectives 2010–2050, EEA, Copenhagen.

EC (2002). New Forms of Work Organization: The Obstacles to Wider Diffusion. European Commission, Final Report.

EIO (2011). The Eco-Innovation Challenge. Pathways to a resource efficient Europe. Eco-Innovation Observatory, Annual Report, May 2011.

Ellerman, A. D., Convery, F. J., de Perthuis, C., (2010). Pricing Carbon: The European Union Emissions Trading Scheme. Cambridge University Press, Cambridge, UK.

Ekins P. (2010), Eco Innovations for environmental sustainability: concepts, progress and policies, International Economics and Economic Policy, 7

FIlippetti A. Archibugi D. (2011), Innovations in time of crisis; national systems of innovation, structure and demand, Research Policy, 40, 179-92.

Gilli M. Mazzanti M. Nicolli F. (2013), Sustainability, Environmental Innovations and competitiveness in evolutionary perspectives. Evidence from the EU, *Journal of Socio Economics*, forthcoming.

Gomez, J., Vargas, P., (2009). The effect of financial constraints, absorptive capacity and complementarity on multiple process technologies. Research Policy 38, 106-19.

Hall B. Helmers C. (2013), Innovation in clean/green technology: Can patent commons help?. Forthcoming Journal of Environmental Economics and Management

Hall B. Mairesse J. Lotti F. (2012), Evidence on the impact of R&D and ICT investment on innovation and productivity in Italian firms, Economics of Innovation and New Technology, also NBER Working Paper No. 18053 (November 2011).

Horbach, J., Rammer, C., Rennings, K. (2012), Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. Ecological Economics, 78: 112-122.

Horbach, J., (2008). Determinants of Environmental Innovations, New Evidence From German Panel Data Sources. Research Policy 37, 163-73.

Kemp, R., (2010). Eco-innovation: Definition, Measurement and Open Research Issues. Economia Politica 3, 397-420.

Kemp, R., Pearson, P., (2007). Final report of the MEI project measuring eco innovation. UM MERIT, Maastricht.

Kemp, R. (2000), Technology and Environmental Policy—Innovation effects of past policies and suggestions for improvement, paper for OECD workshop on Innovation and Environment, 19 June 2000, Paris.

Kemp, R., and S. Pontoglio (2011) The innovation effects of environmental policy instruments—A typical case of the blind men and the elephant?, Ecological Economics, 72: 28-36

Johnstone, N. Hascic I., Popp D., (2010), Renewable energy policies and technological innovation: Evidence based on patent counts, *Environmental & Resource economics*, Vol. 45, pp. 133-155.

Malerba, F., (2006), Innovation and the evolution of industries, *Journal of Evolutionary Economics*, Vol. 16, pp. 3-23.

Malerba, F., Orsenigo, L., (1997), Technological regimes and the firm behaviour, *Industrial and Corporate Change*, Vol. 2 (1), pp. 45-71.

Mancinelli S. Mazzanti M., (2009), Innovation, networking activities and complementarity Empirical evidence on SME performances for a local economic system in Northern Italy, *Annals of Regional sciences*, vol.43, n.3, 567-97.

Marin G., Mazzanti M., (2013), The evolution of environmental and labour productivity dynamics, *Journal of Evolutionary Economics*, April.

Mazzanti M. Musolesi A. (2013), Carbon Kuznets curves for advanced countries, *Applied Economics*, i-first (September)

Mazzanti M. Zoboli R., (2009), Environmental efficiency and labour productivity: trade-off or joint dynamics?, *Ecological Economics*, vol.68, n.4, 1182-94.

Mazzanti, M., Zoboli, R., (2009). Embedding Environmental Innovation in Local Production Systems: SME strategies, networking and industrial relations. International Review of Applied Economics 23, 169-195.

Milgrom, P., Roberts, J., (1990). The Economics of Modern Manufacturing: Technology, Strategy and Organization. American Economic Review 80, 511-528.

Milgrom, P., Roberts, J., (1995). Complementarities and Fit Strategy, Structure and Organizational Change in Manufacturing. Journal of Accounting Economics 19, 179-208.

Milgrom, P., Shannon, C., (1994). Monotone Comparative Statics. Econometrica 62, 157-180.

Mohnen, P. Van Leeuwen, G. (2013) Revisiting the porter hypothesis: An empirical analysis of green innovation for the Netherlands, UNU-MERIT Working Paper Series 002, United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.

Mohnen, P., Roller, L.H., (2005), Complementarities in Innovation Policy. European Economic Review 49, 1431-1450.

