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Beyond the Inducement in Climate Change: Do Environmental Performances Spur Environmental Technologies? A Regional Analysis of Cross-Sectoral Differences

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Beyond the inducement in climate change:
Do environmental performances spur environmental technologies?
A regional analysis of cross-sectoral differences[1].

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ABSTRACT

This paper contributes the debate on the inducement of environmental innovations, by analyzing the extent to which endogenous inducement mechanisms spur the generation of greener technologies in contexts characterized by weak exogenous inducement pressures. In the presence of a fragile environmental regulatory framework, the inducement can indeed be endogenous, and environmental innovations might be spurred by firms' reactions to their environmental performances. The cross-sector analysis is focused on a panel of Italian regions, over the time span 1995-2007 and is conducted by implementing zero-inflated models for count data variables. The empirical results suggest that in a context characterized by substantial lack of regulatory frameworks, like the Italian one, environmental performances have significant and complementary within- and between-sector effects on the generation of green technologies.

Jel Classification Codes: O33, Q53, Q55, Q56, R11

Keywords: Regional NAMEA, Green technologies, Technological innovation, Knowledge production function, Environmental Performance, Knowledge Coherence

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1 Introduction

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

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

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

This paper aims at contributing this strand of literature, by adopting a different and yet complementary perspective on the inducement mechanism. We investigate the extent to which, in a context of weak environmental regulatory framework, endogenous mechanisms may play a key role in inducing green innovations. In this perspective, the incentive to generate green technologies can be the direct outcome of local sectoral environmental performances rather than of the moderating effect of environmental regulation. In other terms, environmental performances in the sector and in related sectors may induce endogenously environmental innovations, while regulation impacts exogenously the production process. This perspective is particularly relevant in those empirical contexts, which are featured by a substantial lack of clear and effective regulatory frameworks.

The cross-sectoral analysis is carried out on a panel of Italian regions observed over the time span 1995-2007, and is based on the matching between regional National Accounting Matrix with Environmental Accounts (NAMEA) data, patent data and regional economic accounts. The econometric results obtained by implementing a zero-inflated binomial model for count data variables, identify interesting and persistent patterns of inducement for different classes of emissions and show a high degree of complementarity between within-sector and cross-sector inducement.

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

2 Induced technological change and environmental innovations

The induced innovation approach is back at the centre stage of the economics of technological change, due mainly to the contribution of two streams of analysis. On the one hand, within the context of the innovation-employment nexus, the so-called skill-bias debate has brought new interest in the matter (Acemoglu, 1998 and 2002). On the other hand, the increasing attention to the determinants and effects of green technologies has recently rejuvenated the discussion on the economic incentives to the production of new technologies.

The original hypothesis actually dates back to Marx and Hicks (1932: 124-125) according to whom "A change in the relative prices of factors of production is itself a spur to invention, and to invention of particular kind – directed to economizing the use of the factor which has become relatively expensive" [2]. Close to this perspective, but wider in scope, the Schumpeterian analysis of innovation dynamics proposes that innovation emerges out of the process of competition within the capitalistic system, as an outcome of the creative response of economic agents, who operate in environments shaped by the conditioning influence of factors both internal and external to the economic system. When there is an unexpected change in one or more of these factors, economic agents have to adjust. The way this happens may reside either within the comfortable borders of the existing practice, or outside its range. Creative response is an adaptation effort carried out by doing something completely new, which alters the data of the system (Schumpeter, 1939 and 1947).

In this direction, the hypothesis that environmental regulation induces technological change has been widely investigated in the environmental economics studies. Within the domain of environmental innovations, it is possible to articulate the inducement hypothesis into at least two set of (complementary) mechanisms. On the one hand one can identify the "exogenous" mechanisms. This strand of literature points to the moderating role played by regulation on the generation of greener technologies. The incentives are here engendered outside the production system, i.e. in the institutional system. More precisely the "exogenously" induced innovation hypothesis in climate treats a stringent policy as an additional cost, which increases total production costs by changing the relative factor prices. As a consequence, this

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

process induces firms to engage in innovation activities aiming to reduce the increased cost, e.g. by developing emission-saving technologies[3].

Empirically the correlation between environmental regulation and technological change, has been investigated either by using patent data, to test whether regulation affected knowledge generation[4] (e.g. Lanjouw and Mody, 1996; Brunnermeier and Cohen 2003; Jaffe and Palmer, 1997; Popp, 2006)or by using survey data, to test whether regulation pushes and/or pulls environmental innovations (e.g. Frondel et al, 2008; Horbach et al., 2012, Rennings and Rammer, 2011; Rennings and Rexhäuser, 2011; for a review see Del Rio Gonzales, 2009). In both the cases, the evidence confirms that regulation exerts a positive effect on innovation[5].

The outcome of such exogenous inducement mechanisms cannot however be taken for granted. The public nature of innovation and the appropriability regime creates indeed a positive externality, which is translated into innovation efforts which are lower than the social optimum, while, conversely, pollution is a case of negative externality, the social costs of which are spread over the entire society, thus inducing firms to pollute more than the social optimum level. Accordingly, without a policy intervention "firms pollute too much and innovate too little compared with the social optimum" and investments in green technologies are in the end too low as "the two market failures are mutually reinforcing" (Johnstone et al., 2010b, p. 9). The need for an environmental regulation is also supported by the "Porter Hypothesis" (Porter and van der Linde, 1997) in its different versions[6], and empirical evidences underline the positive effect of regulation over firms´ competitiveness, e.g. in terms of increased trade for environmental technologies (Costantini and Mazzanti, 2012). However, the regulatory push/pull framework may have different effects across different kinds of

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

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

[5]It is worth noting in this context also the work by Calel and Dechezleprêtre (2012), in which no significant effects of regulation on innovation have been found.

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

environmental innovations (Rennings and Rammer, 2009)[7] and different policy frameworks[8] might generate different innovative outcomes (Popp et al., 2009).Besides, the stringency, predictability, flexibility, incidence and depth of the policy instruments impact on the effort and on the direction of the innovations (Johnstone et al., 2010b)although the measurement of these elements is not an easy process(Kemp and Pontoglio, 2011).

While the traditional "exogenous" inducement hypothesis stresses the impact of changes in the regulatory framework on firms' costs, it neglects the alternative incentives to generate green technologies which are directly engendered from the production system, and are therefore labeled (in this paper) as "endogenous".

A step forwards in the identification of the endogenous incentive for firms to generate green technologies is represented by the literature on corporate social responsibility (CSR). The origins of this approach dates back to the 1950s, and it has been developed to accommodate the traditional firms' maximization objectives and the idea that corporations play a role in the society (see Lee (2008) for an exhaustive review). In the last decades this approach has successfully elaborated a framework that articulates the link between CSR and corporate financial performance (CFP) (Margolis et al., 2003; Orlitzky et al., 2003; Porter and Kramer, 2002 and 2006, Kotler and Lee, 2005).The recent developments of strategic management theories draw upon the extension of the stakeholder theory, as proposed by Freeman (1984). Differently from traditional approaches, in this one firms' objectives should not only take into account shareholders, but also stakeholders, thus involving employees, local communities, governments and customers. As a consequence, the social and economic goals of a corporation are strictly intertwined. The grafting of the CSR onto the stakeholder theory allowed for widening the scope of the concept of CSR so as to include environmental responsibility, diversity, affirmative action, transparent accounting, etc. (Jones, 1995; Clarkson, 1995; Berman et al., 1999).

As remarked by Orlitzky et al. (2011), while the CSR concept appears to be a multifaceted one, the assumption that environmental responsibility is a key part of it is less controversial (Hart, 1997). Accordingly, factors like the moral appeal, sustainability and reputation are particularly relevant in shaping firms' choice to adopt an environment-friendly behavior. The generation of green technologies may allow firms to align the target of lowering the environmental impact of the production process with the target of increasing technology-based competitiveness. The reduction of production costs becomes a potential side effect stemming from the generation of green technologies, while the main inducing factor relates to the likelihood of improving firms' performances through market evaluation.

[7]More precisely, environmental innovations leading to a reduction of the production costs, such as increasing energy efficiency and reducing materials usage, are less regulation-driven than others, and they may generate a typical case of win-win solution (Rennings and Rammer, 2009).

[8] Market-based instruments such as taxes on the emissions or tradable permits have indeed stronger impacts on innovations than direct regulation (e.g. Popp et al., 2009)

These positive business performance effects of firms' environmental innovation strategies, have been systematically assessed by Ambec and Lanoie (2008), who explicitly analyzed the channels through which environmental practices are improving firms' financial performances. On the one hand, environmental performance can increase revenues via a better access to "green" markets, via a product differentiation strategy and via entering a market for their pollution control technologies. On the other hand, it can reduce costs in the following categories: "a) risk management and relations with external stakeholders; b) cost of material, energy and services; c) cost of capital and d) cost of labor" (Ambec and Lanoie, 2008: 46).To sum up, consistently with the broader CSR approach, environmental responsibility may affect firms' financial returns by allowing for the development of new markets, the increase of the market value of publicly traded firms, the reduction of consumers boycotts and the attraction of active consumers[9]. Moreover, a proactive environmental management may also reduce the risks associated with potential regulatory and legal actions (Lee, 2008).

In view of the arguments articulated so far, we are now able to spell out the working hypotheses. Inducement mechanisms play a crucial role in the generation of new technological knowledge, especially in the domain of green technologies. The exogenous constraints set up by the regulatory framework are of particular importance in this respect. However, the relevance and role of either exogenous or endogenous inducement mechanism is context-specific. In contexts characterized by weak regulations and ineffective policy interventions, the inducement mechanism is more likely to be set in motion by endogenous mechanisms, rather than the exogenous ones. In particular one may think on some co-occurring mechanism such as the social responsibility of firms which are responsible of the emissions of pollutants, but also the opportunistic behavior of pre-emptive response to a future regulation.

