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Summary

This paper provides new empirical evidence on regional–national disparities in environmental efficiency, based on case studies of Italy and the Lazio region, which includes the city of Rome. Shift-share analyses provide evidence on the drivers of environmental efficiency and on sector specificity. This confirms the usefulness of this method for studying the environmental economics realm, in order to investigate structural and efficiency factors at the level of within country environmental efficiency performance, even in light of the different shares of services. Our evidence shows that although the Rome region has achieved higher environmental performance compared to Italy mainly thanks to its being less industry based, some critical points in the energy sector and in some services should be taken into account in shaping the future development of the region. Environmental, industrial and sector-oriented policy making may also derive valuable information from the evidence provided by our study.

Keywords: NAMEA, Shift Share, Regional Development, RAMEA, Emission Efficiency, Economic Efficiency

JEL Classification: C67, D57, O4, O18, Q53, Q56

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Empirical evidence from structural shift-share analysis of NAMEA data

Abstract

This paper provides new empirical evidence on regional–national disparities in environmental efficiency, based on case studies of Italy and the Lazio region, which includes the city of Rome. Shift-share analyses provide evidence on the drivers of environmental efficiency and on sector specificity. This confirms the usefulness of this method for studying the environmental economics realm, in order to investigate structural and efficiency factors at the level of within country environmental efficiency performance, even in light of the different shares of services. Our evidence shows that although the Rome region has achieved higher environmental performance compared to Italy mainly thank to its being less industry based, some critical points in the energy sector and in some services should be taken into account in shaping the future development of the region. Environmental, industrial and sector-oriented policy making may also derive valuable information from the evidence provided by our study.

Introduction

This paper develops empirical analyses using NAMEA (*National Accounting Matrix including Environmental Accounts*) data for the Lazio region of Italy, which includes Rome. The data in our analysis are for 2000, the only year that both regional and national level data are available (national level data are available for the period 1990-2003). By comparing regional and national environmental sector intensities, we aim to demonstrate the utility of NAMEA and shift-share analyses for environmental and industrial policy making. NAMEA data are a matrix form statistical source, where economic (value added and employment) and environmental (emissions) indicators can be generated and shown at sector level.[1] We focus here on macro sectors, obtained by aggregating the 24 available productive branches at regional level to capture the potential main differences in environmental performance and associated drivers - manufacturing industries, non-manufacturing industries (other industrial sectors) and services.

In referring to a regional framework, the analysis is very significant since it allows the investigation to focus on structural and idiosyncratic features compared to national averages, providing useful insights for regional policy making on environmental, industrial and economic development dynamics, which is the keystone of economic development. It enables economic policies to be differentiated by regions on the basis of the observed heterogeneity in economic-environmental relationships.

We are aware of some rare examples at international level of regional analyses, and also a few national level studies, including the work carried out by the Wuppertal Institute on environmental input-output methodologies (Nansai et al., 2007; Suh, 2005; Huppes et al., 2005) based on NAMEA-like data, which are mainly focused on emissions but also include waste and materials (Nakamura, 1999; Moll et al., 1999), some good quality Spanish data (Roca and Serrano, 2007a,b), and some unpublished UK studies using data for 1995 and 2002. We should highlight that although current NAMEA availability is somewhat irregular in terms of country and time periods, regional and national NAMEA are becoming increasingly available and being exploited[2] with the aim ultimately of generating a EU NAMEA, covering at least the main EU countries.

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[1] The NAMEA approach originated in a series of studies carried out by Statistics Netherlands. The first NAMEA was developed by the Dutch Central Bureau of Statistics under the supervision of Steven Keuning (De Boo et al., 1991). Haan and Keuning (1996) and Stauvermann (2007) among others, are examples of seminal papers containing long and comprehensive bibliographies of all past works. Furthermore, De Haan (2004) developed and propagated the NAMEA approach in detail and has applied the NAMEA for international comparisons. The first Italian NAMEA, referring to 1990 data, was published in ISTAT (2001). The Italian NAMEA includes the following 10 air pollutants: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), nitrogen oxides (NO_X), sulphur oxides (SO_X), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM_{10}) and lead (Pb). Beyond the emissions related to productive activities, national NAMEA data also include emissions derived from three household consumption activities (transport, heating, and other, such as painting and solvent use); however, we have excluded these sources of emissions because our interest lies mainly in productive activities (for which the available macro sectors are primary, industry and services, disaggregated into 51 sectors). For an overview of the methodological issues related to NAMEA, we refer the reader to Femia and Panfili (2005), and the recent study by ISTAT (2007), the Italian national statistics agency that produces and elaborates NAMEA.

