Beyond inducement in climate change: Does environmental performance spur environmental technologies?

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Does environmental performance spur environmental technologies?
A regional analysis of cross-sectoral differences.

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ABSTRACT

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

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

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

1 Introduction

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

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

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

This paper aims at contributing to this strand of literature by adopting a different and yet complementary perspective on the inducement mechanism. We investigate the extent to which, in a context with a weak environmental regulatory framework, an inducement of environmental technologies can still be at stake. In such a framework, inducement could indeed be *endogenous* rather than *exogenous*. Instead of investigating the direct relationship between an inducing factor (mainly an environmental policy) and the generation of green technologies, as previous literature has done, we posit that it is important to understand if and to which extent such *endogenous* mechanisms are set in motion as a response to environmental performance. In articulating this hypothesis, we provide an interpretation of how those *endogenous* mechanisms work by appreciating the distinction between direct inducement and that exerted by related sectors. To understand the latter, we need to stress the differences and complementarities between the adoption of greener technologies and their generation processes. For the latter, we argue that inducement mechanisms are likely to work through user-producer dynamics based on the derived demand of polluting agents for cleaner technologies rather than through their direct innovating efforts. We put particular emphasis on the importance of vertical linkages and the role of *derived demand* in stimulating the generation of green technologies since environmental innovations may be endogenously pulled by the derived demand of vertically related sectors featuring bad environmental performance. To test for this, we implement a synthetic measure of vertical relatedness across sectors based on input-output tables.

Cross-sectoral analysis is carried out on a panel of Italian regions observed over the time span 2003-2007, and is based on matching of the regional National Accounting Matrix with

Environmental Accounts (henceforth NAMEA) data, patent data and regional economic accounts. The econometric results, obtained by implementing a zero-inflated binomial model for count data variables, identify interesting and persistent patterns of inducement for different classes of emissions. Environmental performance of vertically related sectors, proxied by emission intensities in terms of value added, exerts a positive impact on the generation of green technologies. This would support the hypothesis that sectors with higher levels of green innovativeness are stimulated to generate green knowledge by the demand coming from vertically related sectors with bad environmental performance.

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

2 Induced technological change and derived demand for environmental innovations

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

[1]Habbakuk (1962) provided support to this hypothesis showing how, in American and British historic evidence through the nineteenth century, labour scarcity pushed firms to generate and introduce labour-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 labour-saving and capital-saving innovations can be traced. The relative costs of capital and labour shape the isorevenue that enables identification of an optimum direction of technological change (Binswanger andRuttan, 1978). The approach has been criticized for the lack of microeconomic foundations by Salter (1966), but remains 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.

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

in the institutional system and will for this reason be labelled as exogenous in this paper. The correlation between environmental regulation and technological change has been empirically investigated either by using patent data to test whether regulation affected knowledge generation[3] (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, 2009). In both cases, evidence confirms that regulation exerts a positive effect on innovation.

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

Moreover, the regulatory push/pull framework may have different effects across different typologies of environmental innovations (Rennings and Rammer, 2009; Rexhäuser and Rammer, 2013) and different policy frameworks[5] may generate different innovative outcomes (Popp et al., 2009). What is more, the stringency, predictability, flexibility, incidence and depth of the policy

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

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

[5] 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)

instruments impact on the effort and direction of the innovations (Johnstone et al., 2010b) although the measurement of these elements is not an easy task (Kemp and Pontoglio, 2011).
In contexts characterized by weak environmental regulatory frameworks and/or barriers to policy enforcement, the inducement may come from within the economic system (*endogenous*) rather than from the institutions (*exogenous*).

A step forward in the identification of the endogenous incentive for firms to generate green technologies is represented by the literature on corporate social responsibility (CSR)[6]. As remarked by Orlitzky et al. (2011), although 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 such as moral appeal, sustainability and reputation are particularly relevant in shaping the choice of firms to adopt environment-friendly behaviour. 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 whereas the main inducing factor relates to the likelihood of improving firms' performance through market evaluation.

These positive business performance effects of firms' environmental innovation strategies have been systematically assessed by Ambec and Lanoie (2008) who explicitly analysed the channels through which environmental practices are improving firms' financial performance. 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 labour" (Ambec and Lanoie, 2008: 46).To sum up, consistently with the broader CSR approach, environmental responsibility may affect firms' financial returns by allowing the development of new markets, the increase of the market value of publicly traded firms, the reduction of consumer boycotts and the attraction of active consumers[7]. Moreover, a proactive environmental management may also reduce the risks associated with potential regulatory and legal actions (Lee, 2008).

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[6]The origins of this approach date 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 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 and Walsh, 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). Unlike 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. Consequently, the social and economic goals of a corporation are strictly intertwined. The grafting of the CSR onto the stakeholder theory has allowed the scope of the concept of CSR to be widened to include environmental responsibility, diversity, affirmative action, transparent accounting, etc. (Jones, 1995; Clarkson, 1995; Berman et al., 1999).
[7]This makes CSR closely related to the concept of sustainable consumption (Sanne, 2002; Gilg et al., 2005).

The inducement hypothesis in climate change, by stressing the impact of changes in the regulatory framework on firms' costs, can thus be read as an application of a price-inducement argument to the price of polluting production technologies (Lichtenberg, 1986; Antonelli, 1998). The mechanisms through which the adoption of an environmental regulation is translated into an increase in environmental innovations are to our knowledge still not fully explored. Indeed, it is worth stressing that patent statistics are a reliable proxy of inventive activity, but not of adoption, since polluting firms under a stringent regulation may be willing to adopt green technologies, but they do not always have the necessary competences to generate them. In such cases, the pressure from regulation can engender a *derived demand* of green technologies.

The interplay between the classical inducement mechanism and the derived demand pull dynamics (Schmookler, 1957) allows the relevance of vertical linkages to be stressed (as in Cainelli and Mazzanti, 2013) and gives rise to an extended inducement hypothesis. Downstream firms confronted with stringent regulatory frameworks resort to upstream firms for the supply of new and more environment-friendly technologies in the production process. A stringent regulatory framework thus alters the relative prices of production processes, inducing firms to redefine the characteristics of the intermediate goods they buy on factors' markets[8]. The interactions between users and producers therefore matter in shaping the ultimate effects of the inducement mechanism, in a way that the generation and the adoption of new technologies become strictly complementary (von Hipple, 1988; Lundvall, 1992; Nelson, 1993; Antonelli, 2006; Castellacci, 2008).

In view of the arguments articulated so far, we are now able to spell out our working hypothesis. Inducement mechanisms play a crucial role in the generation of new technological knowledge, especially in the domain of green technologies. The interplay between price-inducement and derived demand-pull mechanisms brings vertical linkages to the centre of our analysis, where the generation of new technologies is likely to be triggered by the derived demand of polluting firms for technologies that improve their environmental performance.

However, the relevance of these inducement mechanisms 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, i.e. internal to the economic system, rather than by the *exogenous* ones, i.e. lying in the policy realm. In particular we hereby mainly consider as *endogenous* mechanisms the following co-occurring mechanism: the social responsibility of firms that are responsible for the emissions of pollutants and the opportunistic behaviour of pre-emptive response to a future regulation.

[8] Alternatively, one can look at the inducement mechanisms as the result of the movement of firms across the Lancastrian space representing the features of the intermediate goods they employ in the production process (Lancaster, 1966)

The paper raises the basic question as to what extent an inducement of environment-related inventing activities may also be depicted in those contexts characterized by weak (*exogenous*) policy inducements. We further draw on this intuition and test on the one hand whether, in the presence of weak policy inducement, some *endogenous* inducement mechanisms are at stake. In particular, we analyse on the one handwhether the generation of green technologies is directly affected by regional and sectoral environmental performance. On the other hand, we test whether vertical relationships are important in that environment-related inventing activities may benefit from an endogenous inducement from downstream firms operating in vertically related sectors To the best of our knowledge, no previous attempts have been made to investigate the inducement environmental region/sector composition plays on the generation on knowledge.

In line with the local dimension of stakeholder 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 inducing the generation of green technologies in upstream sectors, as compared with others, either as a side-effect of their expectation of future stringent regulations or as an effect of increasing environmental responsibility. In other terms, we test whether sectoral environmental performance in the sampled regions is likely to affect sectoral generation of green technologies. More precisely, we hypothesize that environmental performance generated by closely (vertically) related sectors affects green innovative activities whereas the sectors in which the generation of green technologies occurs are also likely to be characterized by better environmental performance.

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. We have argued that in an environmental policy weak context, it may not be appropriate to focus on the regulatory framework since it is more likely that only *endogenous* inducement mechanisms will be set in motion. Although Italy presents one of the higher levels in the amount of environmental taxes[9], we have chosen this country as an environmental policy weak context for the reasons we are now going to discuss. Although Italy is part of a broader European environmental policy framework, country heterogeneities are still at stake and depend on the way policies are implemented. Any policy framework may vary

[9] Italy is the third country, after Germany and United Kingdom, in the level (in absolute terms) of environmental taxes in ranking Eurostat data on Environmental tax revenue for European countries in the last available year (2011) and its position in terms of GDP lies in the middle of the rank. These data include all environmental taxes in the following fields: Energy, Transport, Pollution and Resources (Eurostat: Environmental tax revenue). Since high energy prices can induce green innovations (e.g. Popp, 2001), and the presence of high energy taxes (as is the case of Italy) raises the costs of energy consumption, we will control for the role of energy consumption as a robustness check in our empirical analysis, to be sure that our assumption of weak policy is not engendering a bias in our estimation deriving from omission of the role of energy consumption. See estimation results in Table 7.

according to its characteristics such as its stringency, certainty, incidence, depth and flexibility (for a discussion, see Haščič et al, 2009) and what makes the difference in terms of inducement is not the existence of an environmental policy *per se,* but relative policy stringency. In this respect, Italy is one of the countries reporting lower levels in the indicator of policy stringency[10] (Haščič et al, 2009). Furthermore, higher levels of corruption reduce the stringency of an environmental policy (Damania et al., 2003), and Italy is one of the European countries performing worst in terms of controls of corruption[11]. The country also presents lower levels in stability and transparency[12] of the environmental policy compared with other OECD countries (Johnstone et al., 2010b). Lastly, it does not report many environmental instruments, with the exception of the EU ETS ("European Trading Scheme") sectors which fall under the EU ETS Directive, and the relatively high level of environmental taxes we outlined before.

