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ENVIRONMENTAL PERFORMANCE AND REGIONAL INNOVATION SPILLOVERS

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Environmental Performance and Regional Innovation Spillovers

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Abstract

The achievement of positive environmental performance at national level could strongly depend on differences in local capabilities of both institutions and the private business sector. Environmental regulation alone is a weak instrument if the institutional and business environment cannot transform regulation strengths into opportunities. In this paper, we use the new environmental accounting matrix for polluting emissions now available for the 20 Italian Regions that covers 24 sectors and combines a shift-share approach with spatial econometric modelling. We provide evidence of the role played by internal innovation, innovation spillovers and regional policies in shaping the geographical distribution of environmental performance achievements.

J.E.L. codes: Q53; Q55; Q56; R15

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1. Introduction

This paper investigates the economic drivers which influence the geographical distribution of heterogeneous environmental performance by using the Italian regional NAMEA (*National Accounting Matrix including Environmental Accounts*). We aim to both disentangle the structural (sector/geographic) and efficiency factors behind a regional environmental performance and assess which drivers – productivity, innovation, policy – are relevant in determining environmental performance at regional level.

The first NAMEA was developed by the Dutch Central Bureau of Statistics (De Boo et al., 1993), and earlier contributions such as Ike (1999), Keuning *et al.* (1999), Steenge (1999), and Vaze (1999) provided empirical analyses related to the possible policy implications deriving from different environmental performance. More recently, contributions by De Haan (2004), De Haan and Keuning (1996), Femia and Panfili (2005), Mazzanti and Montini (2009), Mazzanti *et al.* (2008a, 2008b) have emphasised the usefulness of NAMEA datasets for econometric investigations into a number of different economic aspects. In the NAMEA tables, environmental pressures, in particular air emissions, and economic data (value added, final consumption expenditures and full-time equivalent job) are assigned to the economic branches of resident units directly responsible for environmental and economic phenomena.

The current Italian NAMEA covers 1990-2007 (ISTAT, 2009). Though we are not close to a complete NAMEA at EU level given the patchy availability of economic and environmental data by years and countries, it is worth noting that EUROSTAT has intensified its commitment to reach a full EU27 NAMEA, expected to be released by 2011. This effort is considered a silver bullet in EU strategy on environmental data generation for policy support, since it is recognised as a powerful instrument for assessing sustainable production and consumption performance (Watson and Moll, 2008). Although data availability has constrained empirical investigations into a single country (although with sector-specific analysis), the Italian regional NAMEA lets us introduce a geographical dimension into the empirical analysis of environmental performance, providing an original framework of analysis to be used for the complete EU NAMEA.

The regionalisation of the data generation has led to an Italian regional NAMEA for the year 2005, recently published by ISTAT (2009), involving 20 Regions, 24 productive sectors and 10 pollutants and resulting in a quite extensive dataset.[1] This paper analyses which drivers at regional level are capable of promoting positive environmental performance, and which gaps at sectoral level reduce the capacity to obtain them. Indeed, an environmental accounting approach such as that of the Italian regional NAMEA allows both regional and sectoral dimensions, applied to many different pollutants or to aggregated environmental themes differenced by their geographical distribution, such as a more global climate change issue or a more localised acidification process, to be considered. More importantly, interesting results may arise applying to a regional NAMEA the econometric techniques developed by the regional studies literature on the role played by innovation spillovers and environmental externalities on behaviours and location decisions by economic agents.

The paper is structured as follows. Section 2 presents the methodology both for shift-share analysis and the reference model for cross-sectional econometric analysis and Section 3 presents the dataset framework and how we specify spillovers between regions on innovation and emissions. Section 4 presents shift-share analysis empirical findings that disentangle structural and efficiency factors behind environmental performance. Section 5 presents the empirical results from the econometric estimations and Section 6 concludes the paper.

2. Applied analyses on regional NAMEA

2.1 The shift-share analysis

To explore the role of regional productive structures in emission efficiency across regions, shift-share analysis (Esteban, 1972, 2000) is first used to decompose the source of change of the

[1] For an overview of recent developments in regional NAMEA projects in the EU, see Goralzcyck and Stauvermann (2008) and Stauvermann (2007).

specified dependent variable into regional specific components (the *shift*) and the portion that follows national growth trends (the *share*).

Our starting point is the aggregate indicator of emission intensity, represented by total emissions of a particular pollutant on value added, defined as EM/VA for Italy - the benchmark, and as EM^r/VA^r for the analysed *r-th* region This indicator is decomposed as the sum of $(EM_k/VA_k)*(VA_k/VA)$ where VA_k/VA is the share of sector value added on total value added, for the *k-th* sector, with k defined from 1 to n (where n = 24 NACE sectors included in the regional NAMEA).[2]

For clarity, we redefine the index of emission intensity as X for the national average ($X=EM/VA$), as X^r for the *r-th* region ($X^r = EM^r/VA^r$) where $r = 1,\ldots,q$ (q = 20 Italian Regions), and as X_k for each *k-th* sector, resulting in ($X_k^r = EM_k^r/VA_k^r$) for each region and in ($X_k = EM_k/VA_k$) for Italy. We then define the share of sector value added as $P_k=VA_k/VA$ for Italy and $P_k^r=VA_k^r/VA^r$, for the *r-th* region.

On this basis, we can easily identify three effects, as prescribed by the *shift-share* decomposition. The first effect related to the structure or the *industry mix* (m^r), is given by:

$$m^r = \sum_{k=1}^{n}(P_k^r - P_k)X_k \qquad [1]$$

where m^r assumes a positive (negative) value if the region is specialised ($P_k^r - P_k > 0$) in sectors associated with lower (higher) environmental efficiency, given that the gap in value added sector shares is multiplied by the value X of the national average (as if the region were characterised by average national efficiency). The factor m^r assumes lower values if the *r-th* region is specialised in (on average) more efficient sectors.

The second factor represents the differential or efficiency feature (p^r), and is given by:

[2] See Table A1 in the Appendix for the productive sectors and NACE codes considered.

$$p^r = \sum_{k=1}^{n} P_k (X_k^r - X_k) \qquad [2]$$

where p^r assumes a positive (negative) value if the region is less (more) efficient in terms of emissions (the *shift* between regional and national efficiency) based on the assumption that ('as if') value added sector shares were the same for the region and for Italy ($P_k^r - P_k = 0$).

Finally, the covariance effect (a^r), or the allocative component, is as follows:

$$a^r = \sum_{k=1}^{n} (X_k^r - X_k)(P_k^r - P_k) \qquad [3]$$

The a^r factor assumes a minimum value if the region is specialised in sectors where it presents the highest 'comparative advantage' (low intensity of emissions) and the covariance factor is then between m^r and p^r. As Table 1 shows, these investigations provide some interesting insights.