[2] For an overview of recent developments in regional NAMEA (RAMEA) in Italy see the institutional site www.arpa.emr.it/ramea. Stauvermann (2007, p. 73) and Goralzcyck and Stauvermann (2008) present some comparative environmental performances from a RAMEA EU project involving Italy (Emilia-Romagna region, coordinated through ARPA, the regional environment agency), UK (SE England), Poland (Malpolska region), Netherlands (Noord-Brabant), focusing on greenhouse gases (GHG) per unit of production. Tuscany developed a RAMEA at the same time. These regions, along with Lazio, will lead the national establishment of a full Italian NAMEA, which ISTAT hopes to publish in 2009.

At international level there are some academic works, such as Ike (1999), Vaze (1999), and Keuning et al. (1999), which present and discuss some country specific NAMEA experiences from the perspective of structural change analysis. Steenge (1999) provides a policy-oriented analysis related to the possible policy implications of NAMEA. There are also some studies based on a proper environmental economics oriented perspective, for example, Mazzanti et al. (2008), which exploit panel data for Italy to assess environmental Kuznets curve dynamics for 1990-2001.

The paper is structured as follows. Section 2 discusses recent advances and applications of structural decompositions of energy and emissions trends (via index decomposition analysis and input-output structural decomposition analysis), in which, specifically, shift share analysis can be inserted. Section 3 is devoted to presentation of the shift-share empirical model. Section 4 presents the empirical evidence. Section 5 concludes by providing some insights on policy making strategies that may be informed by this analysis.

2. Structural decomposition analysis and related methods: recent studies on energy and the environment

2.1 Structural decomposition analyses, environmental accounts and NAMEA

Decomposition analysis is one of the most effective and widely applied tools for investigating the mechanism influencing energy consumption and emissions and their environmental side-effects. The basic rationale for structural decomposition analysis (SDA) is splitting an identity into its components; this represents a pragmatic alternative to econometric estimation especially for the kind of data required (not in the form of times series as in econometric estimations). The central idea of SDA is that changes in some variables are decomposed – usually in an additive way – in changes in its determinants. Despite some limitations, decomposition has several strengths one of which is that it provides an aggregate measure that captures energy or emissions efficiency trends. SDA has been applied to a wide range of topics (for a detailed survey see Rose and Casler, 1996 and Dietzenbacher and Stage, 2006), including the demand for energy (see, e.g. Jacobsen, 2000 and Kagawa and Inamura, 2004) and the emission of pollutants (see, e.g. Casler and Rose, 1998 and Wier, 1998).

Among the methodologies for decomposing energy and emissions trends, the more prominent are index decomposition techniques or analyses (IDA), input-output structural decomposition analysis (I-O SDA) and related methods such as growth accounting and shift-share analysis.[3]

There are two groups of IDA methods: those linked to the Laspeyres index (Laspeyres-linked methods) and those linked to the Divisia index (logarithmic mean Divisia index methods) (Divisia-linked methods). In the most basic form IDA is primarily a descriptive or accounting tool. The results obtained reveal information that is aggregate in nature and relates to the past. In system modelling and forecasting, it is similar to the well know time series decomposition methodology where a time series is decomposed into trend, seasonal, cyclical and irregular

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[3] Rose and Casler (1996) offer a critical review of the development of SDA and its relationship to other methodologies.

components (Liu and Ang, 2007). In contrast to many other techniques in the toolkit, IDA provides results that reveal broad, long-term trends. It is therefore useful for long term energy demand projections for industry, such as envisaging different scenarios for energy use. The main advantage of IDA over other methods based on I-O matrices, is the abundance of available data and the ease of performing cross-country comparisons due to the uniform assumptions in the relevant databases (Diakoulaki and Mandaraka, 2007).