Popp, D., (2006), International innovation and diffusion of air pollution control technologies: the effects of NOX and SO2 regulation in the US, Japan, and Germany, *Journal of Environmental Economics and Management*, Vol. 51 (1), pp. 46-71.

Porter, M.E., (1991). America's Green strategy. Scientific American 264, 168.

Porter, M.E., (2010). Reflections on a hypothesis: lessons for policy, research and corporate practice. Presentation at the Porter hypothesis at 20 Conference, Montreal, Canada, 28 June, available at www.sustainableprosperity.ca

Repetto, R., (1990). Environmental Productivity and Why It Is So Important. *Challenge* 33(5), 33-38.

Roberts, J., (2006). The Modern Firm. Organizational Design for Performance and Growth. Oxford University Press, Oxford.

Rogge K. Schneiderm M. Hoffman V. (2011), The innovation impact of the EU Emission trading system - findings of company case studies in the German power sector, *Ecological Economics*, vol. 70(3), pp. 513-23.

Rogge K. - Hoffmann V. (2010), The impact of the EU Emission trading system on the sectoral innovation system of power generation technologies- findings for Germany, *Energy Policy*, vol. 38(12), pp. 7639-52.

Schmiedeberg, C., (2008). Complementarities of innovation activities: an empirical analysis. Research Policy 37, 1492-1503.

Topkis, D. M., (1998). Super Modularity and Complementarity. Princeton University Press, Princeton, NJ.

Topkis, D.M., (1995). Comparative statics of the firm. Journal of Economic Theory 67, 370–401.

Veugelers R. (2012), Which policy instruments to induce clean innovating? Research Policy, 41, 1770-1778