When assessing the role of the policy framework in the Italian context on emission 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, 2013: 22).

For these reasons, it is more likely that, in such a context, pressures - if any - to improve the environmental performance 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 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, with its overall GHG emissions reduced by only 3.5%[13] (UNFCCC). Most importantly, it is the European

[10] The study by Haščič et al. (2009) uses data from the World Economic Forum's Executive Opinion Survey to assess both the level of flexibility and stringency across a set of selected countries in the period 2001-2006. For both indicators, which are highly correlated, Italy is performing averagely worse than the other European Countries, with an index of 4.95 for stringency and 3.77 for flexibility in a Likert scale ranging from 1 to 7 (with 7 being the most stringent regime). If we think of the well known case of the Ilva steel production plant in Taranto (Italy), we can find an example which corroborates our assumption of weaknesses (to be fair) in the enforcement of an Italian environmental policy.

[11] In ranking data of the World Bank - Worldwide Governance Indicators- we see that Italy reports for 2011 (the last year available) a value in the indicator on the control of Corruption of -0.007, which is greater only than those reported by Romania and Greece (for European Union countries). This index ranges from -2.5 and + 2.5 and captures the "perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests". For details on the construction of this index, refer to Kaufmann et al. (2010).

[12] In a subsequent study, Johnstone et al. (2010b) in using the same WEF data, presented a rank of countries according to an index on the policy stability and transparency and Italy performs badly also in this last respect.

[13] The target for Italy was to reach by 2012 a total Gg of CO_2 equivalent in GHG equal to 92% of the emissions recorded in 1990. The 3.5% reduction refers to the year 2010, with 1990 as a reference year.

country in the G8 group that is performing worst[14], and it has reached a reduction in GHG which is even lower than the European Union average[15].

The choice of an appropriate country-case is however not enough since 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 find evidence of strong and persistent regional differences which suggest the need to perform analysis at regional level.

Furthermore, the economic literature on sectoral emission patterns and "delinking" with income growth, provides support for the need for a sector-based analysis since strong sectoral patterns have emerged (Marin and Mazzanti, 2013; 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)[16].

>>> INSERT FIGURE 1 ABOUT HERE <<<

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 since 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 Description of data

[14]Indeed, France has achieved a 6% reduction, United Kingdom, 22.5% and Germany 24.8%. These GHG emission reductions refer to the year 2010 compared with the emission levels in 1990. For an overview on the changes in the emissions of other countries refer to UNFCCC, 2012 (http://unfccc.int/resource/docs/2012/sbi/eng/31.pdf). GHG emissions are calculated excluding emissions/removals from land use, land-use change and forestry. When including them, the overall picture remains similar in the sense that Italy still shows reduction performances that are worse than other European countries.

[15] Whose average reduction in 2010 compared with 2012 was equal to 15.4%.

[16]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, 2013; Mazzanti et al., 2008). Unlike the service sectors, Italian manufacturing industry shows strong intra-branches heterogeneities with ceramics, paper, food and fuel manufacturing facing the worst environmental performance dynamics (Marin and Mazzanti, 2013). Furthermore, an "N shaped" or "U shaped" EKC mostly depends on the emission considered in the manufacturing sectors (Mazzanti et al., 2008).These considerations on the Italian sector and regional heterogeneities were behind our decision to ground our empirical analysis on a sector-region level of analysis.

A limited amount of studies has exploited air emission data at sectoral and regional level of disaggregation. Most of these studies draw upon a rich and unique dataset, which is only available at the Nuts II level -to our knowledge- for Italian Regions: the regional NAMEA[17], developed by the Italian Statistical Office (ISTAT). Among them, Mazzanti and Montini (2010) have focused on the drivers of emission 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. (2013a) have focused on the economic drivers behind the geographical distribution of environmental performance for all the Italian regions. Sansoni et al. (2010) have provided a methodological and conceptual framework on the use of a regional NAMEA for international comparisons.

In line with this empirical literature, we employ the Italian regional NAMEA to investigate the impact of environmental performance on the generation of green technologies.

For the empirical analysis, we merged the regional NAMEA with different data sources concerning the economic and technological performance of Italian Regions. We started exploiting patent applications, drawn from the PATSTAT database,[18] to build the proxy for knowledge generation in the domain of green technologies[19]. It should be stressed 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, since we are willing to understand the effect of air emission on the generation on green knowledge, irrespective of whether these inventions then enter 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). After extracting patent 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. Over the considered time-span, the matching between ORBIS and PATSTAT through the OECD-HAN dataset allowed approximately 37% of Italian patents to be assigned to sectors[20].

[17] A description of the NAMEA dataset can be found in the next section.
[18] PATSTAT Version: April 2011.
[19] 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 non-patentable innovations and the fact that they are not the only protecting tool. Moreover, the propensity to patent tends to vary over time according to 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 with analyses drawing upon surveys directly investigating the dynamics of process and product innovation (Acs et al., 2002). In addition to the debate on 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 for the use of patents as a good proxy of technological activities (Hall et al., 1986).
[20] We also considered alternative ways to assign patents to industrial sectors such as the application of the correspondence table implemented by Schmoch et al. (2003). However, the latter is undesirably exclusively focused

Patents were then defined as being *environmental* on the basis of the World Intellectual Property Organization “WIPO IPC green inventory”, an International Patent Classification that identifies patents related to the so-called “Environmentally Sound Technologies” and scatters them into their technology fields (Tab. A3), with the *caveat* that it is not the only possible classification of green technologies and, as with other available classifications, it presents some drawbacks (Costantini et al., 2013b)[21].

The hybrid environmental-economic accounting matrix based on NAMEA applied to Italian NUTS II Regions has been used to assign the level of air emissions at a sectoral levelto each Region [22].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[23].To avoid overlap between variables, we found it more appropriate to ground our analysis on aggregated emissions by environmental impacts, i.e. Greenhouse Gases (GHG), Acidifying Gases (AC) and Ozone Tropospheric precursors (OzTr)[24] and on Particulate matter (PM10)[25]. Input-Output

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on manufacturing sectors. Moreover, the correspondence is therein based on a statistical exercise while the use of the ORBIS dataset allows an official classification to be obtained.

[21] Although interesting, it is out of the scope of the current work to systematically test for the differences that may arise from the choice of classification. We selected the WIPO IPC green inventory since it is currently a wide and well established classification of green technologies. The OECD has indeed also developed the OECD Indicator of Environmental Technologies (OECD, 2011), based on the International Patent Classification (IPC), which features seven environmental areas, i.e. (a) general environmental management, (b) energy generation from renewable and non-fossil sources, (c) combustion technologies with mitigation potential, (d) technologies specific to climate change mitigation, (e) technologies with potential or indirect contribution to emission mitigation, (f) emission abatement and fuel efficiency in transportation, and (g) energy efficiency in buildings and lighting. At the same time, the European Patent Office (EPO) is working on completing its own system of classification (ECLA) to assign each patent a green tag, depending on the environmental aim of each patent. So far, EPO allows tagging 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). More recently, Costantini et al. (2013b) have pointed to the shortcomings of classification methods based on efforts to collect IPCs potentially related to green technologies in one place. Focusing on the biofuels sector, they show that the WIPO Green Inventory is likely to overestimate the number of patents to be assigned due to the fact that IPCs are not specifically designed to identify this narrow and very specific domain. Clinical analysis based on keyword search and validations from experts are likely to yield finer grained classifications. Nonetheless, due to the wide scope of our analysis which encompasses many kinds of green technologies, we will rely on the WIPO Green Inventory.

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

[23]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).

[24]GHG, ACID and OZ are built in the NAMEA tables according to a methodology requiring 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. the potential of global warming associated with each emission when compared with CO_2. To compute GHG equivalent emissions, CO_2, CH4 and N20 (in tons) are multiplied by their coefficients, 1 (CO2) ; 310 (N20) and 21 (CH4)respectively. 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

(Supply and Use) tables provided by ISTAT have consequently been used to build indexes of relatedness among sectors which have been adopted to generate related emissions variables, by weighting direct emissions through a weighting matrix built according to the methodology described in the next section. Unfortunately, a panel for the regionalized NAMEA is not yet available since only observations for the year 2005 have been developed (while at national level, a wide panel for Italy already exists). Consequently, the analysis we are implementing will be a cross-sectional one since the core environmental variables are only available as a cross-section[26]. Despite this limitation, the regional NAMEA has the considerable advantage of being, to our knowledge, the only NAMEA at EU level now available at the Nuts II level. NAMEA and patent data were then merged with regional sectoral economic accounts, regional environmental expenditures and regional data on exporting activities provided by ISTAT. Lastly, regional energy consumption at sectoral level were accounted for through the deployment of TERNA data[27]to test for the robustness of our estimation results. Our sample consists of 24 NACE Rev 1.1 sectors in 20 Regions, which amounts to a pool of 480 potential observations, reduced due to some missing variables to a sample of 456 for our estimations[28].

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 polluting agents in each sector are likely to demand technologies enabling the improvement of 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 calls for investigating the extent to which in each sector-region the generation of green technologies is triggered by the environmental performance of vertically related sectors. We also control for the impact of environmental performance within the same sector.