The paper raises the basic question as to what extent environment-related inventing activities may benefit of an inducement, also in such contexts characterized by weak environmental policy pressures. We further draw on this intuition, and try to test whether, in the absence of a policy inducement, at least some endogenous inducement mechanisms are at stake. In particular we analyze whether in such contexts, the generation of greener technologies may be directly affected by the regional and sectoral environmental performances. To the best of our knowledge, no previous attempts have been performed to investigate the inducement the environmental region/sector composition plays on the generation on knowledge.

In line with the local dimension of stakeholders theory, the hypothesis we are testing is that firms located in highly polluting regions and belonging to strong polluter sectors, will be more prone to generate greener technologies as compared to the others, either as a side-effect of their expectation of future stringent regulations, or as an effect of increasing environmental responsibility. This is equivalent to testing whether sectoral environmental performances in the sampled regions are likely to affect sectoral generation of green technologies.

[9]This makes CSR closely related to the concept of sustainable consumption (Sanne, 2002; Gilg et al., 2005).

Since most of the industrial activities are featured by vertical linkages we expect that the sectoral generation of green technologies is also affected by the environmental performance of related sectors. More precisely, we hypothesize that environmental performances generated by closely related sectors affect green innovative activities.

3 Empirical context

As outlined in the previous section, the strand of literature on the induced innovation hypothesis in climate change, basically tests the existence of a link between environmental regulation and (green) technological change. In an environmental policy weak context, as we highlighted, it may not be appropriate to focus on the regulatory framework, as it is more likely that only internal inducement mechanisms may be set in motion.

In this respect, Italy is one of the countries reporting lower levels in the indicator of environmental policy regime stability and transparency, thus facing less stringent environmental policies as compared to other OECD countries (Johnstone et al., 2009). Furthermore, Italy does not report many environmental instruments, with the exception of the EU ETS ("European Trading Scheme") sectors, which are falling under the EU ETS Directive, and the low stability and transparency in the policy regime and the lack of economic instruments within environmental policy, may furthermore undermine its innovativeness.

When assessing the role of the policy framework in the Italian context on emissions performance, a further confirmation of the weakness of the Italian regulation has emerged in the literature. The insight is that manufacturing "has also not adapted to the new climate change policy scenario, and even the environmental Italian policy as a whole has somewhat lagged behind other leading countries in terms of policy efforts". (Marin and Mazzanti, 2010: 22)

For these reasons it is more likely that, in such a context, pressures - if any - to improve the environmental impact emerge within corporate boundaries rather than from external policy constraints.

The Italian policy weak empirical context justifies our decision to select this country, in order to test our hypothesis on whether the environmental performance, rather than direct policy measure, induces (green) technological change, or, in other terms, whether environmental performance (both direct and related) is correlated with the generation of green knowledge.

The choice of an appropriate country-case is however not enough, as an appropriate level of analysis has to be chosen. Intuitively, the best level of analysis would be the firm level one, but the lack of data availability at this level calls for an alternative solution.

If we look at the regional composition of air emissions in Italy (Figure 1), we found evidences of strong and persistent regional differences, which suggested the need of an analysis to be performed at the regional level.

Furthermore the economic literature on sectoral emission patterns and "delinking" with income growth, provides support to the need of a sector-based analysis, as strong sectoral patterns have emerged (Marin and Mazzanti, 2010; Marin et al., 2012; Mazzanti et al., 2008; Mazzanti and Zoboli, 2009).This literature highlights that the degree of (technological) development is "highly differentiated by sector and geographical entity" (Mazzanti et al., 2008:296).

>>> INSERT FIGURE 1 ABOUT HERE <<<

In the Italian service sectors, the previous literature on the Environmental Kuznets Curve (EKC) outlined the existence of an inverted N-shape relationship between environmental pressure and income per capita (Marin and Mazzanti, 2010; Mazzanti et al., 2008).Contrarily to the service sectors, Italian manufacturing industry shows instead strong intra-branches heterogeneities, with ceramics, paper, food and fuel manufacturing facing the worst environmental performance dynamics (Marin and Mazzanti, 2010). Furthermore, EKC "N shaped" or "U shaped" mostly depends on the emission considered in the manufacturing sectors (Mazzanti et al., 2008).These considerations on the Italian sector and regional heterogeneities, suggested us to ground our empirical analysis on a sector-region level of analysis. The final confirmation of the appropriateness of this focus lies in the consideration that heterogeneities are also expected in the way regions and sectors respond to environmental pressures, as those differences outlined in the social capital endowments (see e.g. Helliwell and Putnam, 1995) may engender different sector-regional innovative reactions.

4 Data, Methodology and Variables

4.1 Data description

A limited amount of studies exploited air emissions data at sectoral and regional level of disaggregation. Most of those studies draw upon a rich and unique dataset, which is available at the Nuts II level -to our knowledge- only for Italian Regions: the regional NAMEA[10], developed by the Italian Statistical Office (ISTAT). Among them, Mazzanti and Montini (2010) have focused on the drivers of emissions efficiency, adopting structural decomposition analysis to disentangle the determinants of changes in the emission efficiency of selected pollutants in Lazio (an Italian region). Costantini et al. (2013) focused on the economic drivers behind the geographical distribution of environmental performance for all the Italian

[10] Next section will provide a description of the NAMEA dataset.

regions. Sansoni et al. (2010) provided a methodological and conceptual framework on the use of a regional NAMEA for international comparisons.

In line with such empirical literature, we employ the Italian regional NAMEA to investigate the impact of environmental performances on the generation of green technologies. The focus on Italy is even more relevant if we look at its overall trends in air emissions. In terms of total Greenhouse Gases (GHG) emission is indeed still far from reaching the 2012 Kyoto target, having reduced its overall GHG emissions only by 3.5%[11] (UNFCC). Most importantly, it is the European country of the G8 group which is performing worst[12], and it has reached a reduction in GHG which is lower even than the European Union average[13].

For the empirical analysis, we merged the regional NAMEA with different data sources concerning the economic and technological performances of Italian Regions. We started exploiting patent applications, drawn from the PATSTAT database,[14] to build the proxy for knowledge generation in the domain of green technologies[15].It has to be highlighted that the main limitation associated with patent data in measuring technological innovation, i.e. that of measuring inventions instead of innovations, is in our case less relevant, as we are willing to understand the effect of air emission on the generation on (green) knowledge, independently on whether these inventions are then entering the market or not. Such dataset covers patent applications of firms over 20 Italian Regions and all sectors (NACE Rev. 1.1, at 2-character alphabetical codes, as in Tab. A2) collected from 1995 to 2007, and counts 6.240 observations. After having extracted patents applications generated by Italian inventors, we assigned these patents to each Italian Region, on the basis of the inventor's address, and to each sector, on the basis of firms' data. In particular, the sectoral assignment required a merge with firm data, which were drawn from the Bureau van Dijk Orbis dataset, and merged with patents on the basis of the OECD HAN correspondence tables. Patents have then been defined as being 'environmental' on the basis of the World Intellectual Property Organization 'WIPO IPC green inventory', an International Patent Classification which allows to identify patents

[11] The target for Italy was to reach by 2012 a total Gg of Co2 equivalent in GHG equal to the 92% of the emissions recorded into 1990. The 3.5% reduction refers to the year 2010, having as a reference year 1990.

[12] France reached a 6% reduction, United Kingdom, 22.5% and Germany 24.8%. For an overview on the remaining countries UNFCC, 2012 (http://unfccc.int/resource/docs/2012/sbi/eng/31.pdf)

[13] Whose average reduction in 2010 with respect to 2012 was equal to 15.4%.

[14]PATSTAT Version: April 2011.

[15] The limits of patent statistics as indicators of technological activities are well known. The main drawbacks can be summarized in their sector-specificity, the existence of not patentable innovations and the fact that they are not the only protecting tool. Moreover the propensity to patent tends to vary over time as a function of the cost of patenting, and it is more likely to feature large firms (Pavitt, 1985; Griliches, 1990). Nevertheless, previous studies highlighted the usefulness of patents as measures of production of new knowledge. Such studies show that patents represent very reliable proxies for knowledge and innovation, as compared to analyses drawing upon surveys directly investigating the dynamics of process and product innovation (Acs et al., 2002). Besides the debate about patents as an output rather than an input of innovation activities, empirical analyses showed that patents and R&D are dominated by a contemporaneous relationship, providing further support to the use of patents as a good proxy of technological activities (Hall et al., 1986).

related to the so-called ‘Environmentally Sound Technologies’ and to scatter them into their technology fields (Tab. A3)[16].

The hybrid environmental-economic accounting matrix based on NAMEA applied to Italian NUTS II Regions has been used to assign to each Region the level of air emissions at a sectoral level[17].The Italian NAMEA has indeed the great advantage of allowing a coherent assignment of environmental pressure to economic branches. Ten Greenhouse gases and air pollutants and three aggregated emissions by environmental impact are available in this dataset[18].To avoid an overlap between variables, we found more appropriate to ground our analysis on the aggregated emissions by environmental impacts, i.e. Greenhouse Gases (GHG), Acidifying Gases (ACID) and Ozone Tropospheric precursors (OZ) [19] and on Particulate matter (PM10)[20]. Input-Output (Supply and Use) tables provided by ISTAT, have consequently been used to build indexes of relatedness among sectors, which have been adopted to weight our “related air emissions variables”, according to the methodology described into the next section. Unfortunately a panel for the regionalized NAMEA is not available yet, as only observations for the year 2005 have been developed (while at the national level a wide panel for Italy already exists). Despite this limitation, the regional NAME has the great advantage of being, to our knowledge, the only NAMEA at EU level now available at the Nuts II level. Lastly, NAMEA and patent data have been merged with regional sectoral economic accounts, regional environmental expenditures and regional data on exporting activities provided by ISTAT.