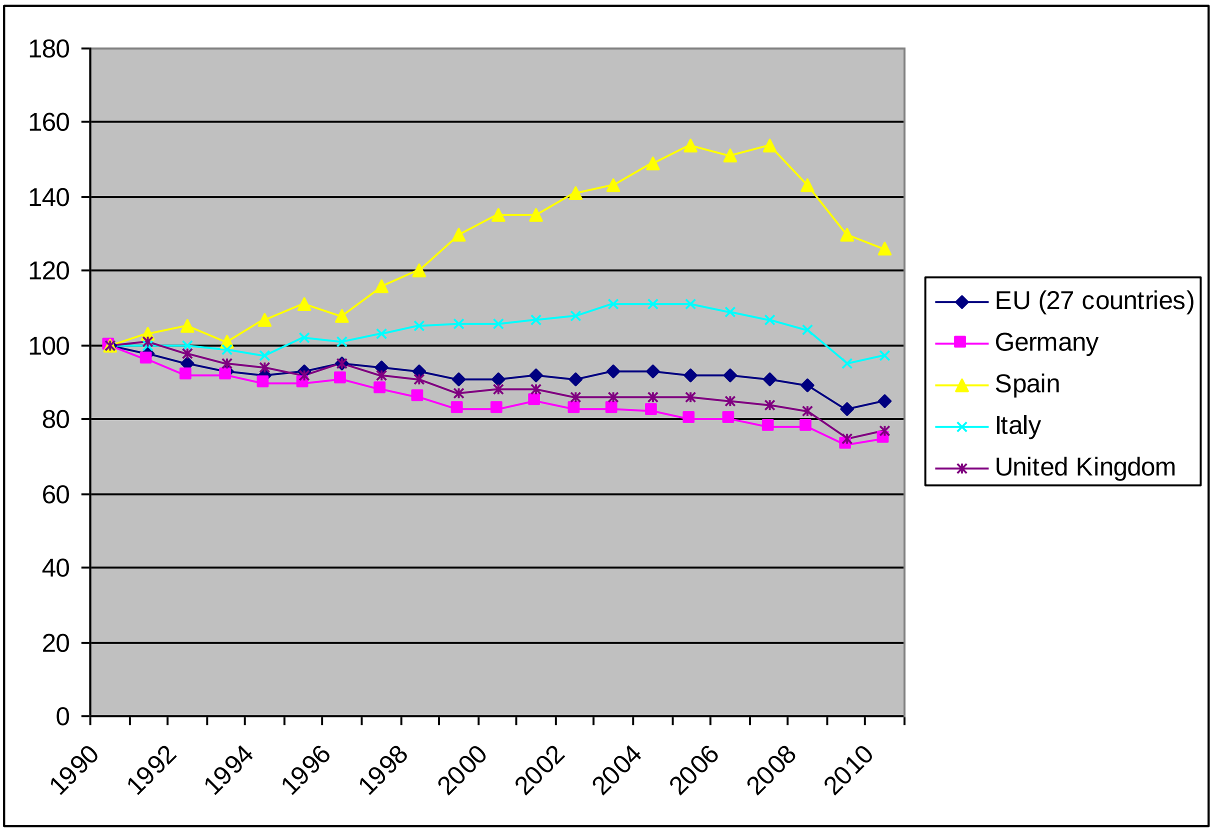

Figure 1 - GHG trends (1990 =100), source EUROSTAT

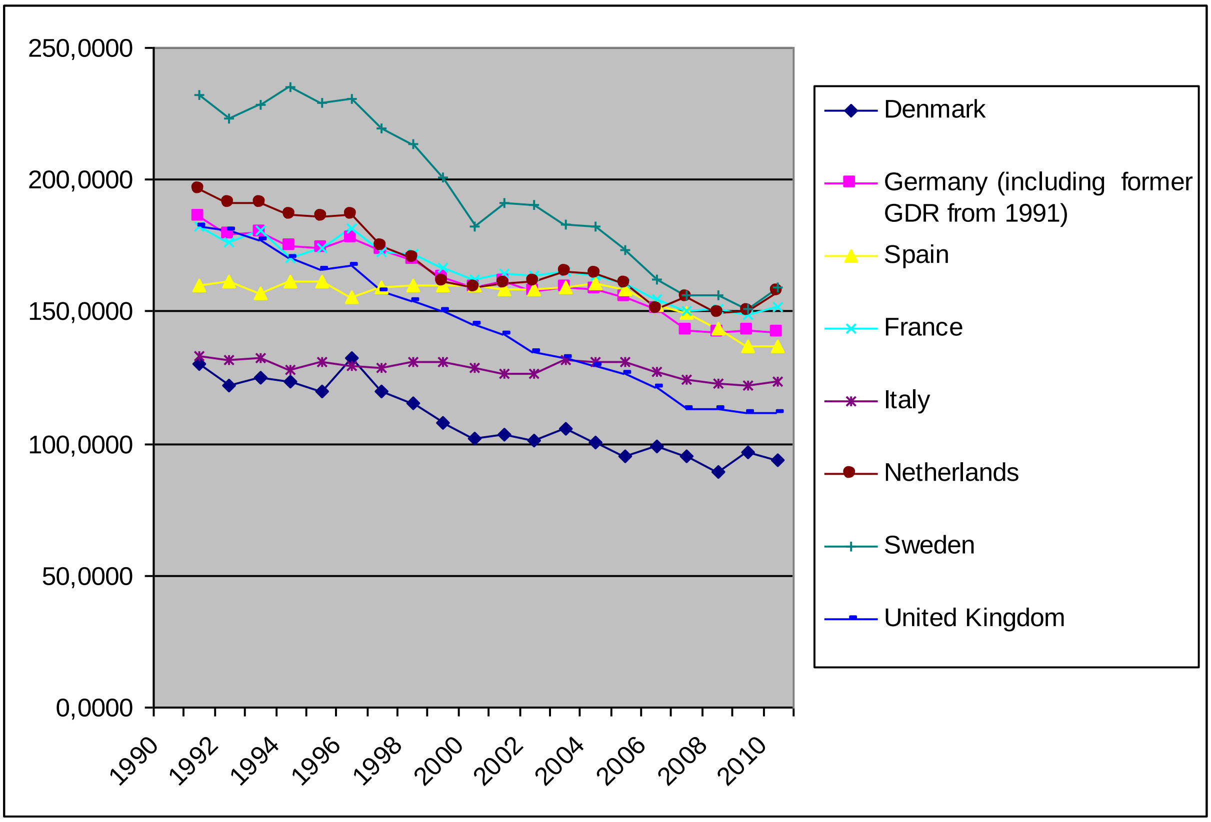

Figure 2 - Energy intensity of GDP, source Eurostat

Appendix

Tab. A1 Correlation Matrix

	VA/CO2 (2010)	EI	Inno_org	Inno_prod	Inno_proc	Labor product	ICT
VA/CO2 (2010)	1						
EI	0.0047	1					
Inno_org	0.0033	0.2095*	1				
Inno_prod	0.0305	0.0417	0.1756*	1			
Inno_proc	0.0451	-0.0191	0.4804*	0.0677	1		
Labor product	0.2982*	0.0309	0.1102*	0.1268*	0.0683	1	
ICT	0.0087	-0.1803*	-0.0571	-0.0792	-0.0264	-0.0712	1

*significant 5%

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