The literature dealing with empirical analysis of regional innovation performance is mostly based on the implementation of the so-called knowledge production (KPF) approach. The knowledge production function is one of the pillars of the applied economics of innovation (Griliches 1979,

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into consideration “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).

[25] PM10 has been included although it is not an aggregation of other emissions, since on the one hand, it was not included in GHG or in ACID or OZ and, on the other, it is strictly connected to production.

[26]We thank two anonymous referees for suggesting a cross-section analysis rather than a panel one which was our first choice.

[27] The company TERNA S.p.A. annually publishes "Statistical Data on Electricity in Italy" in which it collects data on the principal aspects of the national electricity sector, among which we extracted data on energy consumption by Sector and Region.

[28] Sector P (Activities of households) is not covered by NAMEA data and Sector B (Fishing) presents some missing data for six nuts2 Regions :ITC1; ITC2; ITC4; ITI2; ITF5 and ITH1-ITH2 (Trentino Alto Adige)..

1990, 1992; Romer, 1990; Link and Siegel, 2007) and it has been widely applied in a variety of contexts including firms, regions, industries and countries[29].

In order to investigate the impact of pollutant emissions on the regional generation of green technologies across different sectors, we therefore propose 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 equality between conditional variance and conditional mean in the distribution of the dependent variable was violated, suggesting the need for a Negative Binomial class of models instead of a Poisson.

Analysis of the determinants of the generation of GTs in our case poses an additional problem which is due to the excess sector-region combination for which we observe no GTs. This leads to a situation in which we observe an "excess of zeros" in the dependent variable, and investigation is needed to establish whether the observed zeros are due to the overall absence of patenting activity or to a specific lack of green patents in sector-region nonetheless featuring some degree of technological activity. For this specificity, we find the zero-inflated negative binomial (ZINB) model is more appropriate to fit our data since it allows empirical frameworks to be modelled in which the excess of zeros in the dependent variable is generated by a different process than count values. This model simultaneously runs two equations: a binary logistical 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 allows us to discriminate between the zeros due to Regions and sectors generating some patents, but no green patents, and those due to Regions that are not creating any kind of knowledge, *green* or otherwise. In other words, we based our inflation equation (LOGIT part of the model) on a variable (*patid*) that captures the count of the overall patents (irrespective of whether these patents were Environmental Technologies or not) in each region-sector combination. The Voung test confirmed the appropriateness of our choice, as reported in the estimation results tables.

To test our hypothesis, the following basic model is specified:

$$(\mathrm{GT_{ij}})=\beta_0+\beta_1(\mathrm{EM_{ij}})+\beta_2(W_{j,l\neq j}\,EM_{i,l\neq j})+\beta_3(\mathrm{PURD_i})+\beta_4(\mathrm{POL_i})+\beta_5(\mathrm{VA_{ij}}) \qquad (1)$$

$$+\beta_6(\mathrm{DENSITY_i})+\beta_7(\mathrm{EXPORT\_UE_i})+\beta_8(\mathrm{DIRTY_i})+\sum \rho_i+\varepsilon_{ij}$$

[29] In this 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 labour, 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 inputs that make generation of knowledge as an output possible.

where i = 1,…, 20 indicates the Region j =1, … , 24 stands for the Sector and β_0 to β_8 the coefficients to be estimated. The error term is decomposed so as to account for region (ρ_i), fixed effects. The region (ρ_i), fixed effect is accounted for with the inclusion of 4 locational dichotomous variables: *NORTHEAST*, *NORTHWEST*, *SOUTH* and *CENTER* (benchmark).

In a second step (Equation 2), we add a variable to the model to account for the presence of metropolitan areas in the Region (*METRO*):

$$\left(\mathrm{GT_{ij}}\right)=\beta_0+\beta_1\left(\mathrm{EM_{ij}}\right)+\beta_2\left(W_{j,l\neq j}EM_{i,l\neq j}\right)+\beta_3(\mathrm{PURD_i})+\beta_4(\mathrm{POL_i})+\beta_5\left(\mathrm{VA_{ij}}\right) \quad (2)$$

$$+\beta_6(\mathrm{DENSITY_i})+\beta_7\left(\mathrm{EXPORT\_UE_i}\right)+\beta_8(\mathrm{DIRTY_i})+\beta_9(\mathrm{METRO_i})+\sum\rho_i+\varepsilon_{ij}$$

The variables included in equation (1) to (2) are described in the following section.

4.3 Variables

The dependent variable, green technologies (*GT*), is measured by the count of patent applications in "Environmentally Sound" technology fields in the years 2005, 2006 and 2007.

The explanatory variables are all lagged to previous year to overcome endogeneity problems that may arise. The key variables to assess our hypotheses are the environmental ones which consist of a first group of direct emission efficiency (EM_{ij}) and of a second one of related emission efficiency ($W_{jl}*EM_{il\neq j}$). EM_{ij}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:

$$\mathrm{EM_{ij}}=\log\left(\frac{\mathrm{EMISSIONS}_{\mathrm{ij\,2005}}}{\mathrm{VA}_{\mathrm{ij\,2005}}}\right) \quad (3)$$

EMISSIONS is a vector of four emission variables (GHG, AC, PM10 and OzTr as in 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, with the aim of 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 built, 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).

Similarly, $W_{jl}*EM_{il\neq j}$ measures the **emission efficiency of the vertically related sectors** and follows the following specification:

$$W_{j,l\neq j}EM_{i,l\neq j} = \log\left(\frac{\sum_{l\neq j} W_{j,l\neq j}*EMISSION_{i,l\neq j,2005}}{VA_{ij2005}}\right) \quad (4)$$

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 that draws upon the exploitation of input-output data (Essletzbichler, 2013; Fan and Lang, 2000; Feser, 2003).We used, as anticipated, the Italian Input Output “Supply” and “Use”, which contain the flows and value of commodities produced by each industry and the flows and value of commodities consumed by each industry respectively, and constructed a matrix for the input-output relatedness between industries that follows this formulation:

$$W_{j,l} = \frac{1}{2}\left(\frac{F_{j,l}}{\sum_{j=1}^{n} F_{j,l}} + \frac{F_{l,j}}{\sum_{l=1}^{m} F_{l,j}}\right) \quad (5)$$

where $F_{j,l}$ and $F_{l,j}$measure the flows between industry *l* and *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 economic and technology characteristics in the generation of GTs, we included the real value added (*VA*), the share of public R&D (*PURD*) over the total R&D and the effect of export oriented activities (*EXPORT_UE*) in the regression, all taken at average values 2003-2005 and log-transformed[30].

To avoid a possible bias arising from the omission of policy variables, the ISTAT data have been used to build the variable *POL*, given by the natural logarithm of the ratio between average regional expenditure for environmental protection (only capital expenditure) in 2004-2005 of Region i and *VA* in 2004-2005[31] (as in Costantini and Crespi, 2008). To interpret the industry effect better, we included a dichotomous variable, *DIRTY*, equal to 1 for the most polluting sectors and zero otherwise in the model (see Table 1 for details). Lastly, we controlled for the density of the Region, *DENSITY*, measured as the ratio between the Population and the Area.

[30] In a way, export also accounts for the possible role that foreign countries regulations exert on local production, in the case of foreign environmental standards over imported goods, either for consumption or intermediate goods. As a robustness check, we also tested an alternative variable which refers to all exporting activities without restrictions on the European market. Results have proved to be robust and are available upon request.

[31] We thank an anonymous referee for suggesting that we should build this variable on capital expenditure only instead of using total expenditure, which also includes current expenditure such as those for wages. As a robustness check we alternatively constructed this variable by using the total regional expenditure for environmental protection and also the total regional expenditure on environmental R&D (separately). Results remained unaltered and are available upon request.

In equation (2) we added a dichotomous variable to our model, METRO, taking value 1 for those Regions in which a metropolitan area is present[32] since the literature on agglomeration economies suggests that this is where knowledge capabilities are highly concentrated.[33]

Table 1 provides a synthesis of the definition of the variables used in the analysis.

>>> INSERT TABLE 1 ABOUT HERE <<<

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 over-dispersed 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 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 could be expected. In particular, about 41% 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 since therein it produces about 15% of the observed green patents.

>>> INSERT TABLE 3 ABOUT HERE <<<

In Table 3 we also report the sectoral distribution of air emissions related to the sectoral value added. The worst environmental impact for GHG comes from the electricity, gas and water supply sector which is also responsible for high levels of OzTr emissions. This is the reason why in the robustness checks we excluded this sector from the regression to test for the stability of our results. Fishing sector and the manufacturing of non-metallic mineral products are responsible for the highest amount of relative pollution of OzTr, while the Agriculture sector shows the worst relative performance for AC emissions and also relative bad performance in terms of PM10. Intuitively, the transport sector is also responsible for high values, and if we look at the absolute value of equivalent tons (instead of the relative ones), it is the worst performing sector in terms of OzTr and presents high values on all the other pollutants.

Lastly, in Table 4 we show the Spearman Rank correlation coefficients which account for extreme values in the considered variables.

[32] In particular, we considered those developed around the 4 cities of Milan, Rome, Turin and Naplesas metropolitan areas. When applying a less restrictive definition of metropolitan area that also includes Palermo and Florence, results remained unaltered and are available upon request.

[33] We also tested whether the use of more accurate measurement of knowledge capabilities than the METRO variable would have made a difference. We tested in particular for the role of Knowledge Variety, Knowledge Coherence and Knowledge Diversity (following the methodology proposed by Quatraro, 2010). Since these results did not provide better insights but just confirmed the robustness of our already existing ones, for the sake of parsimony, we have omitted these variables from the analysis.