4.2 Methodology

Drawing on the literature highlighted in Section 2 we have hypothesized that, besides the traditional exogenous inducement from policy regulation, the generation of green technologies may be the outcome of an endogenous inducement mechanism. Regional

[16] The WIPO IPC green inventory is currently the classification of green technologies which is better established, but it is not the only one available. European patent Office (EPO) is working in the direction of completing its own system of classification to assign each patent a green tab, depending on the environmental aim of each patents. So far, EPO allows to tag technologies for adaptation or mitigation to climate change (Y02), in terms of buildings (Y02B),energy (Y02E), transportation (Y02T) and capture, storage sequestration or disposal of GHG (Y02C).

[17]For a detailed description of the NAMEA tables see ISTAT (2009) and Tudini and Vetrella (2012).

[18]The following pollutants are available in the dataset but have not been included in our analysis: carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), nitrogen oxides (NOX), sulphur oxides (SOX), ammonia (NH3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and lead (Pb).

[19]GHG, ACID and OZ are built in the NAMEA tables according to a methodology which requires the conversion of the pollutants responsible for each phenomenon in “equivalent tons”. In the case of GHG, the conversion is based on their “Global Warming Potential” (GWP), i.e. to the potential of global warming associated to each emission when compared to CO2. To compute GHG equivalent emissions, CO2, CH4 and N20 (in tons) are multiplied by their coefficients, respectively 1 (CO2) ; 310 (N20) and 21 (CH4). To aggregate emissions responsible for the acidifying process (ACID), the “Potential Acid Equivalent” (PAE) of each emission measured in tons has been computed, and is based on the following coefficients: 0.22 (NOx); 0.31 (SOx) and 0.059(NH3). Ozone precursor emissions (OZ) take into consideration the “tons of potential tropospheric ozone generation”, and are computed through the following coefficients multiplied by the related emission: 0.014(CH4); 1.22 (NOx); 1 (NMVOC) and 0.11 (CO).

[20] PM10 has been included, although it is not an aggregation of other emissions, as on the one side it was not included neither in GHG, nor in ACID or OZ and, on the other side, it is strictly connected to the production.

polluting agents in each sector are likely to commit resource to improve their environmental performance so as to attract new customers, meet the preferences of sustainable customers, improve their reputation and increase their market value. At the aggregate level, this is equivalent to investigating the extent to which in each region the environmental performances of each sector are likely to promote the generation of green technologies in the same sector.

The literature dealing with empirical analysis of regional innovation performances is mostly based on the implementation of the so-called knowledge production (KPF) approach. The knowledge production function is one the pillars of the applied economics of innovation (Griliches 1979, 1990, 1992; Romer, 1990; Linkand Siegel, 2007). It has been widely applied in variety of contexts including firms, regions, industries and countries. In the knowledge production function approach, innovations, usually measured by proxies such as R&D expenses, patents and innovation counts enter the production function either directly, next to capital and labor, or indirectly, through a two-step procedure in a model that estimates its effects on the general efficiency of the same production function. In this context the KPF is indeed what Griliches (1979) used to label "extended production function" (Krafft and Quatraro, 2011). In order to mark the difference with this approach, we will follow Antonelli and Colombelli (2013), and use the expression "knowledge generation function", which studies the direct relations between the inputs that make possible generation of knowledge as an output.

In order to investigate the impact of pollutant emissions on the regional generation of green technologies across different sectors we propose therefore an extended knowledge generation function, in which the number of green technologies (GT) is the dependent variable. The discrete nature and non-negative nature of the dependent variable suggests the adoption of estimation techniques for 'count data' models.

Out of these models, the Poisson regression assumes that the dependent variable follows a Poisson distribution like the following:

$$P\left(Y = y_{ij}\right) = \exp(-\lambda_{ij}) \frac{\lambda_{ij}^{y_{ij}}}{y_{ij}!} \quad (1)$$

The expected patent count for Region *i* and sector *j* equals λ_{ijt}:

$$E\left(Y_{i,j,t+1}\right) = \lambda_{i,j,t+1} = \exp(X_{i,j,t}\beta) \text{with } t = [1995, 2007] \quad (2)$$

Where $X_{i,j,t}$ is the vector of explanatory variables and β the vector of coefficients to be estimated. The Poisson regressions model however assumes the equality between conditional variance and conditional mean in the distribution of the dependent variable. When this condition is not met, like in the present case, the negative binomial (NB) class of models is used, which permits over-dispersion. The NB regression is based on the negative binomial distribution:

$$P(Y = y_{ij}) = \frac{\Gamma(y+\alpha^{-1})}{y!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\lambda}\right)^{\alpha-1}\left(\frac{\lambda}{\alpha^{-1}+\lambda}\right)^{y_{ij}} \quad (3)$$

The expected patent count for region i and sector *j* still equals λ_{ijt}:

$$E(Y_{i,j,t+1}) = \lambda_{i,j,t+1} = \exp(X_{i,j,t}\beta + \varepsilon_{i,j,t}) \text{ with } t = [1995, 2007] \quad (4)$$

Where $\varepsilon_{i,j,t}$ is gamma distributed with mean 1 and variance α (overdispersion parameter).

The analysis of the determinants of the generation of GTs in our case poses an additional problem, which is due to the excess combination sector-region for which we observe no GTs. This brings to a situation in which we observe an "excess of zeros" in the dependent variable, and it requires investigating whether the observed zeros are due to the overall absence of patenting activity or to specific lack of green patents in sector-region nonetheless featured by some degree of technological activity. For this specificity, we find the "zero-inflated negative binomial" (ZINB) model is more appropriate to fit our data, as it allows to modeling empirical frameworks in which the excess of zeros in the dependent variable is generated by a different process than the count values. This model simultaneously runs two equations: a binary logistical 'LOGIT' equation, to model the zeros in the dependent variable and a proper count data estimation (negative binomial or Poisson), to model the count data dependent variable. In our specification, the 'LOGIT' equation allow to discriminating between the zeros due to those Regions and sectors generating some patent, but no green patents, and those due to Regions which are not creating any kind of knowledge, either 'green' or not.

To test our hypothesis the following model is specified:

$$(GT_{ijt}) = \beta_0 + \beta_1(EM_{ijt}) + \beta_2(RelEM_{ijt}) + \beta_3(BERD_{it-1}) + \beta_4(POL_{it-1}) + \beta_5(VA_{ijt-1}) + \beta_6(KC_{it-1}) + \quad (5)$$

$$+\beta_7(KD_{it-1}) + \beta_8(DEN_i i) + \beta_9(EXPORT_{it-1}) + \sum \rho_i * (EM_{ijt}) + \sum \rho_i + \sum \phi_j + \sum \psi_t + \varepsilon_{ijt}$$

Where *i*= 1,…, 20 indicates the Region, *j*=1, … , 24 stands for the Sector and *t*= 1995, …, 2007 indexes time and β_0 to β_9 the coefficients to be estimated. The error term is decomposed so as to account for region (ρ_i), industry (ϕ_j) and time (ψ_t) fixed effects. We also include the interaction between regional dummies and emissions' intensity, to account for possible regional differentials in the enforcement of environmental regulation. The variables included in equation (5) are described in the following section.

4.3 The Variables

The dependent variable, green technologies (GT), is measured by the count of patent applications in 'Environmentally Sound' technology fields.

The explanatory variables consist of a set of key environmental variables, a set of economic variables, a policy variable and a geographic variable. The key variables to assess our hypotheses are the environmental ones, which consist of a first group of direct emission efficiency ($EM_{i,j,t}$) and of a second one of related emission efficiency ($RelEM_{i,j,t}$). $EM_{i,j,t}$ measures the emission efficiency of the Region *i* and Sector *j* in terms of the Value added of *i* and *j*. It is built according to the following specification:

$$EM_{ijt} = \log\left(\frac{EMISSIONS_{ij\,2005}}{VA_{ijt-1}}\right) \tag{6}$$

EMISSIONS is a vector of four emission variables (Table 1), each of them available at the regional and sectoral level for the year 2005 from the ISTAT regionalized NAMEA dataset.

It is worth stressing that previous contributes have used emission intensity measures to account for the stringency of regulation when the absence of specific data on regulation required the use of an approximation (e.g. Fredrikkson and Vollebergh, 2009; Costantini and Crespi, 2008).Fredrikkson and Vollebergh (2009), more precisely, constructed the dependent variable "Energy Intensity" as the physical energy units per unit of value added, aiming at measuring the effects of environmental as well as energy policies. Costantini and Crespi (2008) instead, adopted the level of CO2 emissions per unit of GDP to measure environmental stringency of the importing and exporting countries. Such an indicator however, due to the way it is build, i.e. as a ratio between environmental pressure and economic performance of the Region and Sector, can also capture some structural sector features (e.g. Cainelli, Mazzanti, Zoboli, 2010).

>>> INSERT TABLE 1 ABOUT HERE <<<

Similarly, $RelEM_{i,j,t}$ measures the emission efficiency of the related emissions, and follows the following specification:

$$RelEM_{ijt} = \log\left(\frac{\sum_{l\neq j} W_{j,l\neq j} * EMISSION_{i,l\neq j,2005}}{VA_{ijt-1}}\right) \tag{7}$$

In this case, EMISSIONS are weighted according to the sectoral relatedness, by using a weighting matrix which gives higher values to the emissions generated by strongly related sectors. The matrix of sectoral relatedness has been built according to a methodology which draws upon the exploitation of input-output data (Fan and Lang, 2000; Feser, 2003).We used, as anticipated, the Italian Input Output "Supply" and "Use", which contain, respectively, the flows and value of commodities produced by each Industry and the flows and value of commodities consumed by each Industry. Drawing on Fan and Lang (2000), a matrix for the input-output relatedness between industries has been constructed, according to the following formulation:

$$W_{j,l} = \frac{1}{2}\left(\frac{F_{j,l}}{\sum_{j=1}^{n} F_{j,l}} + \frac{F_{l,j}}{\sum_{l=1}^{m} F_{l,j}}\right) \quad (8)$$

Where $F_{j,l}$ and $F_{l,j}$ measure the flows between industry land j, and have been built by multiplying the matrix of the share of one unit of the commodity c produced by industry l by the value of c consumed by industry j and vice versa.