According to Rose and Casler (1996, p.34), a first formal definition of I-O SDA is "a way of distinguishing major sources of change in an economy. It basically involves a set of comparative static exercises in which sets of coefficients are changed, in turn, and activity levels compared to a reference point". I-O SDA is the examination of the components of economic change by means of a set of comparative static variations in key parameters of the I-O tables. The I-O SDA requires only two I-O tables: one for the initial year and one for the last year of the analysis. I-O studies of energy use frequently adopt the so called "hybrid table", where the rows corresponding to energy sectors are in energy rather than monetary units. In the mid-1970s, several analysts began examining changes in energy utilization, with most work being done on a sectoral basis, though not in an I-O framework, and based on consideration of IDA.

Methods related to SDA are shift-share analysis (discussed in Section 3) and growth accounting. Growth accounting is a broad-based methodology which involves the attribution of economic growth to various underlying factors, with an emphasis on productivity. Applications of this method involve the use of an aggregate production function in which the effects of changing capital, labour inputs and productivity are translated into changes in output growth (Rose and Casler, 1996).

Several studies analyse and apply structural decomposition methodologies. In this survey, we confine our scope to studies applying these technique while recognising that there are several other methods (e.g., econometric ones) to analyse energy and emissions trends (see Greening et al., 2007 for a general overview). Casler and Rose (1998) analysed the impact of various influences on CO_2 emissions to decompose the sources of change in CO_2 emissions in the US in the period 1972-82, using hybrid energy/value tables for the initial and last years. The analysis, which incorporates methodological refinements of I-O structural decomposition analysis, is performed using a two tiered KLEM (capital, labour, energy and materials) production function model, which allows for the estimation of substitution and technological change effects within and between input aggregates.

Dietzenbacher and Los (1998) discuss the problem that there is no unique form to decompose the change in one variable into changes in its determinants. An empirical analysis was carried out for the Netherlands based on the 214-sector I-O tables for 1986 and 1992. Because aggregation does not show high variability, the authors suggest that average effects should be calculated across decompositions and that ranges not just averages should be presented. The same authors (Dietzenbacher and Los, 2000) examine the phenomenon that several determinants are not independent and thus discuss the problems related to the correlation between decomposition factors. A case study of the Dutch economy in 1972 and 1986 (decomposition for value added growth) shows that the results obtained with the new decomposition method may differ from those obtained using the traditional approach. Jacobsen (2000) performs an I-O structural decomposition analysis for Denmark based on trade factors, for the period 1966-1992. He decomposes the changes in the Danish energy consumption for 117 industries into six components and finds that structural factors matter less than final demand and intensity of energy, with the exception of trade factors which show a relevant effect. In fact, structural change in foreign trade patterns can increase domestic energy demand. In the observed period, the effect of strongly increasing exports relative to imports results in dominance of the export effect and an increase in energy demand.

Wier (1998) explores the anatomy of Danish energy consumption and emissions of CO_2, SO_2 and NO_X. Changes in energy-related emissions between 1966 and 1988 (22-year period) were investigated using I-O SDA. The study includes emissions from 117 production sectors as well as emissions from the household sector. Increasing final demand (economic growth) is shown to be the main determinant of changes in emissions (CO_2 emissions increased proportional to energy consumption, NOX emissions increased relatively more, while SO_2 emissions declined considerably in the observed period). The decrease in SO_2 emissions occurred as a result of changes in the fuel mix. De Haan (2001) using I-O analysis, calculates that the main causes of reductions in pollution can be categorised as eco efficiency, changes in the production structure, changes in the demand structure, changes in demand volume. He finds that the scale effects are not compensated for by eco efficiency gains and negligible reductions result from the other two factors, which resulted in a net 20% increase in CO_2 emissions in the Netherlands in 1987-1998. This study confirms the complementarity and increased value in terms of the information to be derived from decomposition analysis compared to delinking studies that calculate the income-environment dynamic elasticity and the drivers of delinking using NAMEA data (Mazzanti et al., 2008, 2007).