Table 1 – Interactions of shift-share parameters with policy actions for environmental performance

industry mix (m)	*efficiency (p)*	*Lines of action*
+	+	Optimal situation: environmental policy with positive effect on economic system performance
-	-	Worse situation: need for strong joint actions on environmental policy and industrial policy sides
+	-	Development industrial policy aimed at enhancing the structural environmental performance jointly with competitiveness
-	+	Environmental and innovation policy favouring more energy and emission efficiency in the sectors which are more relevant in economic and environmental terms in the region

Note: + means the emission intensity is lower than the national average for the specific shift-share component

2.2 *Modelling drivers of environmental performance*

Let us consider environmental pressure here expressed through pollutant emissions for each *k-th* sector in each *r-th* region (E_k^r) as a function of production level (Y_k^r), technology (T_k^r), and environmental price (P_k^r). Emissions can be expressed as the following general function:

$$E_k^r = f\left(Y_k^r, T_k^r, P_k^r\right) \quad [4]$$

As suggested in Medlock and Soligo (2001), emission level may be expressed as a non-constant income elasticity function in the form of:

$$E_k^r = A_k^r {Y_k^r}^{\left(\delta+\gamma \ln Y_k^r\right)} {T_k^r}^{\phi} {P_k^r}^{\lambda} \quad [5]$$

and the logarithmic transformation of equation [5] takes the form of:

$$\ln E_k^r = a_k^r + \delta \ln Y_k^r + \gamma\left(\ln Y_k^r\right)^2 + \phi \ln T_k^r + \lambda \ln P_k^r + \varepsilon_k^r \quad [6]$$

where a_k^r assumes the role of technology-specific fixed effects and ε_k^r is the error term, thus representing a standard Environmental Kuznets Curve form, assuming that δ should be positive and γ negative. Since we are interested in an evaluation of the environmental performance for each sector expressed as a measure of emission intensity, we can transform equation [5] by scaling it with sector/region specific value added, thus obtaining the following reduced form:

$$e_k^r = \alpha_k^r + \beta_1 \ln Y_k^r + \beta_2 t_k^r + \beta_3 p_k^r + \varepsilon_k^r \quad [7]$$

where the lower case letters indicate the value of each variable in terms of sector/region specific value added and $\beta_1 = (\delta - 1)$. Assuming that δ is lower than unity, as economies of scale act in reducing energy consumption and pollutant emissions, consequently β_1 assumes negative values.

Regarding the technology-specific fixed effects (α_k^r), we may disentangle it into two components, where both region (α^r) and sector-specific (γ_k) effects may be included. In addition, Mazzanti and Zoboli (2009a) state that when technology is included in an environmental efficiency function, it is interesting to disentangle the effects related to strict technological innovation from the effects of labour productivity gains, thus replacing the term $\ln Y_k^r$ in eq. [7] with a properly defined labour productivity measure. In this case, we may expect that, *ceteris paribus*, when a productive sector presents higher labour productivity, its environmental performance will increase, thus a negative sign for the β_1 coefficient should come out.

The complementarities between innovations, economies of scale effects, corporate social responsibility behaviours by more innovative firms and sectors and the impure public good nature of environmental innovations that mitigates market failures, are among the factors that may lie behind a hypothesis of this type which often finds confirmation in empirical evidence (Mazzanti and Montini, 2010).

The effect related to technology in a standard emission demand model is represented by the state of technology in the production function where the more innovative firms are those which usually adopt more resource saving and/or less polluting technologies. Hence, the sign of the β_2 coefficient is also expected to be negative where the higher the efforts in technological innovation of the firm/sector, the lower the emission intensity.

Since recent regional economic growth models have increasingly appreciated the role of technological learning and knowledge spillovers, here we have also tested the role of technological spillovers as potential drivers of environmental performance. As Gray and Shadbegian (2007) have emphasised, there is some positive correlation between the effect of extra regional environmental regulation and regional environmental performance. Nonetheless, to the best of our knowledge, there has been no attempt at empirical level to assess the role of regional innovation spillovers in environmental performance. To this end, Kyriakopoulou and

Xepapadeas (2009) find that at theoretical level, environmental policy acts as a centrifugal force since increasing compliance costs reduce the advantage of localizing industrial activities in that region whereas knowledge externalities have a centripetal force fostering agglomeration patterns. The authors affirm that environmental regulation and knowledge spillovers may act as countervailing forces where knowledge spillovers occur when firms may exploit agglomeration economies whereas environmental policy reduces this clustering of economic activity.

Nonetheless, in our opinion, these general findings may only be plausible if we disentangle these potential countervailing effects at sectoral level while considering specific structural features both at geographical and productive level. Since environmental regulation will increase compliance costs for polluting activities only, it may be that a stringent regulatory framework also acts as a centripetal force, indirectly fostering an agglomeration pattern of cleaner (and technologically-advanced) productions via the well-known regulatory inducement effect (Popp, 2002).

We therefore affirm that with a properly defined disaggregation of manufacturing activities, environmental regulation and technological innovation strategies may act coherently towards an agglomeration effect of high-tech less-polluting activities. On this basis, we may well expect a positive effect on environmental performance related to prices for environmental externalities (p_k^r), or, in other words, in this case the β_3 coefficient is also expected to be negative where the more stringent the regulatory framework is at (general) regional level, the lower the emission intensity is at sectoral level.

In this paper, we have proxied the monetary value of environmental externalities by using the incidence of environmental regulation on average regional income (Costantini and Crespi, 2008). In our dataset we are not able to model specific effects for different sectors and we can only consider an overall regional environmental regulatory framework which allows a fixed structural effect to be shaped. As a result, public expenditures for environmental protection may be considered as a proxy of the willingness of citizens to pay to preserve natural environment, practically expressed by exploiting their voting preferences during the regional government elections for policy makers who pledge to make stronger efforts in environmental protection activities (Farzin and Bond, 2006).

According to Maddison (2006), a standard emission intensity econometric estimation may produce biased results due to the potential influence played by emissions 'from abroad' on domestic emissions, given the existence of spatial correlation problems. We argue that other than only a statistical influence of spatial correlation, the emissions produced by the neighbouring regions may well represent the role of economic agglomeration phenomena in explaining environmental performance (Gray and Shadbegian, 2007). A specific variable representing environmental spillovers from the other regions should therefore be included in eq. [7]. Considering environmental and innovation spillovers, eq. [7] is transformed as follows:

$$e_k^r = (\alpha^r + \gamma_k) + \underset{-}{\beta_1} \ln Y_k^r + \underset{+}{\beta_2} es_k^r + \underset{-}{\beta_3} t_k^r + \underset{-}{\beta_4} ts_k^r + \underset{-}{\beta_5} p_k^r + \varepsilon_k^r \qquad [8]$$

where es_k^r and ts_k^r represent the effects of environmental and innovation spillovers, respectively, from the other Italian regions, empirically modelled as described below. The expected positive sign for the β_2 coefficient is explained by the existence of agglomerative forces producing concentration of dirty activities into circumscribed geographical areas which may not correspond to those regions with lesser environmental regulation, as the comparison between shift-share analysis and econometric estimation results will clearly show.

3. Dataset description

The core part of the dataset is based on the 2005 Italian regional NAMEA, to our knowledge the only full regional NAMEA available in the EU. Environmental pressures (10 air pollutants) and economic data (value added, households' consumption expenditures and full-time equivalent job) are assigned to the economic branches of resident units. The accounting approach allows a full dataset to be shaped with information on environmental and economic aspects. Our dataset is organised as a q x n vector where n is the total number of k sectors ($\forall k = 1,...,n$, with n = 24) and q is the total number of 20 r Regions ($\forall r = 1,...,q$, with q = 20), with a potential number of observations equal to 480.