To control for the role of the economic and technology characteristics in the generation of GTs, we included in the regression the real Value Added (VA), the share of Public R&D (PURD) over the total R&D, the effect of export oriented activities (EXPORT)[21] and the following knowledge-related variables.

The knowledge diversity (KD) is measured by the number of IPC technology classes in which regional firms have applied patents. Let the technological universe consist of *m* technological classes, and let $Z_{m,t} = 1$ if a patent in the region *i* has applied been assigned to technology *m* at time *t*, 0 otherwise. The KD of the regional knowledge base is defined as:

$$KD_{i,t} = \sum_{i,m} Z_{i,m,t} \quad (9)$$

The Knowledge Coherence (KC) can be defined as the extent to which the pieces of knowledge that agents within the region combine to create new knowledge are complementary one another. The details for the calculation of the KC index at the regional level can be found in Quatraro (2010).

To avoid a possible bias coming from the omission of policy variables, the ISTAT data have been used to build the variable POL, given by the regional expenditure for environmental protection with respect to the regional Value Added in 2004 [22] (Costantini and Crespi, 2008).Lastly, we controlled for the density of the Region, DENSITY, measured as the ratio between the Population and the Area. Table 1 provides a synthesis of the definition of the variables used in the analysis.

>>> INSERT TABLE 1ABOUT HERE <<<

[21] In a way export also allows to account for the possible role that foreign countries regulations exerts on local production, in the case of foreign environmental standards over imported goods, either for consumption or intermediate. Accordingly, the variable used refers to exporting activities within the European Union. Due to data availability, we could not have an EXPORT continuous variable for each year of our panel dataset. We then adopted an average time invariant variable at the regional level, by exploiting the ISTAT territorial indicators on exporting activities. The variable corresponds to the ratio between the regional average exports between 2001 and 2005, and the regional average value added in 2001 and 2005. As a robustness check, we also tested an alternative variable, which has been built using the average of the same variables but between 2004 and 2007. Results have proved to be robust, and are available upon request.

[22]As in the case of EXPORT, due to data availability, we adopted a time invariant variable at the regional level. As a robustness check, three alternative specifications have been tested, and results were stable (and are available upon request). The first alternative has been built as the ratio between the average environmental expenditure between 2004 and 2007, with respect to the average regional Value Added for the same years. The second one has been built as the ratio between the regional R&D for environmental protection in 2004 and the regional Value Added in 2004. Lastly, we took the average regional R&D for environmental protection between 2004 and 2007 and the average regional Value Added for the same years.

The descriptive statistics of the variables are provided in Table 2. It is worth stressing that the statistics concerning the dependent variable highlight a strongly overdispersed distribution, in which the variance is far higher than the mean, suggesting the appropriateness of a Negative Binomial class of models.

>>>INSERT TABLE 2 ABOUT HERE <<<

Table 3 shows instead the sectoral distribution of green technologies. In Italy over the observed period the bulk of the GT generation is clustered in the manufacturing sector, as one could have expected. In particular, about the 39% of the GTs are produced in the sector dealing with the manufacturing of equipment. This suggests that much of them are embodied in intermediate capital goods. The real estate sector also deserves to be mentioned, as therein it is produced about the 17% of the observed green patents.

>>> INSERT TABLE 3 ABOUT HERE <<<

In table 4 we report the sectoral distribution of air emissions. It is worth noticing that the agriculture sector is responsible for the highest amount of pollution of PM10 and ACID, and is just the second in the ranking as far as GHG and OZ are concerned. Intuitively also the transport sector show high values of equivalent tons for all the four emissions considered, and, in particular, is the worst performing sector in terms of OZ. The worst environmental impact for GHG comes from the electricity, gas and water supply sector, which is also responsible for really high level of OZ emissions.

>>> INSER TABLE 4 ABOUT HERE <<<

Lastly, in Table 5 we show the Spearman Rank correlation coefficients, which allow to account for extreme values in the considered variables.

>>> INSERT TABLE 5 ABOUT HERE <<<

As is clear from this table, emissions' intensity variables are highly correlated. Therefore their joint inclusion in the regressions is likely to engender biased estimations. For this reasons we will carry out separate estimations for each of the considered emissions.

In the next section we present and discuss the results of the econometric estimations.

5 Econometric results

Table 6 reports the results for the zero inflated negative binomial regressions of the equation (5). In the first column we report the baseline model. First of all, it is fair to note that the knowledge-related variables behave well, as the signs of coefficients are in line with previous literature. Knowledge coherence indeed shows a positive and significant coefficient. Coherence is a proxy of the degree of integration of regional knowledge bases. High values of coherence signal the pursuit of exploitation-based search strategies, wherein regional innovative innovating agents move across well-defined areas of the technology landscape, which are coherent with the technological competences, they have accumulated over time. In this direction, higher values of coherence are more likely to be associated with higher innovation and economic performances (Nesta and Saviotti, 2005; Nesta, 2008; Quatraro, 2010; Colombelli, Krafft, Quatraro, 2013).

The proxy for agglomeration economies, DENSITY, shows a positive and significant coefficient, suggesting that these bear positive impacts on the generation of green technologies at the regional level. Consistently with our expectations, and with previous literature, regional policies positively affect our dependent variable, and the same holds for the role of regional value Added (both POL and VALUE ADDED are positive and significant). The share of public R&D expenditures also shows a positive coefficient, although not significant, and the same positive but not significant coefficient is associated to exporting activities.

>>> INSERT TABLE 6 ABOUT HERE <<<

We can now move to the interpretation of the key variables for this study, i.e. the environmental ones.

Pollutants responsible of the Acidifying process (column (4)), which are the ones having more localized effects (e.g. Costantini and Mazzanti, 2012), are reporting positive and significant direct effects on GT. This evidence provides support to our hypothesis on the endogenous inducement to the generation of green technologies. Firms generating polluting emissions in local contexts may be feel responsible of the environmental impact of their activity, and hence commit resources to generate technologies allowing to reducing such an impact. Similarly, GHG (column (1)) exert a direct positive inducement effect (all the coefficients for the direct emissions are positive and significant).However, when we move to the effects of Tropospheric Ozone precursors (column (3)), we find a pretty different picture, as these direct emissions do not show any statistically significant effect on GT, although the coefficient is still positive. The same applies to direct PM10emissions (column (2)).This aggregate evidence is compatible with a microeconomic framework in which firms are increasingly aware of their environmental responsibility, and of the economic benefits that may derive from their engagement in reducing their direct emissions, either when the benefit come for the reason outlined in the literature on the CSR, or when those benefits might be the consequence of a proactive response to future stringent regulations.

Results concerning the effects of the emissions of related sectors allow to refining the interpretation, by looking at emission-pull patterns which are moderated by the vertical linkages across sectors. All the coefficients of the weighted emissions are strongly significant, but the signs are opposite to those of the direct emission. Furthermore, this pattern is persistent across all the considered emissions: the related emissions responsible for the acidifying process (column (4)), for GHGs (column (1)), for the Tropospheric Ozone precursors (column (3)) and for PM10 (column (2)) are all reporting a negative and significant coefficient.

It is worth recalling that the relatedness matrix we have used to weight the impact of emissions of sectors $l \neq j$ on sector j, is based on the input-output matrix. In other words we measure the effects on sector j of the emissions produced by technically related sectors. Technical proximity allows therefore to appreciating the effects of environmental performances of related sectors. These empirical results overall suggest a sort of complementarity between direct and indirect effects of sectoral emissions, which is in a way compatible with a CSR framework. In each region-sector, firms feel responsible for their own environmental performances (direct emissions show positive sign), but not for the environmental performances of firms operating in vertically related sectors (related emissions show negative signs).

5.1 Robustness checks

Several robustness checks have been implemented to support the econometric results we presented above.

At first, we provide in Table A1 the results obtained by running standard Poisson and Negative Binomial estimations. One can observe that the results are well in line with the zero-inflated models presented in Table 6. Knowledge diversity and Knowledge Coherence are positive and significant. Density, Policy and Value Added are also positive and significant. Export activities are positive but not significant in the NB models, in line with our previous results, but significant in the Poisson. Another difference is found for public business R&D, which is positive and significant in both the Poisson and the Negative Binomial specifications. These two differences are however not spoiling our results, as on the one side we acknowledge the model which fits the data better is the ZINB, and, most importantly, as the pattern of emissions-pull generation of GTs is largely confirmed. Direct and indirect effects appear indeed to be complementary also in these specifications. A direct positive effect affect is depicted for Greenhouse Gases, Acidifying Gases and Ozone precursors, and a direct positive and not robustly significant effect for Particulate matters (which is significant in the NB specification, while not in the Poisson). All these emissions show a robust and negative coefficient when moving to the indirect emissions, to confirm the complementarity pattern already outlined in the Zero-Inflated models.

Secondly, we tested the robustness of the results on the related emissions, by adopting different specifications of the fully specified weighting matrix adopted and shown in Table 6, drawing on the consideration that this matrix can be thought as a proxy for technical proximity amongst sectors. In this direction, one can identify a cutoff value discriminating between close and far sector. For this reason we have run further regressions by using two different cutoff points. The choice of these values is somewhat arbitrary, and we based our choice on the basis of the distribution of the weights. Table 7 and Table 8 hence report the results of the estimations obtained by using as cutoff the value of W_{lj} at the 75^{th} and the 90^{th} percentile respectively.

>>> INSERT TABLES 7 AND 8 ABOUT HERE <<<

The results are partially confirmed by these new estimations.