Kagawa and Inamura (2001) applied an I-O SDA model to identify the sources of changes in the energy demand structure, the non-energy input structure, the non-energy product mix and the non-energy final demand of embodied energy requirements in Japan for 1985 to 1990. The authors used a hybrid rectangular input-output model (HRIO) that is expressed in both monetary and physical terms. The results show that total energy requirements increased mainly because of changes in the non-energy final demand, while product mix changes had the effect of energy saving. Another work by the same authors (Kagawa and Inamura, 2004) applies a spatial decomposition via the I-O SDA to measure the effects of changes in intra- and inter-country linkages on embodied energy demand in China and Japan. They use the China-Japan inter-country input-output tables for 1985 and 1990 expressed in constant 1990 prices. The results reveal that the effects of the non-competitive input structural changes in China on the primary energy requirements of Japan were negligible, while the contribution of Japanese final demand shifts on total changes in Chinese primary energy was 40 times larger than that of Chinese final demand shifts in the primary energy requirements of Japan.

Dietzenbacher and Stage (2006) show that in SDA, the hybrid approach may induce arbitrary results which depend on the choice of units, rather than on changes in the economic structure. Some results are determined somewhat arbitrarily by the choice of monetary and energy units rather than being based on the underlying economic factors being studied. The authors propose two modifications to SDA to remove this problem: the first requires full information on the prices paid for final demand energy; the second requires no information on energy prices.

Greening et al. (2007) provide a good survey of different methods by considering the proper structural decomposition and other methods of analysis of energy trends (econometric methods, “top-down” models, "bottom-up" or engineering models and industry-specific micro-economic analyses).[4] They underline the fact that there is no standard or generally accepted method; so, analysts are confronted not only with the issue of identifying and collecting data but also with the issue of selecting the appropriate method. Among the applications proposed, here we consider only those related to the index decomposition techniques and I-O SDA. Liu and Ang (2007) present a useful survey of applications of the IDA technique and underline the fact that standardisation of IDA analysis is needed. This would make international comparisons more meaningful. Diakopulaki and Mandaraka (2007) maintain that IDA is better than I-O SDA in the case of international cross country comparisons; in fact, international comparisons are difficult with I-O based methodologies because of the different matrices and national sources. Diakopulaki and Mandaraka analyse industrial CO_2 emissions trends for 14 EU countries in the period 1990-2003 (by distinguishing two time intervals, prior and following the Kyoto Protocol) applying a refined Laspeyres model to determine the impact of five explanatory factors: output, energy intensity, structure, fuel mix and utility mix. They find that most EU countries have made a considerable but not always sufficient effort to decouple emissions from industrial growth; finally, no significant acceleration was observed for the post-Kyoto period.

2.2 RAMEA emerging frameworks

Within the recent studies exploiting NAMEA data, we should highlight Stauvermann (2007), who presents a Dutch pilot study based on a regional RAMEA (2003 of the Dutch region Noord-Brabant). This work has many elements common to the analysis in this paper and, moreover, is highly complementary to it, in suggesting future research directions. In fact, this work and the research project are highly relevant to and complement our analysis in terms of the aim to bring together different European research experience on NAMEA and RAMEA, in the interests of establishing a future EU-based NAMEA. Standardization of the different experiences that have so far developed more or less independently will be essential, at least for the major countries, in order to allow comparison of evidence and performance in the income-environment indicators of 'sustainable production and consumption' (Watson and Moll, 2008),[5] where trade issues play a major role. As also argued by Stauvermann (2007. p. 7), the integration in NAMEA of trade flows, by linking different country accounting systems, is a valuable research effort for the future. At the moment, though methodological issues are clear, empirical limitations imposed by data availability limits such research or circumscribes it to national case studies for countries with sufficient data, such as the UK, Norway and Denmark (Harris, 2001; Muradian et al., 2002).