>>> INSERT TABLE 4 ABOUT HERE <<<

As is clear from this table, emission intensity variables are highly correlated. Their joint inclusion in the regressions is therefore likely to engender biased estimations. For this reason, 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 5 reports the results for the zero inflated negative binomial regressions of the equation (1), which includes total patents in the inflation part of the model. In this table we report the baseline model.

As far as the control variables are concerned, only value added and R&D are statistically significant and feature a positive coefficient. The key variables of this study are however those concerning sectoral environmental performance at the regional level.

>>> INSERT TABLE 5 ABOUT HERE <<<

The main hypothesis underlying our empirical investigation is that environmental performance may trigger the generation of environmental technologies, working as an endogenous inducement factor. We also stress that inducement mechanisms are likely to work through the derived demand of downstream polluting firms for green technologies produced in upstream vertically related sectors. 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 therefore allows the effects of environmental performance of related sectors to be appreciated.

The first column in Table 5 reports the results concerning greenhouse gas (GHG) emissions. While the direct emissions are not significant, the emissions generated by vertically related sectors show a positive and significant coefficient. This provides initial support to the hypothesis that inducement mechanisms work thorough the transmission of incentives along the value chain. The evidence that the environmental performance of vertically related firms positively impacts the generation of green knowledge represents an aggregate result which is compatible with a microeconomic framework in which firms are increasingly aware of their environmental responsibility or at least of the economic benefits that may derive from their movements towards greener production. This holds either when those benefits come for the reason outlined in the literature on the CSR or when they are the consequence of a proactive response to future stringent regulations. Polluting firms therefore choose to commit resources to feed their demand for green technologies.

In the second column we show the coefficients of the PM10 emissions. Here too, emissions generated in vertically related sectors exert a positive and significant impact on the generation of green technologies. Conversely, the coefficient on direct emissions is negative and significant, suggesting the existence of a negative correlation between bad environmental performance and being a producer of green technologies.

The results presented in column (3) concerning the Tropospheric Ozone precursors (*OzTr*) and in column (4) for acidifying gases (*AC*) are in line with the previous ones. The coefficient of emission intensities from related sectors is positive and significant whereas the one for direct emissions is negative and significant.

Overall,the patterns that emerge from these empirical results suggest the existence of complementarity between direct and related effects of sectoral emission intensities. The positive sign of the emission intensities of vertically related sectors supports the hypothesis of an *endogeneous* inducement channelled by the downstream firms' derived demand for green technologies produced in upstream sectors. The interpretation of such a pattern is compatible with a CSR framework in which firms try to improve their environmental performance by searching for green technologies in the markets for intermediate goods. On the contrary, firms producing and supplying green technologies are more likely to be characterized on average by better environmental performance so that the sign of direct emission intensities is actually negative and, in most cases, significant.

5.1 Robustness checks

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

First of all, in Table 6 we include a dichotomous variable, *METRO,* to account for the presence of metropolitan areas in the sampled regions. In Table 7 we control for the role of energy consumption of each region-sector combination, both in terms of direct (*ENERGY*) and related (*W*ENERGY*)[34] consumption . The results are very consistent with the estimates presented in the previous section. Emissions from vertically related sectors are all featured by positive and significant coefficients, supporting the hypothesis of an inducement mechanism moderated by the derived demand of polluting downstream firms and all direct emission intensities but GHG emissions are featured by negative and significant coefficients.

[34] We thank an anonymous referee for suggesting this further check. Data are extracted from the TERNA database. *ENERGY* is constructed as the ratio between average energy consumption in 2003-2005 and the average value added in 2003-2005 for each Region-Sector combination. *W*ENERGY* applies the weighting matrix described in Equation (5) to *ENERGY*. Since not all the sectors are covered by the TERNA database, the number of observations is reduced to 400.

>>> INSERT TABLES 6 AND 7 ABOUT HERE <<<

Secondly, we tested the robustness of the results on the related emissions by adopting a different specification of the fully specified weighting matrix used in Table 5 and shown in Equation 5. We worked on the consideration that this matrix can be thought of as a proxy for technical proximity amongst sectors. Accordingly, a cutoff value can be identified that discriminates *close* from *far* sectors. The choice of this threshold is necessarily arbitrary and we grounded our choice on the distribution of the weights in the matrix. Table 8 reports the results of the estimations obtained by using the value of W_{lj} at the 75^{th} percentile as cutoff.

>>> INSERT TABLE 8 ABOUT HERE <<<

Columns (1)-(4) show the results for the baseline estimations, whereas in columns (5)-(8) we control for energy consumption. As is clear from the table, results are well in line with those described so far of positive and significant coefficients for the emission intensities of vertically related and negative and significant coefficients for all the direct emission intensities, but GHG. While the inducement mechanisms are channelled by the vertical transmission through the value chain, the sectors responsible for the generation of green technologies are confirmed to be characterized by virtuous environmental performance.

We then found it appropriate to group the emission variables into two factors, resulting from principal component analysis. The first factor represents the direct emissions while the second factor refers to the emission intensities of vertically related sectors.

>>> INSERT TABLE 9 ABOUT HERE <<<

The first three columns in Table 9 report the results of the estimation yield by using the fully specified relatedness matrix whereas columns (4) and (5) show the results obtained by adopting the cutoff value W_{lj} at the 75^{th} percentile. This evidence is consistent with the results of previous estimations and confirms that, even when emission intensities are grouped together in a single factor, those of vertically related sectors feature a positive and significant coefficient whereas the relationship between the production of green technologies and environmental performance is negative and significant.

Our results are confirmed when the Energy sector is excluded from the analysis and also once we controlled for the regional share of manufacturing firms, either in terms of employees or in terms of value added[35]. Lastly, we provide in Table A1 the results obtained by running standard Poisson and Negative Binomial estimations, which are well in line with the zero-inflated models presented in Table 5.

[35] These results are not reported here but are available upon request.

6 Conclusions

The investigation of the determinants of the introduction of environmental innovations has gained momentum in recent years due to the important role that has been attributed to green technologies as a means of coping with economic crisis and simultaneously restoring the competitiveness of countries. In this debate, attention has been largely focused on the shaping role of constraining environmental regulatory frameworks as a mechanism for inducing the generation of green technologies.

The contribution of this paper to this stream of analysis is twofold. First, we propose a complementary framework to the standard inducement argument in climate change that acknowledges that some endogenous mechanism are at stake in the presence of a weak exogenous policy framework. We focused on Italian regions because they have been described as a context characterized by a substantial lack of stringent regulation in terms of environmental policy. Moreover, the evolution of the industrial structure in Italy has been marked by a large prevalence of small and medium sized firms characterized by thick vertical linkages in which user-producer linkages have often been the source of innovation generated in upstream sectors and adopted by downstream firms (Antonelli and Barbiellini Amidei, 2011).

We then qualify the mechanisms through which inducement mechanisms may be working, stressing that polluting firms pushed to adopt green technologies in their production processes may not possess the necessary competences to generate them. The dynamics by which an inducement on polluting firms displays its effects passes through the user-producer relationships, i.e. those established between polluting firms operating downstream and those firms generating green technologies operating upstream. These vertical linkages along the value chain are confirmed as being important in this endogenous inducement framework: increases in the derived demand engendered by the inducing factor trigger the production of green technologies by supplier firms. The underlying explanation is that regional polluting agents, when not exogenously pushed by an environmental policy, choose or are induced to commit resources to technologies enabling the improvement of environmental performance, as an effect of the two main co-occurring mechanisms of an increased social and environmental responsibility, and an opportunistic pre-emptive reaction to future regulations. This translates into an increase of the derived demand which triggers the production of GTs in vertically related sectors.

These results are obtained by applying zero-inflated negative binomial techniques and confirm 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 matrices and find evidence of complementarity between direct and related effects. The generation of GTs appears to be stimulated by vertically related sectors, providing support for the idea that user-producers interactions are shaping the ultimate effects of the inducement mechanisms on the generation of new technologies. Direct sectoral emission intensities, on the other hand, appear to be negatively related to the generation of GTs, suggesting that the sectors producing environment-friendly technologies on average feature virtuous environmental performance.

It is fair to note that our results do not imply by any means that a regulatory framework is not important. They rather suggest that stringent regulation is not the only force behind the choice to commit resources to the production of GTs and that the other way round an inducement mechanism may also be depicted in a policy weak context. Analysis of the endogenous inducement of green technologies leads to some policy measures insights which should complement the regulatory framework set. The importance of firms' awareness of the social and environmental impact of their actions calls for the implementation of entrepreneurship policies devoted to developing an entrepreneurial culture that attributes increasing importance to the environmental performance of firms. Entrepreneurs' awareness of the economic importance of their environmental performance may lead them to commit resources to R&D spending targeted at the generation of green technologies and identify new business opportunities to be exploited by spinoffs or startups. Entrepreneurship policies could therefore benefit when traditional measures dealing with competition, the protection of property rights and the regulation of product and factor markets are complemented by adding measures to shape the entrepreneurial culture (Audretsch et al., 2007).

Our results call for further analyses at micro-level, to investigate the extent to which firms are stimulated to adopt GTs by the prospective gains in terms of reputation, and hence increase sales, or stock market value. Another future strand of possible research is to focus on the effect of environmental performance on the adoption - instead of the generation - of green technologies, by using for instance survey data[36]. Furthermore, a possible extension could be to attribute a role not only to direct environmental performance and to inter-sectoral relatedness, as we have done, but also to regional geographical proximity since the existence of technological and environmental spillovers has been depicted in the literature (Costantini et al. 2013a). Lastly, in future research it might be worth assessing the relationship between regulatory frameworks and environmental performance, treating environmental performance no longer as an explanatory variable, but, on the contrary, as a dependent variable.

[36]We could not use survey data, such as the Italian Community Innovation Survey data, to assign the level of adopted green technologies to each Region since Italian data dissemination rules do not provide researchers with information on the Region of firm respondents. On the other hand, 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 the Italian Statistical Office releases innovation output data with regional information.