In the shift-share analysis we have considered specific pollutant emissions in order to have a clear picture of the distribution at sectoral level of emission intensity among Regions, since each pollutant may be associated with specific production specialisation. When testing the influence of different drivers of environmental performance as expressed by eq. [8], we have adopted the environmental theme aggregation tool provided by NAMEA, where specific pollutants are summed up as greenhouse gas emissions (GHG) and pollutants responsible for acidification process (ACID). To some extent, this choice enables us to make further considerations on potential different impacts of the same drivers associated with environmental damage with a different geographical distribution, since the effects of GHG are globally distributed whereas ACID emissions are more localised and transboundary effects may be confined to neighbouring Regions.

Since technological innovation is considered a crucial driver for explaining environmental performance, and bearing in mind that the role of innovation spillovers are particularly important for restricted geographical dimensions such as the Italian regions, we have divided the role played by technology into two components, a domestic (or internal) variable (t_k^r) and an inter-regional intra-sector spillover effect (ts_k^r).

In order to represent these two dimensions, we have considered a patent count approach due to the smaller amount of sector-based disaggregated data available for regional R&D expenditure. Some drawbacks characterise patents as a valid alternative to R&D data as an economic indicator, but previous studies at regional level have highlighted the helpfulness of patent applications as a measure of production of innovation (Acs *et al.*, 2002).

Patent data are drawn from the REGPAT dataset elaborated by Eurostat from the OECD PATSTAT database, gathering all patents for each Region according to the 3 digit IPC classification granted by the European Patents Office, geographically classified relying on postal codes of the applicants. The number of patent classes at the 3 digit level is 633, and we have considered all patent applications to the EPO by priority year at regional level.

We have adopted an *ad hoc* sector classification in order to assign patents (as classified by IPC codes) to specific manufacturing sectors (as classified by NACE codes) relying on previous concordance proposals such as the OECD Technology Concordance and the methodology developed by Schmoch *et al.* (2003), resulting in 13 available sectors (see Table A2 in the Appendix).[3] As a result of the high variance of patenting activity over time, we have considered patents in the time span 2000-2004 in order to calculate a five-year average value as the best proxy of innovation stock at sectoral level (Antonelli *et al.*, 2010).

We argue that the potential positive influence of innovating activities on environmental performance arises with temporal lags since the adoption of new technologies is not perfectly simultaneous with the invention itself. Since we are considering the impact of innovation on environmental performance as a side effect of innovative capacity at sectoral level, one year lag seems to be the most appropriate choice. Bearing in mind that eq. [8] expresses all terms scaled by value added, we have also computed patents to value added ratios in order to account for the innovation intensity of each sector.

In order to include the potential role of interregional spillovers, we first consider that the probability of innovation to spill from one region to another strictly depends on the fact that localisation economies are associated with the concentration of a particular sector in the two regions. Hence, it is not only a matter of geographical distance which explains the existence and the strength of innovation spillovers, but also economic structure similarity. Los (2000) and Frenken *et al.* (2007) propose adopting an index capturing the technological relatedness between

[3] In the econometric estimations we have been forced to consider only 12 manufacturing sectors, thus reducing potential observations from 480 to 240.

industrial sectors by computing the similarity between two sectors' input mix from input-output tables. When data availability is limited, an alternative solution is to form a similarity matrix based on technological specialisation indicators (Van Stel and Nieuwenhuijsen, 2004). In our case, we have considered knowledge spillovers coming from the same sector located in other regions, thus considering pure agglomerative effects related to environmental performance.

The relative specialisation index (RSI) is as follows:

$$RSI_k^r = \frac{t_k^r}{\sum_{k=1}^{n} t_k^r} \Bigg/ \frac{t_k^{IT}}{\sum_{k=1}^{n} t_k^{IT}} \qquad [9]$$

where t_k^r is the five-year average of patents to valued added ratios for each *k-th* sector and *r-th* region whereas t_{ITk} is the same measure at national level, as $t_{ITk} = \sum_{r=1}^{q} t_k^r$.

The bilateral innovation spillovers (ts_k^{rs}) for each *k-th* sector from the *s-th* Region to the *r-th* Region un-weighted by the geographical distance are expressed as:

$$ts_k^{rs} = \left(\frac{\left| RSI_k^r - RSI_k^s \right|}{\sqrt{RSI_k^r + RSI_k^s}} \right)^{-1} \cdot t_k^s \quad \forall s \neq r \qquad [10]$$

The resulting (*q* x *q*) matrix of spillovers for each *k-th* sector (with a vector of 0 in the diagonal dimension $\forall s = r$) is then synthesised into a linear vector by using geographical distances for aggregating the *s-th* elements. The geographical distances here adopted are calculated as the number of kilometres between the economic centres in each region bilaterally, by using the automatic algorithm based on highway distances with the shortest time criterion.

Following Bode (2004), we have tested several alternative criteria for transforming geographical distances into spatial weights. Since there is no a priori information for which spatial regime should be preferred, we have tested three different plausible regimes: i) the binary contiguity concept where only neighbouring regions matter for knowledge spillovers; ii) the *k* nearest neighbours concept (testing a bound distance of 300 km); iii) the pure inverse distances.

i) first-order binary contiguity

The binary contiguity concept (D_1) assumes that interregional knowledge spillovers only take place between direct neighbours that share a common border. We have only considered the first-order contiguity with direct neighbours, giving weight w_{rs} = 1 to each *s-th* region neighbouring region *r* and w_{rs} = 0 to all other regions. Consequently the variable reflecting interregional knowledge spillovers is defined as the sum of knowledge available in directly neighbouring regions as:

$$D_1 ts_k^r = \sum_{s=1, s \neq r}^{n} \left(ts_k^{rs} w_{rs} \right) \text{ with } \quad w_{rs} = 1 \text{ only if } s \text{ neighbouring } r \qquad [11]$$

ii) k nearest neighbours

We have also tested the role of knowledge spillovers strictly related to effective geographical distances and not only in terms of common border by placing weight w_{rs} = 1 to each *s-th* region at a specific common distance and w_{rs} = 0 to all regions with a greater distance (D_2). The maximum distance commonly found in the empirical literature leading to positive knowledge spillovers at regional level is around 300 km related to the maximum time for having regular face-to-face contacts (Bottazzi and Peri, 2003). In our dataset, establishing a threshold distance of 300 km involves including all neighbouring regions plus a few other regions only in specific cases. A smaller value - such as, for instance, 250 km - will coincide with our definition of neighbouring regions thus overlapping with our first-order binary contiguity matrix perfectly. In this case, interregional spillovers for each *k-th* sector and each *r-th* region results as follows:

$$D_2 ts_k^r = \sum_{s=1, s\neq r}^{n} \left(ts_k^{rs} w_{rs} \right) \text{ with } \quad w_{rs} = D_{rs}^{-1} \text{ only if } D_{rs} \leq 300km \text{, otherwise } w_{rs} = 0 \qquad [12]$$

iii) inverse distances

The third spatial regime relates to the assumption that the intensity of interregional knowledge spillovers may be subject to spatial transaction costs in the sense that the intensity of influences between any two regions diminishes continuously with increasing distance. In this case, we consider that the smaller the distance between *r* and any other region *s*, the higher the weight assigned to *s* with respect to its influence on *r*. Hence, the weight assigned to each region *s* ($\forall s \neq r$) is proportional to the inverse distance between *r* and *s*. Hence, the variable reflecting interregional knowledge spillovers is given by the distance-weighted (D_3) sum of knowledge available in all other regions.

$$D_3 ts_k^r = \sum_{s=1, s\neq r}^{n} \left(ts_k^{rs} w_{rs} \right) \text{ with } \quad w_{rs} = D_{rs}^{-1} \qquad [13]$$

with D_{rs} denoting the bilateral geographical distance between the economic centres of *r* and *s*.