As already outlined, the correlation matrix shows strong correlations among the emissions, which suggested to us to include each direct and related emissions into different regressions. Still, some multicollinearity problem might arise between each direct emission and its related emission variables. To test for that, a "Variance inflation factor" (VIF) test has been performed after each of the four regressions of Equation (5). Recalling that the signal of a variance in the coefficient which is increased because of the existence of significant collinearity in the regressors has to be read in the case of indexes of VIF above 5.00, we depicted some collinearities for W*PM10 (6.29), W*OZ (7.73) and W*AC (6.28). To test the robustness of our previous results in the presence of these VIF values slightly above the critical value, we performed further regressions by including separately either the emission or the related emission variable. Secondly, also the variable Knowledge Diversity shows VIF higher than 5.00, and we thus performed further regressions in which we excluded it, as it was not significant. Out results are generally confirmed by these tests, with the only exception of the direct emission for Acidifying Gases, which loses significance when treated separately.

Lastly, we tested whether having Regions characterized by a higher share of manufacturing sectors than the other might introduce a bias in our analysis deriving from the omission of a relevant variable. To this aim we built two different variables to account for the regional share of manufacturing sectors, the first in terms of value added and the second in terms of employees, and we added them separately into the regressions. These variables were omitted at the sake of parsimony as they were both found to be not significant, but they were both not altering the results, thus confirming our results' robustness.

6 Conclusions

The investigation of the determinants of the introduction of environmental innovations has gained momentum in the last years, due to the important role that have been attributed to green technologies, as a mean to cope with economic crisis and simultaneously restore the competitiveness of countries. In this debate, the attention has been largely focused on the shaping role of constraining environmental regulatory frameworks as a mechanism to induce the generation of green technologies.

This paper contributes this stream of analysis by taking a different and yet complementary perspective to the standard inducement arguments proposed by the extant literature, by analyzing an environmental policy weak context, to test the existence of an impact of environmental performances as a push which "endogenously" induces firms to generate GTs. The empirical evidence concerns the Italian regions, which have been largely described as a context characterized by a substantial lack of any stringent regulation in terms of environmental policy. We therefore wondered whether any inducement effects, although endogenous, may be depicted also in policy weak contexts, and whether any direct effect of emissions on the generation of GTs could be detected. The underlying idea is that regional polluting agents, although when not exogenously pushed by an environmental policy, choose (are induced) to commit resources to the generation of GTs as an effect of the two main co-occurring mechanism of an increased social and environmental responsibility, and an opportunistic pre-emptive reaction to future regulations.

The results of the econometric estimations obtained by applying zero-inflated negative binomial techniques show an interesting pattern of relationships between environmental performance and the generation of GTs. We could indeed discriminate between direct and related effects, by implementing a relatedness matrix across sectors based on input-output matrixes. We found evidence of complementarity between direct and related effects: the generation of GTs appears to be directly stimulated by within-sector emissions of acidifying gases and Greenhouse Gases, and by the emissions of GHGs, ACIDs, Tropospheric Ozone precursors and PM10 produced in technically related sectors.

It is fair to note that by no means our results imply that the regulatory framework is not important. Indeed, when controlling for its influence, even in a policy weak context like Italy it turned out to be significant. Our results rather suggest that stringent regulation is not the only force underlying the choice to commit resources to the production of GTs, and that an inducement mechanism may be depicted also in a policy weak context. The results of this analysis conducted at the aggregate level are in particular compatible with the argument of increasing corporate social responsibility. Moreover, they shed an interesting light on the role of inter-sectoral linkages.

The analysis of the endogenous inducement of green technologies points therefore at the implementation of policy measures which should complement the traditional action on the regulatory framework. The importance of firms’ awareness of the social impact of their action calls for the implementation of entrepreneurship policies specifically dedicated to development of an entrepreneurial culture which pays attention to the environmental performances of firms. Once entrepreneurs become aware of the importance for their financial performances the improvement of their environmental performances, the commitment of resources to R&D generating green technologies may also allow for the identification of new business opportunities to be exploited by spinoffs or startups. Entrepreneurship policies should therefore be complemented, by adding the shaping of entrepreneurial culture to the traditional measures dealing with competition, the protection of property rights and the regulation of product and factor markets (Audretsch et al., 2007).

However, these results call for further analyses at the micro-level, aiming for example at investigating the extent to which firms are stimulated to generate GTs by the prospective gains in terms of reputation, and hence increasing sales, or stock market value. Another future strand of possible research is to focus on the effect of environmental performances on the adoption -instead of the generation- of greener technologies, by using for instance survey data[23]. Furthermore, a possible extension would be to attribute a role not only to direct environmental performance and to the inter-sectoral relatedness, as we did, but also to the regional geographical proximity, as the existence of technological and environmental spillovers has been depicted in the literature (Costantini et al. 2013). Lastly, it might be worth assessing in future research the relationship between regulatory framework on environmental performance, treating environmental performance no more as an explanatory variable, but, on the contrary, as the dependent variable.

[23]We could not use survey data, such as the Italian Community Innovation Survey data, to assign to each Region the level of adopted green technologies, as Italian data dissemination rules do not allow to provide researchers with information about the Region of firm respondents. On the other side, Italy is the only European country to have developed a NAMEA dataset at the regional level. This future line of research is not feasible, as long as either other countries implement a regional NAMEA or Italian Statistical Office release innovation output data with regional information.

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Tables and Figures

Table 1 - Description of the variables used in the analysis

Variable	Description	Source
GT	Count of green technologies in region *i* and sector *j* at time *t*	PATSTAT-REGPAT-ORBIS- IPCC Green Inventory
GHG	Emission intensity of Greenhouse Gases (mainly CO2, CH4 and N2O), given by the natural logarithm of the ratio between GHG and the lagged real Value Added of Region *i*, Sector *j*, in *t-1*	ISTAT: regional NAMEA
ACID	Emission intensity of Acidifying Gases (mainly NOx, SOx and NH3), given by the natural logarithm of the ratio between GHG and the lagged real Value Added of Region *i*, Sector *j*, in *t-1*	ISTAT: regional NAMEA
OZ	Emission intensity of Tropospheric ozone precursors (mainly caused by NOx, COVNM, CO, CH4) given by the natural logarithm of the ratio between GHG and the lagged real Value Added of Region *i*, Sector *j*, in *t-1*	ISTAT: regional NAMEA
PM10	Emission intensity of PM10 (Particulates< 10µm), given by the natural logarithm of the ratio between GHG and the lagged real Value Added of Region *i*, Sector *j*, in *t-1*	ISTAT: regional NAMEA
KD	Natural Logarithm of knowledge diversity of Region *i*	PATSTAT-REGPAT- ORBIS
KC	Natural Logarithm of Knowledge Coherence of Region *i*	PATSTAT-REGPAT- ORBIS
PURD	Given by the natural logarithm of the ratio between Real Public R&D and Total R&D (Business R&D + Public R&D+ Universities R&D)	ISTAT
DENSITY	Given by the ratio of population in the Region *i* on the area of *i*	ISTAT
VALUE ADDED	Real Value Added of Region *i*, Sector *j*	ISTAT
EXPORT	Ratio between average Export (within European Union) 2001-2005 of Region *i* and the average Value Added Region *i*2001-2005	ISTAT
POL	Ratio between expenditure for environmental protection in 2004 of Region *i* and the Value Added Region *i*in 2004.	ISTAT

Table2–Descriptivestatistics

Variable	N	Mean	Std.Dev.	Min	Max	Skewness	Kurtosis
GT	6240	0.48	2.38	0	46	11.87	189.36
GHG	4888	1.32	1.69	4.61	3.70	0.34	2.51
ACID	4888	3.89	1.80	7.27	1.66	0.62	2.69
OZ	4888	0.53	1.64	3.33	6.24	-0.12	2.66
PM10	4888	2.67	1.75	6.45	3.17	0.47	2.64
KD	6240	160.93	134.51	5	492	0.80	2.51
KC	6240	0.25	1.60	6.41	8.50	1.70	11.21
DENSITY	5760	1.93	0.64	3.33	0.85	-0.28	2.37
VALUE ADDED	5645	2245.82	4027.98	0	51750.3	5.11	42.92
EXPORT	6240	503.67	744.59	17.01	2653.15	1.48	4.14
POL	6240	-3.05	0.42	-3.75	-2.25	0.34	1.94
PURD	5016	-1.99	0.58	-3.71	-0.61	0.01	3.63

Table 3 - Sectoral distribution of green technologies

Sector	Green Technologies	Frequency
A	15	0.5
B	8	0.27
C	141	4.72
DA	0	0
DB	25	0.84
DC	11	0.37
DD, DH, DN	255	8.55
DE	12	0.40
DF, DG	267	8.95
DI	10	0.34
DJ	139	4.66
DK, DL, DM	1165	39.07
E	58	1.94
F	47	1.58
G	162	5.43
H	0	0
I	26	0.87
J	89	2.99
K	496	16.63
L	5	0.17
M	0	0
N	8	0.27
O	43	1.44
P	0	0
Total	2982	100

Table 4 - Sectoral Distribution of Emissions

Sector	GHG	ACID	OZ	PM10
A	2310.94	1241.24	10394.16	2163.54
B	55.53	16.18	1055.83	79.58
C	87.10	5.66	391.92	21.60
DA	515.36	24.36	2857.04	65.28
DB	439.01	19.57	850.20	44.10
DC	49.11	2.51	1961.37	7.22
DD, DH, DN	255.88	13.39	4131.95	40.91
DE	343.46	5.95	1310.06	16.88
DF, DG	2259.92	233.47	7145.87	194.59
DI	2533.58	197.69	6974.56	925.33
DJ	1118.43	71.57	6612.94	932.13
DK, DL, DM	454.28	20.53	2997.93	54.91
E	7264.37	295.08	7776.65	263.64
F	195.51	20.48	4293.19	245.18
G	949.37	95.36	7228.23	433.37
H	142.16	12.19	771.24	46.31
I	2084.62	389.56	18668.91	1183.43
J	51.23	4.61	288.89	19.23
K	358.60	36.88	2338.24	162.16
L	151.17	20.88	1604.82	93.99
M	48.29	2.95	160.13	7.89
N	152.18	6.99	401.75	19.75
O	1154.80	47.16	2879.42	68.46
P	-	-	-	-
Total	1011.38	122.44	4087.16	311.26