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Figures and Tables

Figure 1 – Regional distribution of air emissions (weighted by regional value added at 2005)

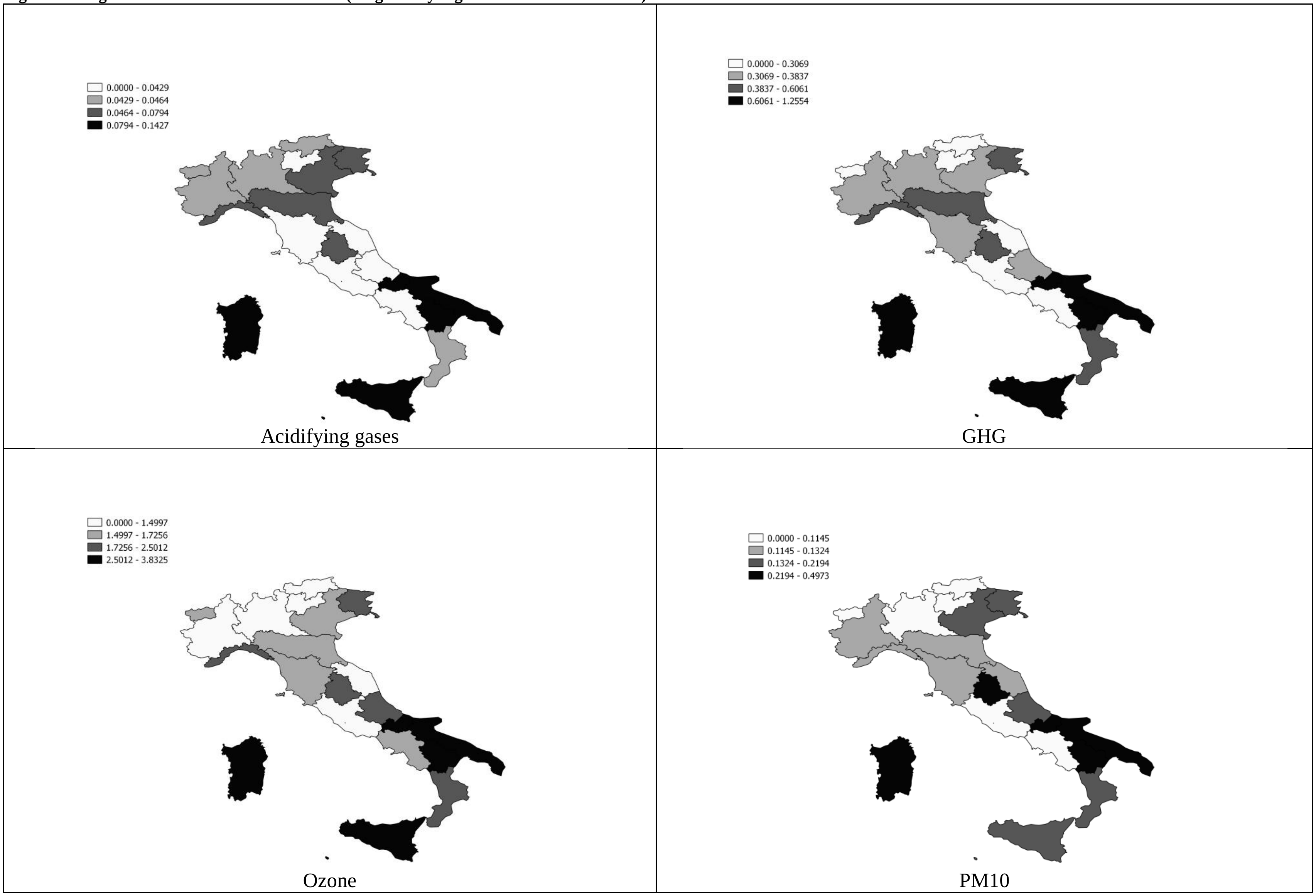

Table 1 - Description of variables used in analysis

Variable	Description	Source	Year
GT	Cumulative count of green technologies in Region i and Sector j in the years 2005 to 2007	PATSTAT-REGPAT- ORBIS-IPCC Green Inventory	2005-2007
AC	Emission intensity of Acidifying Gases (mainly NOx, SOx and NH3), given by the natural logarithm of the ratio between AC and the real value added of Region i, Sector j	ISTAT: regional NAMEA	2005
DENSITY	Given by the ratio of mean population in the Region i on the area of i in 2003-2005	ISTAT	2003-2005
DIRTY	Dummy equal to one for the most polluting sectors. In the NACE Revision 1.1 respectively : A, DF, DG, DI, E, I.		2005
ENERGY	Natural Logarithm of the ratio between mean Energy Consumption of Sector j in 2003-2005 and its mean value added in 2003-2005	TERNA	2003-2005
EXPORT_UE	Natural Logarithm of the ratio between average Export (within European Union) 2003-2005 and meanvalue added 2003-2005.	ISTAT	2003-2005
GHG	Emission intensity of Greenhouse Gases (mainly CO2, CH4 and N2O), given by the natural logarithm of the ratio between GHG real value added of Region i, Sector j	ISTAT: regional NAMEA	2005
METRO	Dummy equal to one for Regions to which belong one of the following metropolitan areas: Milano, Roma, Torino, Napoli		2005
NORTHWEST; NORTHEAST; CENTER; SOUTH	Location dummy variables for NorthernEastern-NorthernWestern-Central-Southern Regions.		2005
OzTr	Emission intensity of Tropospheric ozone precursors (mainly caused by NOx, COVNM, CO, CH4) given by the natural logarithm of the ratio between OzTr real value added of Region i, Sector j	ISTAT: regional NAMEA	2005
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	2005
POL	Natural Logarithm of the ratio between average expenditure for environmental protection (only capital expenditure) in 2004-2005 of Region i and the mean value added of Region i in 2004-2005.	ISTAT	2004-2005
PURD	Given by the natural logarithm of the ratio between real mean Public R&D and mean Total R&D (Business R&D + Public R&D+ Universities R&D) in 2003-2005	ISTAT	2003-2005
VA	Natural Logarithm of the mean real value added of Region i, Sector j 2003-2005	ISTAT	2003-2005
W*AC	Emission intensity of AC in 2005 from vertically integrated sectors	ISTAT: Regional NAMEA and Input-Output Tables	2005
W*ENERGY	Mean Energy Consumption of vertically integrated sectors on mean value edded in 2003-2005	TERNA & ISTAT: Input Output Tables	2003-2005
W*GHG	Emission intensity of GHG in 2005 from vertically integrated sectors	ISTAT: Regional NAMEA and Input-Output Tables	2005
W*OzTr	Emission intensity of OzTr in 2005 from vertically integrated sectors	ISTAT: Regional NAMEA and Input-Output Tables	2005
W*PM10	Emission intensity of PM10 in 2005 from vertically integrated sectors	ISTAT: Regional NAMEA and Input-Output Tables	2005

Table2 - Variables' Descriptive Statistics

VAR	N	mean	sd	min	max	skewness	kurtosis
GT	454	1.500	7.566	0	130	12.17	190.79
GHG	454	0.479	0.619	0.012	3.300	2.037	7.268
W*GHG	454	0.778	0.818	0.043	4.276	1.830	6.289
PM10	454	0.206	0.353	0.002	2.804	2.812	13.262
W*PM10	454	0.382	0.510	0.020	3.473	2.810	13.160
OzTr	454	1.260	0.996	0.036	5.821	1.058	4.283
W*OzTr	454	1.621	1.119	0.268	6.239	1.343	4.819
AC	454	0.091	0.197	0.001	1.489	3.484	16.840
W*AC	454	0.184	0.318	0.005	2.474	3.969	23.860
VA	454	6.639	1.783	-1.563	10.819	-0.739	3.917
PURD	454	-1.981	0.552	-3.135	-0.674	0.281	3.506
DENSITY	454	-1.912	0.636	-3.283	-0.857	-0.290	2.372
DIRTY	454	0.220	0.415	0	1	1.350	2.822
POL	454	0.091	0.091	0.011	0.311	1.196	3.152
EXPORT_UE	454	4.433	0.812	1.839	5.249	-1.482	5.674
NORTHWEST	454	0.196	0.397	0	1	1.531	3.345
NORTHEAST	454	0.200	0.401	0	1	1.497	3.240
SOUTH	454	0.352	0.478	0	1	0.618	1.382
CENTER	454	0.403	0.491	0	1	0.395	1.156
METRO	454	0.198	0.399	0	1	1.514	3.292
ENERGY	400	0.097	1.016	0.000	20.099	19.189	377.969
W*ENERGY	400	0.118	1.364	0.000	27.081	19.409	384.021

Table 3 - Sectoral Distribution of Green Technologies and Emissions (on value added)

Sector (Nace Rev 1.1)	GHG	OzTr	AC	PM10	GT	Freq(GT)
A	1.643	7.391	0.883	1.538	4	1%
B	1.361	25.880	0.396	1.951	3	0%
C	0.465	2.090	0.030	0.115	37	5%
DA	0.487	2.698	0.023	0.062	0	0%
DB	0.477	0.924	0.021	0.048	9	1%
DC	0.180	7.194	0.009	0.026	2	0%
DD, DH, DN	0.201	3.250	0.011	0.032	56	8%
DE	0.522	1.992	0.009	0.026	1	0%
DF, DG	3.067	9.699	0.317	0.264	62	9%
DI	4.039	11.119	0.315	1.475	5	1%
DJ	0.611	3.613	0.039	0.509	29	4%
DK, DL, DM	0.145	0.954	0.007	0.017	282	41%
E	6.157	6.591	0.250	0.223	21	3%
F	0.064	1.408	0.007	0.080	12	2%
G	0.140	1.064	0.014	0.064	18	3%
H	0.072	0.390	0.006	0.023	0	0%
I	0.453	4.055	0.085	0.257	8	1%
J	0.019	0.109	0.002	0.007	17	2%
K	0.031	0.201	0.003	0.014	102	15%
L	0.045	0.473	0.006	0.028	3	0%
M	0.018	0.059	0.001	0.003	0	0%
N	0.047	0.125	0.002	0.006	0	0%
O	0.773	1.927	0.032	0.046	10	1%
P	missing	missing	missing	missing	0	0%