Following empirical findings by Costa and Iezzi (2004) on technological spillovers among the Italian regions, we have considered only Marshall-Arrow-Romer type externalities, as innovation spillovers mainly derive from firms belonging to the same industry, while Jacob type externalities among sectors are rather smaller.

Since including innovation variables built on patent data reduced the number of NAMEA sectors in the analysis, forcing us to exclude the “Electricity, gas and water supply” sector (E in NACE codes), we have calculated emissions from electricity consumption for each sector as a measure of indirect emissions (while remembering that NAMEA only provides direct emissions). In this way, emissions associated with the E sector can be easily excluded while accounting for emissions due to energy consumption directly at sectoral level. This change in emission data allows us to obtain two additional valuable tools. The first one is not to consider emissions related to electricity production, whose energy mix choices are often decided at national rather than at regional level. The second advantage is related to the direct effect associated with innovation adoption on energy consumption. The decision to adopt technological innovation with a positive environmental (side) effect mostly depends on the possibility to exploit the resource-saving property of the innovation itself, and energy consumption reduction is particularly appreciated by Italian firms due to the relatively higher costs compared with other environmental resources.

We have calculated electricity consumption for each sector by using data provided by TERNA (the Italian major electricity transmission grid operator) and we have assigned related emissions by using an average national emission intensity factor per KWh for the two aggregated environmental themes such as greenhouse gas emissions responsible for climate change (GHG) and air pollutants responsible for the acidification process (ACID), with parameters equal to 0.38 and 0.016 respectively.[4]

Since we are arguing that environmental performance may well be affected by agglomeration effects associated with a cluster-based choice of the adopted production technique, the term (es_k^r) in eq. [8] has been proxied by the emission intensity of the surrounding regions. To this purpose, we have built a sort of negative environmental spillover as the sum of sectoral emissions per unit of value added from the other regions (e_k^s) valid for $\forall s \neq r$, weighted by distances expressed in the three different regimes described above (D_1, D_2 and D_3).

To some extent, we can interpret this variable as a sign of agglomerative effects for each sector

[4] We have considered an average value at national level assuming a common energy mix for all the Italian regions, depending on the fact that the decision of the energy mix adopted for each power plant is not completely regionally-based. Considering also that the electricity produced into each region may now be consumed anywhere due to electricity market liberalization, it is not possible to assume the energy mix related to the specific electricity consumed by firms a priori.

related to the technological frontier adopted. If, *ceteris paribus*, firms are located in one region surrounded by regions where firms adopt polluting production technologies, the probability that firms will adopt cleaner production technologies will decrease, so that a sort of polluting firm cluster emerges for selected geographical areas. The three environmental spillover measures are as follows:

$$D_1 es_k^r = \sum_{s=1, s\neq r}^{n} \left(e_k^s w_{rs}\right) \text{ with } \quad w_{rs} = 1 \text{ only if } s \text{ neighbouring } r \qquad [14]$$

$$D_2 es_k^r = \sum_{s=1, s\neq r}^{n} \left(e_k^s w_{rs}\right) \text{ with } \quad w_{rs} = D_{rs}^{-1} \text{ only if } D_{rs} \leq 300km, \text{ otherwise } w_{rs} = 0 \qquad [15]$$

$$D_3 es_k^r = \sum_{s=1, s\neq r}^{n} \left(e_k^s w_{rs}\right) \text{ with } \quad w_{rs} = D_{rs}^{-1} \qquad [16]$$

Finally, since environmental prices are considered drivers of environmental performance in eq. [8], we can proxy them by the stringency of the environmental regulatory framework. Environmental regulation is then represented by three alternative public expenditure measures, related to current, capital and R&D expenditures for environmental protection activities as emerging from accounting documents of each Region (ISTAT, 2007).

4. Shift-share analysis

For the sake of simplicity, in the shift-share analysis we restrict comments on main Regions and on five pollutants (CO_2, SO_X, NO_X, PM10, NMVOC). Table 2 shows how Italian Regions behave with respect to the national average when emission intensities are compared before they are decomposed. Table 3 already shows a quite clear North-South divide which we can investigate further with regard to its innovation/policy/industrial structural drivers. Nevertheless, it also shows that some central and southern regions (Lazio and Campania) behave quite well whereas some rich industrial regions (Veneto, Friuli Venezia Giulia) do not perform so satisfactorily, highlighting idiosyncrasies and criticalities that may be related to more complex issues bringing together geographical, economic and policy issues.

Table 2 – Regional performance§ with regard to the national average (geographical area in brackets)

10 out of 10	Marche (C), Lazio (C) and Campania (C)
9 out of 10	Trentino Alto Adige (NE)
8 out of 10	Lombardia (NO) and Toscana (C)
7 out of 10	Piemonte (NO), Valle d'Aosta (NO) and Liguria (NO)
6 out of 10	Emilia Romagna (NE) and Abruzzo (C)
5 out of 10	Veneto (NE)
4 out of 10	Calabria (S), Sicilia (I) and Umbria (C)
1 out of 10	Puglia (S) and Basilicata (S)
0 out of 10	Sardegna (I)

Notes: NW= North West; NE= North East, C=Centre, I=Islands, S=South.
§ number of pollutants out of 10 with a better performance than the national average.

Table 3 – CO_2 and SO_X emission intensity (kg x 1M€ of value added, increasing order)

Region	CO_2	Region	SO_X
Trentino Alto Adige	136	Trentino Alto Adige	39
Campania	141	Valle d'Aosta	45
Valle d'Aosta	153	Abruzzo	69
Piemonte	185	Campania	78
Lazio	204	Lombardia	99
Marche	206	Lazio	101
Lombardia	209	Marche	108
Abruzzo	258	Piemonte	108
Veneto	267	Calabria	123
Emilia Romagna	270	Basilicata	224
Toscana	278	Emilia Romagna	226
Italy	301	Molise	276
Calabria	307	Veneto	300
Umbria	342	Italy	315
Friuli Venezia Giulia	353	Toscana	349
Basilicata	430	Umbria	373
Liguria	472	Friuli Venezia Giulia	539
Sicilia	547	Puglia	859
Molise	689	Liguria	886
Sardegna	824	Sicilia	1,347
Puglia	971	Sardegna	1,530

If we examine the decomposition of industry mix and efficiency/differential components, interesting insights emerge. Table 4 sums up the industry mix heterogeneous effect: while it is evident that more industrialised regions in the North are penalised by this structural component (Lombardia, Emilia Romagna, Veneto, three main industrialised regions), southern regions benefit from an environmental perspective of their less industrialised specialisation.[5]

It is also significant that, among the largest main regions, Lazio (the region of Rome), as a service-oriented region, benefits from a productive structure of this type in environmental terms, and two small but economically important regions in the North, with a high degree of (fiscal and legislative) autonomy and cultural idiosyncrasies (including regional languages), such as Trentino Alto Adige and Friuli Venezia Giulia, also benefit on average from the industry mix component. Summing up, this part of the shift-share analysis tells us that the North-South divide regarding industrial development obviously affects the environmental comparative advantage of a region, other things being equal. But this is only half, or part, of the story.