Table 5 - Spearman's Rank Correlation coefficient

	GT	KD	KC	VA	GHG	ACID	OZ	PM10	PURD	EXP	POL	DENSITY
GT	1											
KD	0.3582*	1										
KC	0.0974*	0.1679*	1									
VA	0.3214*	0.5899*	0.0214	1								
GHG	-0.0516*	-0.0748*	-0.0149	-0.4320*	1							
ACID	-0.0811*	-0.1082*	-0.0186	-0.3786*	0.9212*	1						
OZ	-0.0541*	-0.0931*	-0.0323*	-0.4650*	0.8623*	0.8608*	1					
PM10	-0.0792*	-0.1231*	-0.0283	-0.3261*	0.7536*	0.8970*	0.8084*	1				
PURD	-0.0649*	-0.2073*	0.0636*	-0.0791*	0.0311*	0.0464*	0.0654*	0.0458*	1			
EXP	-0.0821*	-0.2608*	-0.1258*	-0.2485*	0.0224	0.0313*	0.0274	0.0522*	-0.1205*	1		
POL	-0.2951*	-0.8338*	-0.2086*	-0.4785*	0.0693*	0.1139*	0.0908*	0.1115*	0.2609*	0.2496*	1	
DENSITY	0.2429*	0.6759*	0.0014	0.5372*	-0.0861*	-0.0881*	-0.0468*	-0.0779*	0.0403*	-0.1591*	-0.5226*	1

Table 6 - Econometric results (I)

VARIABLES	(I) GT	(II) GT	(III) GT	(IV) GT
KD	-0.0122	0.0607	0.0111	0.0334
	(0.166)	(0.161)	(0.166)	(0.162)
KC	1.454***	1.257***	1.306***	1.209***
	(0.388)	(0.370)	(0.382)	(0.373)
GHG	0.180***			
	(0.0659)			
W*GHG	-0.147**			
	(0.0590)			
PM10		0.0418		
		(0.0583)		
W*PM10		-0.179***		
		(0.0656)		
OZ			0.139	
			(0.0921)	
W*OZ			-0.175**	
			(0.0724)	
ACID				0.192***
				(0.0622)
W*ACID				-0.315***
				(0.0562)
VALUE ADDED	0.000110***	0.000104***	0.000104***	9.36e-05***
	(1.05e-05)	(9.72e-06)	(1.02e-05)	(9.78e-06)
PURD	0.0297	0.0665	0.0757	0.0963
	(0.102)	(0.0985)	(0.101)	(0.101)
DENSITY	0.403***	0.322**	0.424***	0.438***
	(0.146)	(0.141)	(0.145)	(0.143)
POL	0.527**	0.662***	0.644**	0.699***
	(0.259)	(0.254)	(0.260)	(0.257)
EXPORT	1.53e-05	0.000112	0.000111	1.43e-05
	(0.000139)	(0.000137)	(0.000139)	(0.000136)
Constant	-2.195	-1.839	-1.454	-1.307
	(1.378)	(1.350)	(1.367)	(1.382)
Time Dummies	Yes	Yes	Yes	Yes
Regional Dummies	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes
InteractionEmission*Region	Yes	Yes	Yes	Yes
		INFLATE		
Pat-id	-1.196***	-1.234***	-1.202***	-1.357***
	(0.22)	(0.24)	(0.22)	(0.27)
Observations	4.089	4.089	4.089	4.089
Log-Likelihood	-2343.263	-2317.960	-2335.155	-2325.992
Pr>LR	0.00	0.00	0.00	0.00
McFadden's Adj R^2	0.262	0.270	0.265	0.268
AIC	1.163	1.151	1.159	1.155
Likelihood-ratio test α=0 (Chi^2)	689.24	366.83	513.99	607.56
Pr>Chi^2	0.00	0.00	0.00	0.00
Vuong Test (z)	12.90	12.95	12.61	12.87
Pr>z	0.00	0.00	0.00	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7 - Econometric results (II)

VARIABLES	(I) GT	(II) GT	(III) GT	(IV) GT
KD	-0.00141	0.356**	0.0177	0.0372
	(0.167)	(0.155)	(0.167)	(0.164)
KC	1.409***	1.046***	1.200***	1.259***
	(0.389)	(0.341)	(0.383)	(0.379)
GHG	0.158**			
	(0.0658)			
W*GHG	-0.0732			
	(0.0471)			
PM10		-0.0170		
		(0.0569)		
W*PM10		0.0539		
		(0.0589)		
OZ			0.0494	
			(0.0910)	
W*OZ			-0.0185	
			(0.0630)	
ACID				0.141**
				(0.0615)
W*ACID				-0.168***
				(0.0464)
VA	0.000117***	9.26e-05***	0.000112***	0.000109***
	(1.00e-05)	(7.94e-06)	(9.97e-06)	(9.63e-06)
PURD	0.0109	-0.0448	0.0538	0.0588
	(0.101)	(0.0959)	(0.101)	(0.101)
DENSITY	0.370**	0.369***	0.371**	0.387***
	(0.145)	(0.138)	(0.144)	(0.143)
POL	0.521**	0.716***	0.612**	0.682***
	(0.259)	(0.242)	(0.261)	(0.259)
EXPORT	4.18e-05	0.000288**	0.000135	7.59e-05
	(0.000139)	(0.000134)	(0.000139)	(0.000137)
Constant	-2.283*	-2.015	-1.547	-1.475
	(1.384)	(1.318)	(1.373)	(1.395)
Time Dummies	Yes	Yes	Yes	Yes
Regional Dummies	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes
InteractionEmission*Region	Yes	Yes	Yes	Yes
		INFLATE		
Pat-id	-1.195***	-0.174***	-1.209***	-1.336***
	(0.214)	(0.028)	(0.212)	(0.248)
Observations	4.089	4.089	4.089	4.089
Log-Likelihood	-2345.138	-2325.545	-2338.005	-2334.825
Pr>LR	0.00	0.00	0.00	0.00
McFadden's Adj R^2	0.262	0.269	0.264	0.265
AIC	1.164	1.155	1.161	1.159
Likelihood-ratio test α=0 (Chi^2)	739.44	422.92	563.22	683.12
Pr>Chi^2	0.00	0.00	0.00	0.00
Vuong Test (z)	13.18	11.32	12.92	12.99
Pr>z	0.00	0.00	0.00	0.00

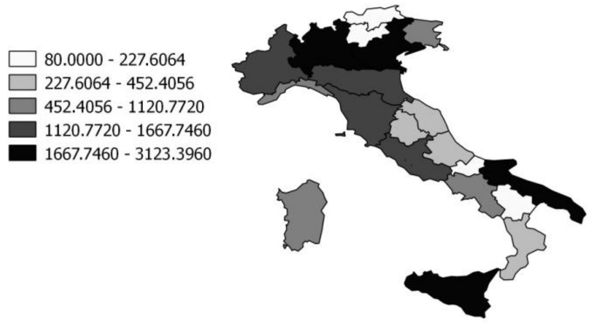
Note: weighting matrix cutoff at the 75^{th} percentile.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 8 - Econometric results (III)

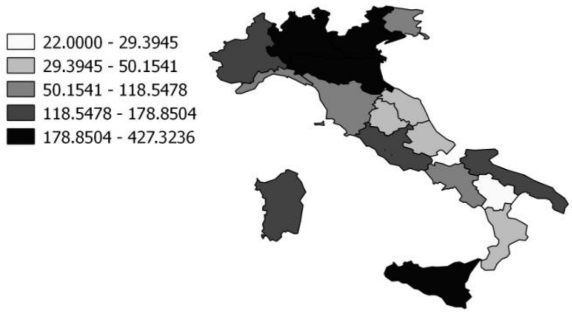
VARIABLES	(I) GT	(II) GT	(III) GT	(IV) GT
KD	0.0357	0.174	0.0613	0.0641
	(0.170)	(0.164)	(0.168)	(0.166)
KC	1.305***	1.270***	1.263***	1.268***
	(0.384)	(0.369)	(0.385)	(0.381)
GHG	0.130*			
	(0.0719)			
W*GHG	-0.000156			
	(0.0552)			
PM10		-0.0599		
		(0.0584)		
W*PM10		0.129***		
		(0.0436)		
OZ			0.118	
			(0.0940)	
W*OZ			-0.102	
			(0.0698)	
ACID				0.207***
				(0.0669)
W*ACID				-0.174***
				(0.0453)
VA	0.000121***	0.000112***	0.000114***	0.000119***
	(9.87e-06)	(9.17e-06)	(9.83e-06)	(9.56e-06)
PURD	0.0195	0.0554	0.0842	0.0605
	(0.102)	(0.0988)	(0.101)	(0.101)
DENSITY	0.315**	0.233*	0.322**	0.282**
	(0.146)	(0.141)	(0.144)	(0.143)
POL	0.526**	0.534**	0.714***	0.731***
	(0.260)	(0.256)	(0.265)	(0.261)
EXPORT	5.96e-05	0.000188	0.000140	5.19e-05
	(0.000140)	(0.000139)	(0.000140)	(0.000139)
Constant	-2.272	-2.531*	-1.690	-1.577
	(1.398)	(1.373)	(1.382)	(1.405)
Time Dummies	Yes	Yes	Yes	Yes
Regional Dummies	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes
InteractionEmission*Region	Yes	Yes	Yes	Yes
		INFLATE		
Pat-id	-1.138***	-1.070***	-1.1794***	-1.2968***
	(0.200)	(0.207)	(0.204)	(0.232)
Observations	3.959	3.959	3.959	3.959
Log-Likelihood	-2321.158	-2291.276	-2310.022	-2309.103
Pr>LR	0.00	0.00	0.00	0.00
McFadden's Adj R^2	0.260	0.270	0.264	0.264
AIC	1.190	1.175	1.185	1.184
Likelihood-ratio test α=0 (Chi^2)	801.52	381.79	587.68	721.35
Pr>Chi^2	0.00	0.00	0.00	0.00
Vuong Test (z)	13.11	12.88	12.82	12.95
Pr>z	0.00	0.00	0.00	0.00