Table 4 - Spearman'sRankCorrelationcoefficient

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	GT	1										
2	GHG	-0.0282	1									
3	PM10	-0.0988*	0.6944*	1								
4	OzTr	-0.0534	0.843*	0.7287*	1							
5	AC	-0.0706	0.9094*	0.8583*	0.8192*	1						
6	ENERGY	-0.2871*	0.4379*	0.257*	0.4359*	0.3461*	1					
7	VA	0.3095*	-0.4117*	-0.2493*	-0.424*	-0.3236*	-0.995*	1				
8	PURD	-0.1272*	0.0561	0.0646	0.0625	0.0619	0.1957*	-0.1965*	1			
9	DENSITY	0.2508*	-0.0907	-0.0948	-0.0459	-0.0963	-0.5366*	0.5398*	-0.1798*	1		
10	POL	-0.3007*	0.0704	0.1208*	0.0911	0.1208*	0.4456*	-0.4471*	0.3189*	-0.609*	1	
11	EXPORT_UE	0.2602*	-0.0005	-0.0819	-0.0828	-0.0524	-0.2216*	0.2214*	-0.5155*	-0.0541	-0.4496*	1

Table 5 - EconometricResults (I)

	(I)	(II)	(III)	(IV)
GHG	-0.5715			
	(0.3841)			
W*GHG	1.1484***			
	(0.4087)			
PM10		-1.8422***		
		(0.6615)		
W*PM10		1.4823*		
		(0.8130)		
OzTr			-0.6823**	
			(0.3340)	
W*OzTr			1.1372***	
			(0.3950)	
AC				-2.1572*
				(1.2424)
W*AC				2.8542**
				(1.4255)
VA	0.6525***	0.4763**	0.6804***	0.5391***
	(0.1907)	(0.1928)	(0.2441)	(0.1830)
PURD	0.6547*	0.6978*	0.6061	0.7217*
	(0.3898)	(0.3951)	(0.3818)	(0.4037)
DENSITY	-0.0812	0.3114	-0.1060	0.1780
	(0.5976)	(0.5952)	(0.6182)	(0.6153)
DIRTY	0.1230	0.0658	0.1067	0.0367
	(0.4672)	(0.3414)	(0.4179)	(0.3840)
POL	-3.6634	-2.2849	-3.6687	-3.2615
	(4.1181)	(4.2125)	(4.1062)	(4.4774)
EXPORT_UE	0.5729	0.6247	0.5480	0.5551
	(0.4530)	(0.4526)	(0.4470)	(0.4560)
NORTHWEST	0.8026	0.5623	0.8366	0.6773
	(0.5340)	(0.5478)	(0.5278)	(0.5593)
NORTHEAST	-0.1791	-0.3045	-0.0918	-0.3130
	(0.4487)	(0.4470)	(0.4454)	(0.4524)
SOUTH	-0.7283	-0.7170	-0.8506	-0.6439
	(0.6338)	(0.6522)	(0.6344)	(0.6378)
_cons	-5.3711**	-3.1241	-5.9275**	-3.5039
	(2.3147)	(2.1622)	(2.8804)	(2.1403)
inflate				
patid	-0.1138***	-0.1132***	-0.1087***	-0.1134***
	(0.0438)	(0.0409)	(0.0384)	(0.0422)
_cons	1.9077***	1.9705***	1.9013***	1.9552***
	(0.2595)	(0.2521)	(0.2582)	(0.2539)
lnalpha				
_cons	0.1875	0.1151	0.1462	0.1833
	(0.2847)	(0.2818)	(0.2788)	(0.2817)
N	454	454	454	454
Log-Likelihood	-359.376	-359.162	-359.069	-360.887
Pr>LR	0.00	0.00	0.00	0.00
Likelihood-ratio test α=0 (Chi²)	530.38	510.41	523.63	539.74
Pr>Chi²	0.00	0.00	0.00	0.00
Vuong Test (z)	4.73	4.93	4.47	5.03
Pr> z	0.00	0.00	0.00	0.00
Mc Fadden'sR²	0.205	0.205	0.205	0.201
AIC	748.7513	748.3243	748.1389	751.7745
BIC	810.5228	810.0957	809.9104	813.5459

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 - EconometricResults (II)

	(I)	(II)	(III)	(IV)
GHG	-0.6016			
	(0.3792)			
W*GHG	1.2563***			
	(0.4070)			
PM10		-2.0648***		
		(0.6667)		
W*PM10		1.7543**		
		(0.8023)		
OzTr			-0.8263**	
			(0.3327)	
W*OzTr			1.3378***	
			(0.3986)	
AC				-2.3252*
				(1.2269)
W*AC				3.0559**
				(1.3960)
METRO	-0.6075	-0.6800	-0.8019*	-0.4840
	(0.4294)	(0.4269)	(0.4293)	(0.4255)
VA	0.7315***	0.5649***	0.7967***	0.5880***
	(0.1946)	(0.1939)	(0.2468)	(0.1825)
PURD	0.7164*	0.7735*	0.6663*	0.7712*
	(0.3904)	(0.3948)	(0.3811)	(0.4037)
DENSITY	0.1633	0.5727	0.1848	0.3887
	(0.5967)	(0.5806)	(0.6045)	(0.6142)
DIRTY	0.2580	0.2095	0.3420	0.1454
	(0.4741)	(0.3451)	(0.4235)	(0.3906)
POL	-2.0263	-0.4677	-1.5390	-1.9045
	(4.2152)	(4.2716)	(4.1957)	(4.5460)
EXPORT_UE	0.7255	0.7932*	0.7477	0.6741
	(0.4714)	(0.4691)	(0.4676)	(0.4719)
NORTHWEST	0.8417	0.5720	0.8822	0.6914
	(0.5457)	(0.5623)	(0.5402)	(0.5715)
NORTHEAST	-0.5462	-0.7555	-0.5683	-0.6338
	(0.5297)	(0.5468)	(0.5288)	(0.5469)
SOUTH	-0.9681	-1.0408	-1.2133*	-0.8585
	(0.6572)	(0.6879)	(0.6694)	(0.6684)
_cons	-5.9593**	-3.7215*	-6.9295**	-3.7802*
	(2.3484)	(2.1584)	(2.9147)	(2.1293)
inflate				
patid	-0.1069***	-0.1070***	-0.1012***	-0.1089***
	(0.0352)	(0.0336)	(0.0291)	(0.0367)
_cons	1.8991***	1.9612***	1.8926***	1.9502***
	(0.2517)	(0.2448)	(0.2483)	(0.2492)
lnalpha				
_cons	0.1241	0.0467	0.0540	0.1435
	(0.2701)	(0.2693)	(0.2605)	(0.2722)
N	454	454	454	454
Log-Likelihood	-358.389	-357.911	-357.363	-360.244
Pr>LR	0.00	0.00	0.00	0.00
Likelihood-ratio test α=0 (Chi²)	521.31	489.00	507.92	530.32
Pr>Chi²	0.00	0.00	0.00	0.00
Vuong Test (z)	4.75	4.99	4.51	5.04
Pr> z	0.00	0.00	0.00	0.00
Mc Fadden'sR²	0.207	0.208	0.209	0.203
AIC	748.7779	747.8210	746.7252	752.4885
BIC	814.6675	813.7106	812.6147	818.3780

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7 - Econometric Results (IV) accounting for Energy Consumption

	(I)	(II)	(III)	(IV)
GHG	-0.6721*			
	(0.3964)			
W*GHG	1.3581***			
	(0.4545)			
PM10		-1.8818***		
		(0.6748)		
W*PM10		1.9819**		
		(1.0017)		
OzTr			-0.7282**	
			(0.3519)	
W*OzTr			1.2293***	
			(0.4190)	
AC				-2.2769*
				(1.2752)
W*AC				4.2012**
				(1.8355)
ENERGY	-4.7427	2.2641	-5.3562	-5.3980
	(36.0608)	(31.7458)	(29.0462)	(46.8024)
W*ENERGY	-0.6266	-7.9814	0.9905	-2.8441
	(26.9952)	(24.1452)	(22.6012)	(33.6626)
VA	0.5910***	0.4636**	0.6206***	0.4949***
	(0.1925)	(0.1890)	(0.2399)	(0.1761)
PURD	0.6626*	0.7798*	0.6088	0.8263*
	(0.3947)	(0.4042)	(0.3862)	(0.4226)
DENSITY	-0.0242	0.2154	-0.0517	0.1185
	(0.5862)	(0.5861)	(0.6112)	(0.5961)
DIRTY	0.0544	-0.0455	0.0285	-0.1316
	(0.4682)	(0.3464)	(0.4368)	(0.3860)
POL	-3.2780	-2.2149	-3.2237	-3.8100
	(4.1150)	(4.1616)	(4.1098)	(4.4197)
EXPORT_UE	0.7006	0.7143	0.6326	0.7220
	(0.4681)	(0.4606)	(0.4559)	(0.4822)
NORTHWEST	0.8061	0.6609	0.8456	0.7821
	(0.5331)	(0.5496)	(0.5314)	(0.5620)
NORTHEAST	-0.1683	-0.2814	-0.0857	-0.2789
	(0.4471)	(0.4458)	(0.4459)	(0.4512)
SOUTH	-0.8463	-0.8350	-0.9495	-0.7463
	(0.6337)	(0.6593)	(0.6390)	(0.6345)
_cons	-5.3964**	-3.4850	-5.7812**	-3.8392*
	(2.2935)	(2.1598)	(2.8410)	(2.1220)
inflate				
patid	-0.0970***	-0.1011***	-0.0962***	-0.0959***
	(0.0315)	(0.0346)	(0.0310)	(0.0316)
_cons	1.6880***	1.7621***	1.7109***	1.7147***
	(0.2657)	(0.2624)	(0.2640)	(0.2621)
lnalpha				
_cons	0.1362	0.0894	0.1134	0.1366
	(0.2559)	(0.2647)	(0.2578)	(0.2571)
N	400	400	400	400
Log-Likelihood	-348.747	-348.578	-349.072	-349.944
Pr>LR	0.00	0.00	0.00	0.00
Likelihood-ratio test α=0 (Chi²)	518.71	493.19	513.38	527.09
Pr>Chi²	0.00	0.00	0.00	0.00
Vuong Test (z)	4.40	4.60	4.28	4.69
Pr> z	0.00	0.00	0.00	0.00
Mc Fadden'sR^2	0.201	0.202	0.201	0.199
AIC	731.4940	731.1565	732.1431	733.8871
BIC	799.3489	799.0114	799.9980	801.7420