Table 4 – Shift-share results: industry mix vs. production specialisation component (*m*)

Region	CO_2	SO_X	NO_X	NMVOC	PM
Lombardia (North)	-0.089	-0.222	-0.208	-0.09	-0.017
Trentino Alto Adige (North)	-0.144	-0.268	-0.215	-0.112	-0.037
Friuli Venezia Giulia (North)	0.089	0.284	0.268	0.401	0.026
Veneto (North)	-0.048	-0.029	-0.071	-0.082	-0.002
Emilia Romagna (North)	-0.054	-0.156	-0.136	0.009	-0.017
Lazio (Centre)	-0.086	-0.211	-0.096	0.301	-0.037
Puglia (South)	0.654	0.663	0.7	0.168	0.175
Sicilia (South)	0.265	0.916	0.577	1.179	0.039

Note: the lower the value, the better the environmental performance.

Table 5 shows the efficiency driver results. The efficiency gap is the main driving force behind regional comparative advantage and Table 4 shows various cases of best and worst situations that highlight how efficiency and North-South structural differences are jointly relevant in explaining different striking performances.

It is noteworthy that Friuli Venezia Giulia, a developed industrialised region associated with high income per capita, performs badly on average, and not because of its industry mix, as we commented on above, but because of specific inefficiency features. The North-East as a whole, an area of the country with high economic performance driven by export intensive manufacturing and some heavy industry, appears to perform worse than the North-West

[5] All detailed results of the shift-share analysis are available upon request.

(Piemonte and Lombardia).[6] The former is currently the region that, as far as the subset of 5 emissions we consider here is concerned, always performs better than average with regard to both industry mix and efficiency (although the Municipality of Milan was recently taken to court for pollution levels above predetermined thresholds, this shows likely differences in performance between industries and transport/household, with lower environmental performance).

Table 5 – Shift-share results: efficiency vs. differential component (*p*)

Region	CO_2	SO_X	NO_X	NMVOC	PM
Lombardia (North)	0.019	0.065	-0.036	0.079	-0.009
Trentino Alto Adige (North)	-0.009	-0.059	-0.017	-0.038	0.013
Friuli Venezia Giulia (North)	-0.029	-0.069	-0.055	-0.011	-0.008
Veneto (North)	0.024	0.01	0.017	0.098	0.007
Emilia Romagna (North)	0.047	0.033	0.095	0.025	0.025
Lazio (Centre)	-0.022	-0.002	-0.019	-0.129	-0.028
Puglia (South)	0.002	-0.035	0.055	-0.033	0.03
Sicilia (South)	-0.022	-0.009	0.033	-0.083	0.015

Note: the lower the value, the better the environmental performance.

In other northern industrial regions, on average, but not for all emissions, efficiency gains tend to compensate for unfavourable industry mix features. Given the often proposed dichotomy between the type of industrial development in the North-East of Italy, relatively based more on small and medium enterprises (SMEs) and districts rather than on large corporate firms with outsourcing collars, it is interesting to stress that at least at macro level, the economic development model based on SMEs seems to link less strictly economic and environmental performance. At a descriptive level, we note that, though not all innovative activities are captured by official data in SMEs (Mazzanti and Zoboli, 2009b), the R&D performance of the north-western part of the country are massively higher, driven probably by the larger share of big corporate firms in the North-West (FIAT for example). One interesting case is once again Friuli Venezia Giulia, which is characterised by high innovative industrial niches but also hosts industrial sites that exploit coal quite intensively (some energy power and steel factories in

[6] The most industrialized Italian regions are definitely Lombardia (NW), Veneto and Emilia Romagna (NE), with a GDP share of around 33-34%, whereas Piemonte (NW) and Friuli Venezia Giulia (NE) are less industrialized.

Trieste). The reasoning on regional energy structure also points to the evident good performance of a region like Trentino Alto Adige (Table 6) which emerges with the best gap in 3 out of 5 emissions examined. This region is less industrialised than other northern ones, and also depends enormously on renewable energy (mostly hydroelectric). Energy sector is also relevant in southern regions, around 3% of value added, but the type of energy mix drastically affects performance. We use this result to comment on the direct nature of NAMEA emissions whereas accounting for the indirect generation of emissions would partially change the results. Though we will stick to this intrinsic NAMEA feature, a weakness in the benefits of using a fully coherent integrated emission-economic accounting system, we will tackle this issue in the following sections by also accounting for indirect emissions caused by electricity consumption (as described in par. 3).

Shift-share analysis has shown that the North-South divide in economic and environmental performance is, as mostly expected, the crucial part of the story, with some interesting exceptions (Table 6). We also mention how intense and polluting development of this type has done little to help the South to achieve economic convergence with the North.

Table 6 – Largest gaps and main driver between regions and the Italian average

	CO_2	SO_X	NO_X	NMVOC	PM_{10}
Emissions/Value added					
Italy	0.301	0.315	0.713	0.460	0.111
Best region	Trentino Alto Adige	Trentino Alto Adige	Lombardia	Trentino Alto Adige	Lazio
Gap region/Italy	0.136	0.079	0.465	0.241	0.055
Worst region	Puglia	Sardegna	Sardegna	Sicilia	Puglia
Gap region/Italy	0.971	1.53	1.574	0.749	0.3
Ratio worst/best	7.14	19.37	3.38	3.11	5.45
Shift-share parameters					
Best region for industry mix (m) or efficiency (p)	Trentino Alto Adige	Trentino Alto Adige	Lombardia	Trentino Alto Adige	Lazio
Gap region/Italy	0.144	0.268	0.208	0.215	0.037
Main factor	p	p	p	p	p
Worst region gap for industry mix (m) or efficiency (p)	Puglia	Sardegna	Sardegna	Sicilia	Puglia
Gap region/Italy	0.654	1.481	0.956	1.179	0.175
Main factor	p	p	p	p	p

North and South performances could well be affected by differences in innovation and regulatory efforts. The main aim of the following econometric analysis is to study, in a multivariate setting, what role geographical and sector-based factors play, with specific attention paid to understanding if and to what extent environmental performance is affected by innovation and environmental spillovers, while also accounting for the relevance of spatial correlation and clustering of economic and environmental performance.

5. Emission intensity drivers: econometric evidence

Looking at the geographical distribution of polluting emissions in Italy, there is a strong spatial concentration of dirty sectors in restricted areas which may not always correspond to regions with relatively less stringent environmental regulation. Shift-share analysis has therefore, on the one hand, given a clear picture of the geographical and sectoral distribution of environmental performance whereas, on the other, the spatial econometric analysis provides insights into the relative importance of distinct drivers.