Note: weighting matrix cutoff at the 90^{th} percentile.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

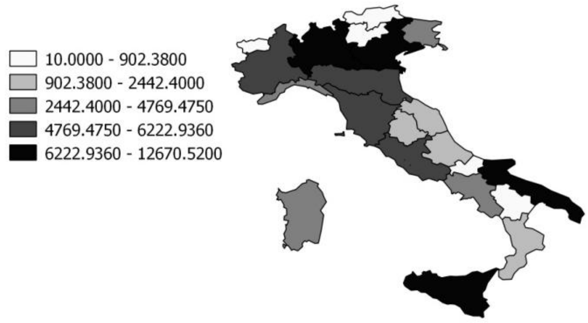
Figure 1 - Regional Distribution of MainEmissions



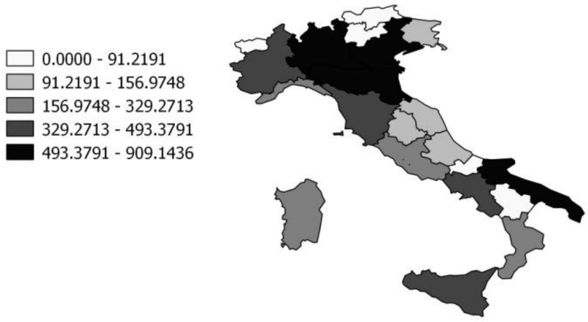
GHG



ACID



OZ



PM10

APPENDIX

Table A1: Econometric results Poisson and Negative Binomial

VARIABLES	POISSON (I)	POISSON (II)	POISSON (III)	POISSON (IV)	NB (I)	NB (II)	NB (III)	NB (IV)
KD	0.852***	0.858***	0.868***	0.793***	0.819***	0.806***	0.787***	0.824***
	(0.106)	(0.104)	(0.104)	(0.104)	(0.144)	(0.142)	(0.144)	(0.143)
KC	1.198***	0.913***	0.990***	0.710***	1.196***	1.037***	1.157***	1.024***
	(0.194)	(0.194)	(0.195)	(0.196)	(0.306)	(0.301)	(0.307)	(0.302)
ACID				0.186***				0.155***
				(0.0352)				(0.0575)
W*ACID				-0.642***				-0.370***
				(0.0314)				(0.0510)
GHG	0.223***				0.137**			
	(0.0347)				(0.0612)			
W*GHG	-0.704***				-0.252***			
	(0.0366)				(0.0517)			
OZ			0.101*				0.202**	
			(0.0527)				(0.0801)	
W*OZ			-0.694***				-0.369***	
			(0.0426)				(0.0609)	
PM10		0.0252				0.0950*		
		(0.0395)				(0.0566)		
W*PM10		-0.583***				-0.301***		
		(0.0346)				(0.0567)		
VALUE ADDED	8.23e-05***	9.18e-05***	8.67e-05***	8.20e-05***	0.000149***	0.000155***	0.000152***	0.000139***
	(2.65e-06)	(2.50e-06)	(2.59e-06)	(2.57e-06)	(1.18e-05)	(1.15e-05)	(1.17e-05)	(1.13e-05)
PURD	0.185***	0.157***	0.178***	0.256***	0.215**	0.205**	0.229**	0.246***
	(0.0609)	(0.0601)	(0.0606)	(0.0614)	(0.0953)	(0.0935)	(0.0947)	(0.0944)
DENSITY	0.463***	0.299***	0.462***	0.438***	0.208	0.172	0.275**	0.242*
	(0.0857)	(0.0848)	(0.0854)	(0.0857)	(0.136)	(0.133)	(0.135)	(0.133)
POL	0.569***	0.825***	0.733***	0.724***	0.507**	0.639***	0.610**	0.715***
	(0.157)	(0.157)	(0.156)	(0.157)	(0.246)	(0.245)	(0.246)	(0.246)
EXPORT	0.000224**	0.000217**	0.000316***	0.000246***	0.000132	0.000180	0.000189	0.000136
	(8.92e-05)	(8.90e-05)	(8.99e-05)	(8.97e-05)	(0.000130)	(0.000129)	(0.000130)	(0.000129)

Constant	-7.384***	-6.717***	-5.602***	-6.191***	-7.463***	-6.870***	-6.613***	-6.689***
	(0.845)	(0.846)	(0.850)	(0.838)	(1.250)	(1.238)	(1.247)	(1.249)
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
InteractionEmission*Region	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4.089	4.089	4.089	4.089	4.089	4.089	4.089	4.089
Log-Likelihood	-3344.468	-3263.084	-3337.838	-3254.477	-2590.990	-2580.474	-2590.835	-2575.387
Pr>LR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
McFadden'sAdj R^2	0.499	0.511	0.509	0.513	0.186	0.189	0.186	0.191
AIC	1.651	1.612	1.648	1.607	1.283	1.278	1.283	1.276
Likelihood-ratio test $\alpha=0$ (Chi^2)	-	-	-	-	1506.95	1365.22	1494.01	1358.18
Pr>Chi^2	-	-	-	-	0.00	0.00	0.00	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2 – Sectoral Classification

Sector NACE REV 1.1	Description
A	Agriculture, hunting and forestry
B	Fishing
C	Mining and quarrying
DA	Manufacture of food products, beverages and tobacco
DB	Manufacture of textiles and textile products
DC	Manufacture of leather and leather products
DD, DH, DN	Manufacture of wood and wood products; Manufacture of rubber and plastic products; Other manufacture
DE	Manufacture of pulp, paper and paper products; publishing and printing
DF, DG	Manufacture of coke, refined petroleum products and nuclear fuel; Manufacture of chemicals, chemical products and man-made fibres
DI	Manufacture of other non-metallic mineral products
DJ	Manufacture of basic metals and fabricated metal products
DK, DL, DM	Manufacture of machinery and equipment n.e.c.; Manufacture of electrical and optical equipment; Manufacture of transport equipment
E	Electricity, gas and water supply
F	Construction
G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
H	Hotels and restaurants
I	Transport, storage and communication
J	Financial intermediation
K	Real estate, renting and business activities
L	Public administration and defence; compulsory social security
M	Education
N	Health and social work
O	Other community, social and personal service activities
P	Activities of households

Table A3 – WIPO IPC Green Inventory

TOPIC	IPC
ALTERNATIVE ENERGY PRODUCTION	
Bio-fuels	
Solid fuels	C10L 5/00, 5/40-5/48
Torrefaction of biomass	C10B 53/02
	C10L 5/40, 9/00
Liquid fuels	C10L 1/00, 1/02, 1/14
Vegetableoils	C10L 1/02, 1/19
Biodiesel	C07C 67/00, 69/00
	C10G
	C10L 1/02, 1/19
	C11C 3/10
	C12P 7/64
Bioethanol	C10L 1/02, 1/182
	C12N 9/24
	C12P 7/06-7/14
Biogas	C02F 3/28, 11/04
	C10L 3/00
	C12M 1/107
	C12P 5/02
From geneticallyengineeredorganisms	C12N 1/13, 1/15, 1/21, 5/10, 15/00 A01H
Integrated gasification combined cycle (IGCC)	C10L 3/00
	F02C 3/28
Fuelcells	H01M 4/86-4/98, 8/00-8/24, 12/00-12/08
Electrodes	H01M 4/86-4/98
Inert electrodes with catalytic activity	H01M 4/86-4/98
Non-activeparts	H01M 2/00-2/04 , 8/00-8/24
Withinhybridcells	H01M 12/00-12/08
Pyrolysis or gasification of biomass	
	C10B 53/00
	C10J
Harnessing energy from manmade waste	
Agriculturalwaste	C10L 5/00
Fuel from animal waste and crop residues	C10L 5/42, 5/44
Incinerators for field, garden or wood waste	F23G 7/00, 7/10
Gasification	C10J 3/02, 3/46
	F23B 90/00
	F23G 5/027

TOPIC	IPC
Chemicalwaste	B09B 3/00
	F23G 7/00
Industrial waste	C10L 5/48
	F23G 5/00, 7/00
Using top gas in blast furnaces to power pig-iron production	C21B 5/06
Pulp liquors	D21C 11/00
Anaerobic digestion of industrial waste	A62D 3/02
	C02F 11/04, 11/14
Industrial woodwaste	F23G 7/00, 7/10
Hospital waste	B09B 3/00
	F23G 5/00
Landfill gas	B09B
Separation of components	B01D 53/02, 53/04, 53/047, 53/14, 53/22, 53/24
Municipalwaste	C10L 5/46
	F23G 5/00
Hydroenergy	
Water-powerplants	E02B 9/00-9/06
Tide or wave power plants	E02B 9/08
Machines or engines for liquids	F03B
	F03C
Using wave or tide energy	F03B 13/12-13/26
Regulating, controlling or safety means of machines or engines	F03B 15/00-15/22
Propulsion of marine vessels using energy derived from water movement	B63H 19/02, 19/04
Ocean thermal energy conversion (OTEC)	F03G 7/05
Wind energy	F03D
Structural association of electric generator with mechanical driving motor	H02K 7/18
Structural aspects of wind turbines	B63B 35/00
	E04H 12/00
	F03D 11/04
Propulsion of vehicles using wind power	B60K 16/00
Electric propulsion of vehicles using wind power	B60L 8/00
Propulsion of marine vessels by wind-powered motors	B63H 13/00
Solar energy	
Photovoltaics (PV)	
Devices adapted for the conversion of radiation energy into electrical energy	H01L 27/142, 31/00-31/078 H01G 9/20
	H02N 6/00
Using organic materials as the active part	H01L 27/30, 51/42-51/48
Assemblies of a plurality of solar cells	H01L 25/00, 25/03, 25/16, 25/18, 31/042
Silicon; single-crystalgrowth	C01B 33/02