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8 Econometric results Matrix cutoff at 75th percentile

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
GHG	-0.5620				-0.6680*			
	(0.3806)				(0.3862)			
W*GHG	1.1276***				1.3603***			
	(0.3951)				(0.4462)			
PM10		-2.1162***				-2.1455***		
		(0.6637)				(0.6870)		
W*PM10		2.6448***				3.0951***		
		(0.9782)				(1.1448)		
OzTr			-0.7417**				-0.7981**	
			(0.3217)				(0.3311)	
W*OzTr			1.2613***				1.3859***	
			(0.3447)				(0.3662)	
AC				-2.4729*				-2.6568**
				(1.2737)				(1.3056)
W*AC				3.7941**				5.3625***
				(1.5944)				(1.9587)
ENERGY					3.1483	-15.9464	-4.1860	-4.5206
					(87.8513)	(85.3080)	(66.9215)	(91.7332)
W*ENERGY					-7.8736	11.2740	0.3342	0.6328
					(96.6540)	(92.3098)	(73.3982)	(100.2348)
VA	0.5521***	0.5162***	0.6315***	0.4973***	0.4851***	0.4627***	0.5626***	0.4549***
	(0.1627)	(0.1615)	(0.2051)	(0.1497)	(0.1675)	(0.1640)	(0.2030)	(0.1547)
PURD	0.6474*	0.7126*	0.5709	0.7290*	0.6367	0.7481*	0.5611	0.7689*
	(0.3920)	(0.3805)	(0.3720)	(0.3922)	(0.3910)	(0.3876)	(0.3737)	(0.3929)
DENSITY	-0.0733	0.1067	-0.1507	0.1228	0.0139	0.1075	-0.0592	0.1268
	(0.6003)	(0.5683)	(0.5805)	(0.5891)	(0.5776)	(0.5579)	(0.5722)	(0.5661)
DIRTY	0.0886	0.2655	0.1811	0.1867	0.0167	0.1868	0.0995	0.0899
	(0.4628)	(0.3450)	(0.4033)	(0.3896)	(0.4584)	(0.3440)	(0.4080)	(0.3861)
POL	-4.1789	-3.5561	-4.3420	-3.7009	-4.0075	-3.2392	-3.9679	-4.4989
	(4.1917)	(4.1625)	(3.9919)	(4.3806)	(4.1469)	(4.1330)	(3.9889)	(4.3907)
EXPORT_UE	0.5266	0.6428	0.5566	0.5928	0.6345	0.7407	0.6530	0.7277
	(0.4531)	(0.4445)	(0.4399)	(0.4532)	(0.4597)	(0.4573)	(0.4471)	(0.4675)
NORTHWEST	0.9605*	0.7044	0.9065*	0.8140	0.9566*	0.7633	0.8976*	0.8813
	(0.5520)	(0.5339)	(0.5171)	(0.5578)	(0.5382)	(0.5338)	(0.5170)	(0.5459)
NORTHEAST	-0.0558	-0.1789	-0.0217	-0.1911	-0.0322	-0.1500	-0.0147	-0.1313
	(0.4540)	(0.4412)	(0.4364)	(0.4523)	(0.4494)	(0.4417)	(0.4346)	(0.4482)
SOUTH	-0.6736	-0.8284	-0.9763	-0.7211	-0.7967	-0.9267	-1.1057*	-0.8266
	(0.6365)	(0.6343)	(0.6206)	(0.6279)	(0.6296)	(0.6355)	(0.6228)	(0.6183)
_cons	-4.2643**	-3.9366*	-5.5531**	-3.4690*	-4.1172**	-3.9246*	-5.3490**	-3.6926*
	(2.0516)	(2.0349)	(2.4937)	(1.9655)	(2.0226)	(2.0323)	(2.4469)	(1.9749)
inflate								
patid	-0.1159**	-0.1076***	-0.1010***	-0.1083***	-0.0963***	-0.0937***	-0.0880***	-0.0888***
	(0.0493)	(0.0382)	(0.0321)	(0.0385)	(0.0320)	(0.0307)	(0.0260)	(0.0276)
_cons	1.9086***	1.9177***	1.8432***	1.9099***	1.6727***	1.7049***	1.6369***	1.6661***
	(0.2618)	(0.2498)	(0.2548)	(0.2537)	(0.2665)	(0.2571)	(0.2603)	(0.2582)
lnalpha								
_cons	0.1848	0.0567	0.0722	0.1550	0.1229	0.0251	0.0292	0.0790
	(0.2986)	(0.2816)	(0.2696)	(0.2758)	(0.2588)	(0.2626)	(0.2523)	(0.2547)
N	454	454	454	454	400	400	400	400
Log-Likelihood	-358.806	-356.874	-356.315	-359.698	-347.949	-346.580	-345.942	-348.614
Pr>LR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Likelihood-ratio test α=0 (Chi²)	526.40	486.58	508.05	532.59	511.34	481.76	497.71	518.31
Pr>Chi²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vuong Test (z)	4.79	5.01	4.56	4.99	4.45	4.73	4.39	4.69
Pr> z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mc Fadden'sR^2	0.206	0.210	0.211	0.204	0.203	0.206	0.208	0.202
AIC	747.6124	743.7481	742.6296	749.3961	729.8975	727.1605	725.8846	731.2280
BIC	809.3839	805.5196	804.4010	811.1676	797.7524	795.0154	793.7395	799.0829

Standard errors in parentheses * $p< 0.10$, ** $p< 0.05$, *** $p< 0.01$

1) The weighting matrix for Related Emissions (W*GHG, W*AC; W*PM10; W*OzTr) has been built with a cutoff at the 75th percentile
2) The weighting matrix for Related Energy (W*ENERGY) has been built with a cutoff at the 75th percentile

Table 9 - Econometric Results (III) Principal Component Analysis

	(I)	(II)	(III)	(IV)	(V)
F1_DIRECT	-0.3802**	-0.4273**	-0.4012**	-0.3898**	-0.4069**
	(0.1679)	(0.1679)	(0.1743)	(0.1645)	(0.1664)
F2_RELATED	0.6234**	0.7083***	0.7820***	0.6431***	0.7841***
	(0.2446)	(0.2438)	(0.2892)	(0.2119)	(0.2402)
ENERGY			-11.1750		-15.5135
			(46.2253)		(76.7143)
W*ENERGY			2.9506		11.9643
			(33.6447)		(82.6422)
VA	0.5857***	0.6746***	0.5454***	0.5401***	0.4915***
	(0.2076)	(0.2090)	(0.2035)	(0.1736)	(0.1753)
PURD	0.6254	0.6838*	0.6851*	0.6202	0.6364*
	(0.3894)	(0.3883)	(0.4000)	(0.3807)	(0.3812)
DENSITY	0.0527	0.3223	0.0326	-0.0172	0.0273
	(0.6010)	(0.5897)	(0.5889)	(0.5799)	(0.5629)
DIRTY	0.3293	0.5253	0.2077	0.3993	0.2899
	(0.4379)	(0.4460)	(0.4468)	(0.4314)	(0.4303)
POL	-3.1558	-1.2427	-2.8519	-3.9019	-3.8408
	(4.2167)	(4.3004)	(4.2006)	(4.1719)	(4.1403)
EXPORT_UE	0.5410	0.7058	0.6731	0.5493	0.6628
	(0.4435)	(0.4596)	(0.4627)	(0.4401)	(0.4503)
NORTHWEST	0.6914	0.7148	0.7578	0.8340	0.8609
	(0.5390)	(0.5517)	(0.5411)	(0.5371)	(0.5290)
NORTHEAST	-0.2259	-0.6621	-0.1959	-0.1042	-0.0676
	(0.4423)	(0.5308)	(0.4414)	(0.4412)	(0.4383)
SOUTH	-0.7888	-1.1009	-0.9013	-0.8409	-0.9653
	(0.6379)	(0.6698)	(0.6386)	(0.6257)	(0.6201)
METRO		-0.6906			
		(0.4211)			
_cons	-3.9349*	-4.5023**	-4.0007*	-3.8529*	-3.7731*
	(2.1405)	(2.1513)	(2.1029)	(1.9759)	(1.9516)
inflate					
patid	-0.1109***	-0.1042***	-0.0953***	-0.1065***	-0.0896***
	(0.0405)	(0.0320)	(0.0310)	(0.0380)	(0.0278)
_cons	1.9345***	1.9260***	1.7036***	1.8911***	1.6546***
	(0.2548)	(0.2468)	(0.2632)	(0.2541)	(0.2600)
lnalpha					
_cons	0.1177	0.0422	0.0807	0.0823	0.0288
	(0.2860)	(0.2692)	(0.2613)	(0.2833)	(0.2582)
N	454	454	400	454	400
Log-Likelihood	-358.869	-357.546	-348.190	-357.195	-346.398
Pr>LR	0.00	0.00	0.00	0.00	0.00
Likelihood-ratio test α=0 (Chi²)	508.03	491.65	501.10	499.74	492.56
Pr>Chi²	0.00	0.00	0.00	0.00	0.00
Vuong Test (z)	4.80	4.85	4.47	4.84	4.55
Pr> z	0.00	0.00	0.00	0.00	0.00
Mc Fadden'sR^2	0.206	0.209	0.203	0.209	0.207
AIC	747.7379	747.0929	730.3808	744.3900	726.7964
BIC	809.5094	812.9825	798.2357	806.1614	794.6513