As described above, the econometric estimations aim to investigate the relative strength of the effects associated with internal and external innovation drivers as well as the role of the environmental regulatory framework. In particular we test the influence of such factors over the geographical and sectoral distribution of environmental performance for two aggregated damage effects due to pollutant emissions, such as GHG and ACID, characterised by differences in the diffusion paths. To some extent, the reaction from the community will be consistent with these differences, since we expect the impact of knowledge externalities to be higher for more localised polluting emissions. With regard to more relatively local externalities, the collective action (played by consumers but also by firms) may play a relevant role because the convenience to exploit innovation externalities from neighbouring areas is potentially higher. In fact, the inducement effect on a technology path oriented toward less-polluting production processes also comes from private initiative, and not only from public enforcement, due to a stronger and more diffused perception of damages directly associated with environmental externalities. In this sense, the probability that an innovation will also be suitable for environmental protection purposes will be higher, and the probability of a higher diffusion speed will also increase.

We also test how relevantly spatial correlation is influencing results, by implementing diagnostics for spatial dependence (Maddison, 2006).[7]

As a first outcome, we note that the impact of labour productivity on explaining the environmental performance is rather high in both models (GHG and ACID emissions), and the expected negative coefficient associated with this variable can be interpreted as a positive correlation between productivity and environmental efficiency gains which is an expected result depending on the interplay of multiple 'drivers' along the evolution of innovation, industrial and policy paths. Consistently with expectations and other analyses on NAMEA data in Italy we referred to, this coefficient is larger for ACID than for GHG, as this second environmental theme is rather more complex and influenced by a broader mix of driving factors.

Since we have disentangled pure innovation effects from all other characteristics in the production function, we can affirm that labour productivity explains all structural features in the production process such us the adoption of environmental management systems, quality control, highly efficient mechanical appraisals, which are not specifically caught by the innovative capacity of the economic sector captured by patent intensity.[8]

Secondly, with regard to environmental efficiency spillovers, it is worth noting that they play a significant role in explaining environmental performance better for GHG emissions, and their statistical robustness is clearly reinforced by using the spatial lag model. The maximum distance where the environmental spillovers occurs coincides with regions in the range of 300 km so that

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[7] The spatially corrected econometric model is then estimated for GHG, where the diagnostic significantly supports the need for spatial correction, (Table 7) whereas for ACID the statistics for the lag and error spatial dependence clearly show that the OLS estimations are unbiased (Table 8). Although the spatial diagnostics are carried on an OLS with no geographical dummies, for ACID we then included regional dummies obtaining substantial improvements in statistical robustness of our model.

[8] We have also included a specific variable related to energy intensity for each sector, and we have introduced a dummy variable which absorbs the effect of specific dirty industries. In this way, productivity gains and innovation effects can be interpreted as the real impact on environmental efficiency related to investments in technology and labour productivity. The specific dirty industries assuming value 1 in the dummy are: Agriculture, Manufacture of coke, refined petroleum products and nuclear fuel, Manufacture of chemicals and chemical products, Manufacture of other non-metallic mineral products.

emission intensity of the same sector into other regions influences internal emission intensity within two spatial regimes, the D_1 and D_2 (eq. [14] and eq. [15] respectively).[9] The expected positive coefficient can be interpreted as a first evidence of the existence of clusters not only intended as agglomeration of specific sectors into restricted areas, but also as a first influence of the technology adopted in the production processes. The lower environmental efficiency of the neighbouring sectors is, the lower the internal environmental performance of each specific sector. This means that together with the agglomeration of specific sectors into restricted areas, there is also some convergence in production processes and techniques. Indeed, when controlling for sector fixed effects, the negative impact on environmental performance related to environmental spillovers still remains. To some extent, we can affirm that the clustering process of specific polluting sectors in relation to contiguous geographical areas may be followed by common choices in the adoption of cleaner or dirtier technologies. This evidence is nevertheless not present for the more localised damage (ACID), also when controlling for sector specific and geographical fixed effects.

On the other hand, it is worth noting that the level of 'internal innovation', expressed as the number of patents per value added, plays a limited role in explaining environmental efficiency since the coefficient, although it is negative as expected, presents low size and very limited statistical robustness. This evidence is robust across both specifications. We can interpret this result by considering the fact that our innovation variable relates to the general efforts by firms/sectors to produce technology, without a definition of specific environmental purposes.

On the contrary, technological interregional spillovers seem to play a more effective role in improving environmental efficiency, with clear robustness in the spatially-lagged models. The higher impact of innovation spillovers compared with internal innovation can be explained by the

[9] Tables 7 and 8 show coefficients for D_2 spatial regimes, but results are also consistent with D_1. Regime D_3 is not significant both for environmental (eq. [16]) and technological (eq. [13]) spillovers. For the sake of simplicity, results are not shown in the Tables but they are available upon request from the authors.

nature of our innovation variable.[10]

Table 7 – Main drivers for environmental performance in the GHG estimation

	OLS with diagnostic for spatial dependence			Spatially-lagged models		
	(1)	(2)	(3)	(1)	(2)	(3)
Labour productivity	-0.707***	-0.695***	-0.671***	-0.676***	-0.665***	-0.650***
	(-4.77)	(-4.68)	(-4.56)	(-4.71)	(-4.64)	(-4.57)
Environ. Spillovers	0.081	0.090*	0.099**	0.171***	0.183***	0.185***
	(1.60)	(1.79)	(2.06)	(3.01)	(3.27)	(3.43)
Internal Innovation	-0.033*	-0.031*	-0.022	-0.030*	-0.029*	-0.022
	(-1.90)	(-1.78)	(-1.31)	(-1.79)	(-1.68)	(-1.38)
Tech. Reg. Spillovers	-0.046*	-0.051**	-0.043*	-0.057**	-0.060**	-0.055**
	(-1.90)	(-2.06)	(-1.76)	(-2.40)	(-2.52)	(-2.30)
Env. Reg. Current Exp.	-0.123*			-0.086		
	(-1.88)			(-1.34)		
Env. Reg. Capital Exp.		-0.081			-0.054	
		(-1.48)			(-1.00)	
Env. Reg. R&D Exp.			-0.050*			-0.035
			(-1.76)			(-1.27)
Energy Intensity	0.639***	0.634***	0.627***	0.647***	0.644***	0.639***
	(15.44)	(15.24)	(15.68)	(16.06)	(15.89)	(16.35)
Dirty Sector dummy	1.197***	1.184***	1.171***	1.223***	1.215***	1.206***
	(9.36)	(9.25)	(9.30)	(9.80)	(9.73)	(9.80)
Constant	3.904***	3.886***	3.464***	3.740***	3.712***	3.428***
	(7.25)	(7.10)	(6.53)	(7.17)	(7.02)	(6.69)
Spatial Lag				-0.113***	-0.119***	-0.116***
				(-2.59)	(-2.75)	-(2.64)
No obs.	209	209	209	209	209	209
Adj R-sq	0.74	0.74	0.74	0.76	0.76	0.76
F-stat	76.66	75.99	76.45			
LM (lag)	3.11 (0.08)	3.55 (0.06)	3.39 (0.07)			
Robust LM (lag)	7.38 (0.01)	7.78 (0.01)	7.25 (0.01)			
LM (error)	1.25 (0.26)	1.03 (0.31)	0.81 (0.37)			
Robust LM (error)	5.51 (0.02)	5.27 (0.02)	4.66 (0.03)			
Log L				-199.19	-199.58	-199.27
Breusch-Pagan test				74.07	61.84	50.46
LR test				4.38	4.98	4.65

Notes: ***, **, *, for *p-values* of 0.01, 0.05, 0.1, respectively; *t-stat* values in parentheses.