TOPIC	IPC
	C23C 14/14, 16/24
	C30B 29/06
Regulating to the maximum power available from solar cells	G05F 1/67
Electric lighting devices with, or rechargeable with, solar cells	F21L 4/00
	F21S 9/03
Chargingbatteries	H02J 7/35
Dye-sensitised solar cells (DSSC)	H01G 9/20
	H01M 14/00
Use of solar heat	F24J 2/00-2/54
For domestic hot water systems	F24D 17/00
For spaceheating	F24D 3/00, 5/00, 11/00, 19/00
For swimming pools	F24J 2/42
Solar updrafttowers	F03D 1/04, 9/00, 11/04
	F03G 6/00
For treatment of water, waste water or sludge	C02F 1/14
Gas turbine power plants using solar heat source	F02C 1/05
Hybrid solar thermal-PV systems	H01L 31/058
Propulsion of vehicles using solar power	B60K 16/00
Electric propulsion of vehicles using solar power	B60L 8/00
Producing mechanical power from solar energy	F03G 6/00-6/06
Roof covering aspects of energy collecting devices	E04D 13/00, 13/18
Steam generation using solar heat	F22B 1/00
	F24J 1/00
Refrigeration or heat pump systems using solar energy	F25B 27/00
Use of solar energy for drying materials or objects	F26B 3/00, 3/28
Solar concentrators	F24J 2/06
	G02B 7/183
Solar ponds	F24J 2/04
Geothermalenergy	
Use of geothermalheat	F01K
	F24F 5/00
	F24J 3/08
	H02N 10/00
	F25B 30/06
Production of mechanical power from geothermal energy	F03G 4/00-4/06, 7/04
Other production or use of heat, not derived from combustion, e.g. natural heat	F24J 1/00, 3/00, 3/06
Heat pumps in central heating systems using heat accumulated in storage masses	F24D 11/02
Heat pumps in other domestic- or space-heating systems	F24D 15/04
Heat pumps in domestic hot-water supply systems	F24D 17/02
Air or water heaters using heat pumps	F24H 4/00

TOPIC	IPC
Heatpumps	F25B 30/00
Using wasteheat	
To produce mechanicalenergy	F01K 27/00
Of combustionengines	F01K 23/06-23/10
	F01N 5/00
	F02G 5/00-5/04
	F25B 27/02
Of steamengineplants	F01K 17/00, 23/04
Of gas-turbine plants	F02C 6/18
As source of energy for refrigeration plants	F25B 27/02
For treatment of water, waste water or sewage	C02F 1/16
Recovery of waste heat in paper production	D21F 5/20
For steam generation by exploitation of the heat content of hot heat carriers	F22B 1/02
Recuperation of heat energy from waste incineration	F23G 5/46
Energy recovery in air conditioning	F24F 12/00
Arrangements for using waste heat from furnaces, kilns, ovens or retorts	F27D 17/00
Regenerativeheat-exchangeapparatus	F28D 17/00-20/00
Of gasificationplants	C10J 3/86
Devices for producing mechanical power from muscle energy	F03G 5/00-5/08
TRANSPORTATION	
Vehicles in general	
Hybrid vehicles, e.gHybrid Electric Vehicles (HEVs)	B60K 6/00, 6/20
Control systems	B60W 20/00
Gearingstherefor	F16H 3/00-3/78, 48/00-48/30
Brushlessmotors	H02K 29/08
Electromagneticclutches	H02K 49/10
Regenerativebrakingsystems	B60L 7/10-7/22
Electric propulsion with power supply from force of nature, e.g. sun, wind	B60L 8/00
Electric propulsion with power supply external to vehicle	B60L 9/00
With power supply from fuel cells, e.gfor hydrogen vehicles	B60L 11/18
Combustion engines operating on gaseous fuels, e.ghydrogen	F02B 43/00
	F02M 21/02, 27/02
Power supply from force of nature, e.g. sun, wind	B60K 16/00
Charging stations for electric vehicles	H02J 7/00
Vehicles other than rail vehicles	
Drag reduction	
	B62D 35/00, 35/02
	B63B 1/34-1/40
Human-poweredvehicle	B62K
	B62M 1/00, 3/00, 5/00, 6/00

TOPIC	IPC
Railvehicles	B61
Drag reduction	B61D 17/02
Marine vessel propulsion	
Propulsive devices directly acted on by wind	B63H 9/00
Propulsion by wind-powered motors	B63H 13/00
Propulsion using energy derived from water movement	B63H 19/02, 19/04
Propulsion by musclepower	B63H 16/00
Propulsion derived from nuclear energy	B63H 21/18
Cosmonautic vehicles using solar energy	B64G 1/44
ENERGY CONSERVATION	
Storage of electricalenergy	B60K 6/28
	B60W 10/26
	H01M 10/44-10/46
	H01G 9/155
	H02J 3/28, 7/00, 15/00
Powersupplycircuitry	H02J
With powersavingmodes	H02J 9/00
Measurement of electricityconsumption	B60L 3/00
	G01R
Storage of thermalenergy	C09K 5/00
	F24H 7/00
	F28D 20/00, 20/02
Lowenergylighting	
Electroluminescent light sources (e.g. LEDs, OLEDs, PLEDs)	F21K 99/00
	F21L 4/02
	H01L 33/00-33/64, 51/50
	H05B 33/00
Thermal building insulation, in general	E04B 1/62, 1/74-1/80, 1/88, 1/90
Insulating building elements	E04C 1/40, 1/41, 2/284-2/296
For door or window openings	E06B 3/263
For walls	E04B 2/00
	E04F 13/08
For floors	E04B 5/00
	E04F 15/18
For roofs	E04B 7/00
	E04D 1/28, 3/35, 13/16
For ceilings	E04B 9/00
	E04F 13/08
Recoveringmechanicalenergy	F03G 7/08
Chargeable mechanical accumulators in vehicles	B60K 6/10, 6/30
	B60L 11/16

TOPIC	IPC
WASTE MANAGEMENT	
Waste disposal	B09B
	B65F
Treatment of waste	
Disinfection or sterilisation	A61L 11/00
Treatment of hazardous or toxic waste	A62D 3/00, 101/00
Treating radioactively contaminated material; decontamination arrangements therefor	G21F 9/00
Refuseseparation	B03B 9/06
Reclamation of contaminatedsoil	B09C
Mechanical treatment of waste paper	D21B 1/08, 1/32
Consumingwaste by combustion	F23G
Reuse of wastematerials	
Use of rubber waste in footwear	A43B 1/12, 21/14
Manufacture of articles from waste metal particles	B22F 8/00
Production of hydraulic cements from waste materials	C04B 7/24-7/30
Use of waste materials as fillers for mortars, concrete	C04B 18/04-18/10
Production of fertilisers from waste or refuse	C05F
Recovery or working-up of waste materials	C08J 11/00-11/28
	C09K 11/01
	C11B 11/00, 13/00-13/04
	C14C 3/32
	C21B 3/04
	C25C 1/00
	D01F 13/00-13/04
Pollution control	
Carbon capture and storage	B01D 53/14, 53/22, 53/62
	B65G 5/00
	C01B 31/20
	E21B 41/00, 43/16
	E21F 17/16
	F25J 3/02
Air quality management	
Treatment of wastegases	B01D 53/00-53/96
Exhaust apparatus for combustion engines with means for treating exhaust	F01N 3/00-3/38
Renderingexhaustgasesinnocuous	B01D 53/92
	F02B 75/10
Removal of waste gases or dust in steel production	C21C 5/38
Combustion apparatus using recirculation of flue gases	C10B 21/18
	F23B 80/02
	F23C 9/00

TOPIC	IPC
Combustion of waste gases or noxious gases	F23G 7/06
Electrical control of exhaust gas treating apparatus	F01N 9/00
Separating dispersed particles from gases or vapours	B01D 45/00-51/00
	B03C 3/00
Dustremoval from furnaces	C21B 7/22
	C21C 5/38
	F27B 1/18
	F27B 15/12
Use of additives in fuels or fires to reduce smoke or facilitate soot removal	C10L 10/02, 10/06
	F23J 7/00
Arrangements of devices for treating smoke or fumes from combustion apparatus	F23J 15/00
Dust-laying or dust-absorbing materials	C09K 3/22
Pollutionalarms	G08B 21/12
Control of water pollution	
Treating waste-water or sewage	B63J 4/00
	C02F
To produce fertilisers	C05F 7/00
Materials for treating liquid pollutants	C09K 3/32
Removing pollutants from open water	B63B 35/32
	E02B 15/04
Plumbing installations for waste water	E03C 1/12
Management of sewage	C02F 1/00, 3/00, 9/00
	E03F
Means for preventing radioactive contamination in the event of reactor leakage	G21C 13/10
AGRICULTURE / FORESTRY	
Forestrytechniques	A01G 23/00
Alternative irrigationtechniques	A01G 25/00
Pesticidealternatives	A01N 25/00-65/00
Soilimprovement	C09K 17/00
	E02D 3/00
Organic fertilisers derived from waste	C05F
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS	
Commuting, e.g., HOV, teleworking, etc.	G06Q
	G08G
Carbon/emissions trading, e.gpollution credits	G06Q
Staticstructure design	E04H 1/00

TOPIC	IPC
NUCLEAR POWER GENERATION	
Nuclearengineering	G21
Fusion reactors	G21B
Nuclear (fission) reactors	G21C
Nuclearpowerplant	G21D
Gas turbine power plants using heat source of nuclear origin	F02C 1/05