Standard errors in parentheses * p< 0.10, ** p< 0.05, *** p< 0.01

1) The weighting matrix for Related Emissions (W*GHG, W*AC; W*PM10; W*OzTr) has been built with a cutoff at the 75th percentile in column (IV) and (V) and without any cutoff in coulmn (I) to (III)
2) The weighting matrix for Related Energy (W*ENERGY) has been built with a cutoff at the 75th percentile column (VI) and without any cutoff in coulmn (IV)
3) F1_DIRECT is the linear combination of the different classes of air emissions yield by applying principal component analysis
4) F2_ RELATED is the linear combination of the different classes of air emissions from vertically related sectors yield by applying principal component analysis

ANNEXES

Table A1 - Econometric Results (V) Poisson and Negative Binomial regression

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
GT								
GHG	-0.0900				-0.4616			
	(0.3287)				(0.4436)			
W*GHG	1.3491***				1.6826***			
	(0.3875)				(0.4437)			
PM10		-1.8214**				-1.7559**		
		(0.7247)				(0.7824)		
W*PM10		1.5883***				2.0148**		
		(0.5323)				(0.7944)		
OzTr			0.0239				-0.3251	
			(0.2759)				(0.3525)	
W*OzTr			1.3616***				1.7994***	
			(0.4485)				(0.4265)	
AC				-2.2413**				-2.6652*
				(1.1378)				(1.4938)
W*AC				1.3490*				2.7192**
				(0.7757)				(1.3250)
VA	0.9994***	0.7663***	1.2643***	0.6523***	0.9751***	0.7123***	1.3124***	0.6403***
	(0.1995)	(0.1975)	(0.2369)	(0.1986)	(0.2170)	(0.2216)	(0.2710)	(0.2044)
PURD	0.6126	0.5690	0.6798	0.5400	1.0785***	1.1375***	1.0687***	1.1044***
	(0.4063)	(0.3632)	(0.4351)	(0.3566)	(0.4093)	(0.4133)	(0.4024)	(0.4215)
DENSITY	-0.2881	-0.0290	-0.6787	0.1200	0.5135	1.0725	0.0058	1.1604
	(0.7474)	(0.7050)	(0.8114)	(0.7227)	(0.7019)	(0.6964)	(0.7447)	(0.7126)
DIRTY	-0.3705	0.1268	-0.5882	0.0625	0.2257	0.4581	-0.1094	0.4812
	(0.5095)	(0.4377)	(0.4724)	(0.4635)	(0.5591)	(0.4649)	(0.5094)	(0.5117)
POL	-5.8767	-6.6079	-6.6268	-6.5536	-0.4526	1.8802	-1.5947	1.6881
	(6.0241)	(5.8091)	(6.2293)	(5.6637)	(4.4439)	(4.4524)	(4.4801)	(4.7039)
EXPORT_UE	0.5192	0.5415	0.3889	0.5614	1.4046**	1.4321**	1.3082**	1.4142**
	(0.5525)	(0.5386)	(0.5441)	(0.5295)	(0.5754)	(0.5583)	(0.5769)	(0.5661)
NORTHWEST	1.4031*	1.3655*	1.6638**	1.3152**	1.1363**	0.9487*	1.2696**	0.9599*
	(0.7667)	(0.6969)	(0.8432)	(0.6663)	(0.5475)	(0.5633)	(0.5418)	(0.5795)
NORTHEAST	0.3398	0.3292	0.5237	0.2871	-0.1681	-0.2499	-0.1578	-0.2834
	(0.6413)	(0.6218)	(0.6620)	(0.6077)	(0.5431)	(0.5398)	(0.5480)	(0.5477)
SOUTH	-0.9719	-0.8717	-0.9729	-0.8560	-1.0881*	-1.1215*	-1.1919**	-1.0170*
	(0.6479)	(0.5778)	(0.7022)	(0.5644)	(0.5806)	(0.5832)	(0.5821)	(0.5809)
_cons	-9.6938***	-7.1787**	-12.7023***	-6.0527**	-11.5838***	-8.2176***	-15.6544***	-7.4037***
	(3.0106)	(2.9686)	(3.3939)	(2.8701)	(2.6016)	(2.4526)	(3.2125)	(2.3673)
lnalpha								
_cons					1.9639***	1.9932***	1.9344***	2.0239***
					(0.1536)	(0.1545)	(0.1542)	(0.1545)
N	454	454	454	454	454	454	454	454
Log-Likelihood	-1072.175	-1080.726	-1050.894	-1105.112	-402.429	-405.393	-400.564	-407.060
Pr>LR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Likelihood-ratio test α=0 (Chi²)	-	-	-	-	1339.49	1350.67	1300.66	1396.11
Pr>Chi²	-	-	-	-	0.00	0.00	0.00	0.00
Mc Fadden'sR²	0.422	0.418	0.434	0.404	0.110	0.104	0.114	0.100

AIC	2168.3509	2185.4519	2125.7887	2234.2246	830.8572	836.7855	827.1286	840.1190
BIC	2217.7680	2234.8691	2175.2059	2283.6418	884.3924	890.3208	880.6638	893.6543

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3) Results in column (I) to (IV) applied a Poisson regression estimation
4) Results in column (V) to (VIII) applied a Negative Binomial regression estimation

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
Vegetable oils	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 genetically engineered organisms	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
Within hybridcells	H01M 12/00-12/08
Pyrolysis or gasification of biomass	
	C10B 53/00
	C10J
Harnessing energy from manmade waste	
Agricultural waste	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
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 wood waste	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
Municipal waste	C10L 5/46
	F23G 5/00
Hydroenergy	
Water-power plants	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

TOPIC	IPC
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-crystal growth	C01B 33/02
	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
Charging batteries	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 space heating	F24D 3/00, 5/00, 11/00, 19/00
For swimming pools	F24J 2/42
Solar updraft towers	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
Geothermal energy	
Use of geothermal heat	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

TOPIC	IPC
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
Heat pumps	F25B 30/00
Using waste heat	
To produce mechanical energy	F01K 27/00
Of combustion engines	F01K 23/06-23/10
	F01N 5/00
	F02G 5/00-5/04
	F25B 27/02
Of steam engine plants	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
Regenerative heat-exchange apparatus	F28D 17/00-20/00
Of gasification plants	C10J 3/86
Devices for producing mechanical power from muscle energy	F03G 5/00-5/08
TRANSPORTATION	
Vehicles in general	
Hybrid vehicles, e.g Hybrid Electric Vehicles (HEVs)	B60K 6/00, 6/20
Control systems	B60W 20/00
Gearingstherefor	F16H 3/00-3/78, 48/00-48/30
Brushless motors	H02K 29/08
Electromagnetic clutches	H02K 49/10
Regenerative braking systems	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.g for hydrogen vehicles	B60L 11/18
Combustion engines operating on gaseous fuels, e.g hydrogen	F02B 43/00
	F02M 21/02, 27/02
Power supply from force of nature, e.g. sun, wind	B60K 16/00

TOPIC	IPC
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-powered vehicle	B62K
	B62M 1/00, 3/00, 5/00, 6/00
Rail vehicles	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 muscle power	B63H 16/00
Propulsion derived from nuclear energy	B63H 21/18
Cosmonautic vehicles using solar energy	B64G 1/44
ENERGY CONSERVATION	
Storage of electrical energy	B60K 6/28
	B60W 10/26
	H01M 10/44-10/46
	H01G 9/155
	H02J 3/28, 7/00, 15/00
Power supply circuitry	H02J
With power saving modes	H02J 9/00
Measurement of electricity consumption	B60L 3/00
	G01R
Storage of thermal energy	C09K 5/00
	F24H 7/00
	F28D 20/00, 20/02
Low energy lighting	
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

TOPIC	IPC
	E04F 15/18
For roofs	E04B 7/00
	E04D 1/28, 3/35, 13/16
For ceilings	E04B 9/00
	E04F 13/08
Recovering mechanical energy	F03G 7/08
Chargeable mechanical accumulators in vehicles	B60K 6/10, 6/30
	B60L 11/16
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
Refuse separation	B03B 9/06
Reclamation of contaminated soil	B09C
Mechanical treatment of waste paper	D21B 1/08, 1/32
Consuming waste by combustion	F23G
Reuse of waste materials	
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

TOPIC	IPC
Air quality management	
Treatment of waste gases	B01D 53/00-53/96
Exhaust apparatus for combustion engines with means for treating exhaust	F01N 3/00-3/38
Rendering exhaust gases innocuous	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
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
Dust removal 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
Pollution alarms	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	
Forestry techniques	A01G 23/00
Alternative irrigation techniques	A01G 25/00
Pesticide alternatives	A01N 25/00-65/00
Soil improvement	C09K 17/00

TOPIC	IPC
	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.g pollution credits	G06Q
Static structure design	E04H 1/00

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