As in the case of environmental spillovers, the same spatial regimes (D_1 and D_2) give robust results, meaning that innovation effects also spread out of the regional borders for a limited distance only. Consistently with our expectations, the positive influence of technological spillovers on environmental performance is rather higher for more localised pollutants (ACID) since the collective reaction to better perceived environmental damage will be to adopt the

[10] We have also tested the potential influence of a general internal spillovers effect coming from all other sectors and a general spillover effect coming from all other sectors of the other regions (Jacobs type externalities), but results are not statistically significant. Thus the only significant result is associated to the existence of Marshall-Arrow-Romer type externalities as technological spillovers from innovation activities of firms in the same sector located in the neighbouring regions.

innovations available in each sector more rapidly and diffusely. In this case, the size of the coefficient – its economic significance – is much larger comparing to GHG, also confirming the evidence previously found for labour productivity.

Since we are including in our covariates some variables related to regional innovation and technological spillovers from the other regions in the same time period (one year lag), a multicollinearity problem may arise if regional innovation can be explained by spillovers, as a standard result in regional economic convergence literature. In order to check for robustness of our model, we have tested a potential endogeneity of the regressor explaining regional innovation by performing the Hausman test on the two alternatives, a standard OLS and an instrumental variable (IV) estimator where regional patents are instrumented by spillovers and other common variables in the technology diffusion literature. The test rejected the hypothesis that the IV estimator performs better than the OLS which remains consistent and efficient.[11]

Finally, with regard to public environmental expenditure, coefficients show an expected negative sign since an increase in the social price of negative externalities would force firms to adopt more efficient production processes. Variables related to current and capital expenditures, as well as to specific R&D environmental expenditures, have been tested with one lag. Nonetheless, we can affirm that overall effects are not significant and even 10% significance fades away when spatially corrected estimates are considered. This is partially due to their sector invariance and to the limited lag between expenditure occurrence (2004) and environmental performance (2005), but we believe that other elements are also important. Evidence can highlight a more substantial and well-known weakness of Italian environmental policy on average that does not present a structural, clear and long-term strategy to climate change. Italy has not achieved the Kyoto targets (-6.5%) and may well be embedded in the 'climate change sceptical countries' as far as the effective abatement target is now around -13% of the 1990 emissions level. This negligible effect

[11] We have also tested robustness of our specification by including alternatively the two innovation dimensions and coefficients which remain stable in signs and statistically significant both for regional innovation and regional spillover effects.

of policies and expenditures is to be further checked by future studies using regional and national statistics.

Table 8 – Main drivers for environmental performance in the ACID estimation

	OLS with diagnostic for spatial dependence			OLS with regional dummy variables		
	(1)	(2)	(3)	(1)	(2)	(3)
Labour productivity	-1.375***	-1.394***	-1.347***	-1.323***	-1.343***	-1.356***
	(-7.08)	(-7.25)	(-7.19)	(-6.66)	(-6.76)	(-7.05)
Environ. Spillovers	0.027	0.016	0.043	0.060	0.050	0.043
	(0.39)	(0.24)	(0.71)	(0.84)	(0.70)	(0.64)
Internal Innovation	-0.016	-0.020	-0.012	-0.035	-0.037*	-0.036*
	(-0.75)	(-0.94)	(-0.61)	(-1.62)	(-1.72)	(-1.73)
Tech. Reg. Spillovers	-0.043	-0.046	-0.042	-0.109***	-0.107***	-0.106***
	(-1.52)	(-1.60)	(-1.45)	(-3.10)	(-3.03)	(-3.03)
Env. Reg. Current Exp.	-0.045			0.009		
	(-0.58)			(0.12)		
Env. Reg. Capital Exp.		-0.072			-0.022	
		(-1.07)			(-0.26)	
Env. Reg. R&D Exp.			-0.009			-0.042
			(-0.25)			(-1.17)
Energy Intensity	0.424***	0.430***	0.418***	0.439***	0.443***	0.447***
	(8.97)	(9.16)	(9.17)	(9.34)	(9.46)	(9.73)
Dirty Sector dummy	2.447***	2.474***	2.404***	2.346***	2.374***	2.393***
	(10.95)	(11.33)	(11.54)	(10.09)	(10.23)	(10.78)
Constant	4.306***	4.429***	4.135***	3.857***	3.968***	3.768***
	(6.17)	(6.33)	(6.18)	(5.27)	(5.19)	(5.39)
Geographical dummies				Yes	Yes	Yes
No obs.	209	209	209	209	209	209
Adj R-sq	0.73	0.73	0.73	0.74	0.74	0.74
F-stat	81.04	81.48	80.89	50.38	50.40	50.84
LM (lag)	2.44 (0.12)	2.80 (0.09)	2.21 (0.14)			
Robust LM (lag)	0.25 (0.62)	0.25 (0.62)	0.17 (0.68)			
LM (error)	5.44 (0.02)	6.11 (0.01)	4.73 (0.03)			
Robust LM (error)	3.24 (0.07)	3.56 (0.06)	2.70 (0.10)			

Notes: ***, **, *, for *p-values* of 0.01, 0.05, 0.1, respectively; *t-stat* values in parentheses.

In addition, we can highlight that a mix of different regional peculiarities behind environmental regional actions can statistically lead to overall insignificant evidence. For example, if we take a look at recent data on regional resources (2007-2013 regional expenditure linked to the regional plans, approved in 2007 by the European Commission which funds the Fund on regional development) devoted to sustaining environmental innovations in SMEs, the picture is mixed.[12] In some cases high/low expenditures correlate and have driven good/bad performance whereas

[12] Both the Northern developed regions with good environmental performances and Southern regions with critical environmental hot spots we commented on in the shift-share analysis are found at the top of the ranking (Puglia, 9.3% share devoted to eco-innovations out of the total; Piemonte 6.94%, Lazio and Trentino 4.7%) since other areas with medium and low performances are lagging (Veneto 3.4%, Lombardia 1.89%, Emilia Romagna 1.89%, Friuli 0%).

in other cases, high expenditures are a structural reaction to bad performance and they will take time to take effect.

As a robustness check, we have also tested the potential effects of neighbouring environmental regulatory system in line with Gray and Shadbegian (2007), but we have not found any significant effect on emission intensity reduction.

To sum up, our results provide evidence of the existence of an agglomeration effect at sectoral level leading to a higher concentration of polluting firms adopting dirtier production processes. There is also a countervailing force fostering environmental performance produced by the existence of centripetal forces associated with innovation spillovers among regions. The clustering effect in both cases is robust and coincides with a delimited geographical dimension since the limiting distance up to which spillovers – both environmental and technological – exist is 300 km.

Nonetheless, there are also some differences associated with the relative strengths of these countervailing forces since for the global pollutants (GHG), the agglomerative impact associated with environmental efficiency externalities overwhelms the clustering effect due to general innovation spillovers, whereas for the more localised environmental damage (ACID) the opposite occurs, with only technological spillovers being significant.

Finally, the differentiated strengths of these contrasting forces, as well as their relative differences for alternative pollutants, clearly confirm the heterogeneous distribution of territorial environmental performance previously described in the shift-share analysis.

6. Conclusions

The achievement of positive environmental performance at national level could strongly depend on differences in local/regional capabilities of both institutions and the private business sector. This paper has developed diverse and complementary empirical analyses using the 2005 Italian regional NAMEA released in 2009 for the first time. This is a unique and new data source that may open the way to more integrated and multi country NAMEA studies at European level.

First, the decomposition of industry mix and efficiency components revealed by shift-share analysis tells us that the Italian North-South divide regarding industrial development and productive specialisation patterns obviously affects regional environmental performance.

The strong North-South differences in environmental performance, on the one hand may reflect coherence with economic development stages and priorities but, on the other hand, can also signal regulatory and industrial policy failures/successes occurring in different regions even at similar income levels. Industrial regional specialisation matters but efficiency effects also play a crucial role. The North-East as a whole, a leading economic area of the country with high economic performance driven by export intensive manufacturing sectors, appears to perform worse than the Western part of the industrialised North. Traditional elements of the North-South divide are not therefore an exhaustive explanation of the heterogeneous geographical distribution of pollution in Italy. Sector-specific features as well as inter-sectoral relationships allow this information gap to be reduced.

Through a spatial econometric analysis we have explored how geographical and sector-based factors play a role together with other potential drivers of environmental performance such as innovation related factors, public interventions, as well as spatial elements such as technological spillovers, correlation and clustering of economic and environmental performance. Especially for a more global environmental theme such as GHG emissions, it is worth noting that environmental spatial spillovers play a significant role in explaining environmental performance. This result can be interpreted as a first evidence of the existence of clusters not only intended as agglomeration of specific sectors into restricted areas, but also as the influence of the technology adopted in the production processes into neighbouring areas. As the environmental efficiency of the neighbouring sectors decreases, the internal environmental performance for each specific sector decreases as well. This means that together with the agglomeration of specific sectors into restricted areas, there is also some convergence in the production process techniques. The clustering process of specific polluting sectors into selected geographical areas seems to be followed by common choices in the adoption of cleaner or dirtier technologies. This helps us to explain why the same sector specialisation into different regions may be characterised by different emission intensity or efficiency as found in the shift-share analysis.

A second important result is that technological interregional spillovers seem to play a more effective role than internal innovation in improving environmental efficiency, with an increasing effect for more localised pollutants.

As a concluding remark, our results have shown that environmental performance of the Italian regions may well be affected by differences in sector-specific features such as labour productivity, innovation efforts and region-specific regulatory frameworks. The current and future design of industrial, innovation, and environmental policies at national and regional level should therefore be more coordinated, while also accounting for geographical and sectoral features as well as the intrinsic nature of the environmental issue considered.

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APPENDIX

Table A1 – Productive branches and NACE code

Productive branches (ATECO 2001)

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

Table A2 – Concordance classification for NACE sectors, NAMEA sectors and IPC codes

CODE NAMEA	CODE NACE	CODE IPC
1	A - Agriculture	A01
3	C - Mining and quarrying	E21
4	DA15 - Manufacture of food products and beverages DA16 - Manufacture of tobacco products	A21-A22-A23-A24-C12-C13
5	DB17 - Manufacture of textiles DB18 - Manufacture of wearing apparel; dressing; dyeing of fur	A41-A42-D01-D02-D03-D04-D05-D06
6	DC19 - Tanning, dressing of leather; manufacture of luggage	A43-B68-C14
7	DD20 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials DH25 - Manufacture of rubber and plastic products DN36 - Manufacture of furniture; manufacturing n.e.c.	A44-A45-A46-A47-A63-B09-B27-B29-C02-C30-G10
8	DE21 - Manufacture of pulp, paper and paper products DE22 - Publishing, printing, reproduction of recorded media	B31-B42-B43-B44-D21-G09
9	DF23 - Manufacture of coke, refined petroleum products and nuclear fuel DG24 - Manufacture of chemicals and chemical products	C01-C05-C06-C07-C08-C09-C10-C11-C40-F16
10	DI26 - Manufacture of other non-metallic mineral products	B28-B32-C03-C04
11	DJ27 - Manufacture of basic metals DJ28 - Manufacture of fabricated metal products, except machinery and equipment	B25-B26-C21-C22-C23-C25-D07-E02-E05
12	DK29 - Manufacture of machinery and equipment n.e.c. DL30 - Manufacture of office machinery and computers DL31 - Manufacture of electrical machinery and apparatus n.e.c. DL32 - Manufacture of radio, television and communication equipment and apparatus DL33 - Manufacture of medical, precision and optical instruments, watches and clocks DM34 - Manufacture of motor vehicles, trailers and semi-trailers DM35 - Manufacture of other transport equipment	A61-A62-B01-B02-B03-B04-B05-B06-B07-B08-B21-B22-B23-B24-B30-B41-B60-B61-B62-B63-B64-B65-B66-B67-B81-B82-F01-F02-F03-F04-F15-F21-F23-F24-F25-F26-F27-F41-F42-G01-G02-G03-G04-G05-G06-G07-G08-G11-G12-H01-H02-H03-H04-H05
13	E - Electricity, gas and water supply	E03-F17-F22-F28-G21-H02
14	F - Construction	E01-E04-E06

Source: own elaborations on Schmoch *et al.* (2003)

Table A3 – Variables description

Labour productivity	Value added per full-time equivalent job unit
Environ. Spillovers (D1)	Sector-specific pollutant emissions in directly neighbouring regions eq. [14]
Environ. Spillovers (D2)	Sector-specific pollutant emissions in regions ≤ 300 km maximum distance eq. [15]
Environ. Spillovers (D3)	Sector-specific pollutant emissions in all regions eq. [16]
Energy intensity	Electricity consumption to value added ratio for each specific sector
Env.Reg.Curr.Exp.	Environmental regional expenditure 2004 (current)
Env.Reg.Cap.Exp.	Environmental regional expenditure 2004 (capital)
Env.Reg.R&D.Exp	Environmental R&D regional expenditure 2004
Internal Innovation	Number of patents per value added; five-year average 2000-2004
Tech. Reg. Spillovers (D1)	Sector-specific innovation spillovers from patents intensity (five-year average 2000-2004) available in directly neighbouring regions eq. [11]
Tech. Reg. Spillovers (D2)	Sector-specific innovation spillovers from patents intensity (five-year average 2000-2004) available in regions ≤ 300 km maximum distance eq. [12]
Tech. Reg. Spillovers (D3)	Sector-specific innovation spillovers from patents intensity (five-year average 2000-2004) available in all regions eq. [13]
Dirty Sector dummy	Dummy for heavy polluting sectors as explained in footnote n. 10