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[4] A recent special issue of *Energy Economics* (29 (4), 2007) discusses decomposition methodologies and presents some applications.

[5] This paper uses environmentally extended I-O analyses to investigate, for 8 European countries, the difference between the two perspectives: a production perspective (based on national accounting), and the global environmental pressures activated by our national demand for goods and services, that is a consumption perspective,. "This latter perspective includes pressures arising in other countries to produce our imports, but excludes those taking place at home to produce exports. It argues that the consumption perspective, although more difficult to evaluate and monitor, gives a better measure of sustainability on the global scale. It is found that specialisation of an economy in an impact-intensive industry can potentially lead to global environmental benefits, even though it may cause the country to appear less sustainable than its neighbours using traditional monitoring mechanisms. Policy frameworks which lead to industrial specialisation giving global environmental benefits are identified, along with frameworks which have the opposite effect" (Watson and Moll, 2008, p. 1).

However, even in this case, data constraints make it necessary to make strong assumptions regarding the emissions intensity of trading partners, in the absence of real NAMEA data for other countries. In other cases (Mazzanti et al., 2008), the integration of NAMEA data could be limited to the inclusion of trade openness indicators among drivers of 'environmental efficiency', in order to infer whether pollution haven hypothesis forces or production specialization in the energy/environment intense sector, prevail. These analyses refer to the old debate around the 'Leontief paradox' which has produced recent interesting insights even in the environmental realm (Dietzenbacher and Mukhopadhay, 2006).

In addition, such series of integrated NAMEA and EU-level evidence may complement EKC-oriented evidence, based on econometric analysis of the dynamic income-environment relationship, which is robust in assessing dynamic facts and drivers of environmental pressure, but often lacks comprehensive investigation of the structural factors behind increases or decreases in environmental efficiencies.

The Dutch RAMEA also connects to the various RAMEA experiences which ISTAT and some Italian regions have been developing over recent years, with the objective of establishing a full Italian RAMEA covering all 20 Italian regions or most of them, which would allow more robust shift-share analysis in the near future and eventually, if a sufficient – at least 2 years - panel dataset were created, even structural decomposition analysis, robustly rooted in a NAMEA matrix environment. Stauvermann focuses on the environmental and economic aspects of a region, but proposes future extensions on the social dimensions that could be added for a RAMEA. Among the many complementary and interlinks between this work, Stauvermann (2007, p.13) notes that "the aggregate environmental damage of a country or of a region does not only depends of the country's size and development stage but also on its structure of economic activities". This is a value added that NAMEA, and with increasing detail RAMEA, possesses with respect to decoupling[6] analysis, based on the EKC framework, which often lacks assessment of the structural factors of change as additional explanatory factors for the core income-environment relationship.

We highlight that the present paper, which exploits official ISTAT data for Lazio recovered from a sample of regional local emission sources, does not involve the problem pointed out by Stauvermann (2007), which is that, if value added is available at regional and sector level, environmental information on emissions "exists only at the national level, so that we must estimate these data". Based on the assumption of 'within country homogeneity', regional environmental data are derived directly by observing a country-regions comparison regarding economic data. In other words, translation of national environmental data into regional data is implemented by using economic data available at both levels. Though limited and critical aspects of the analysis, the reliability of the method is testable from a statistical perspective. A real regional emissions dataset, though possibly exposed to other estimation biases, is a priority, if feasible. This is a key issue in the establishment of compatible and robust RAMEA data. While the Netherlands has resolved this problem, to our knowledge the Lazio RAMEA is being constructed by ISTAT using a bottom-up approach based on regional inventory sources provided by APAT (the

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[6] The concept of decoupling (or delinking) has achieved global recognition as a significant conceptualisation of successful economy-environment integration. The decoupling of environmental pressures from economic growth has become the desired policy outcome, both in climate policy and in a wider context.

Italian environment agency).[7] Tuscany has also used regional inventory data while, Emilia-Romagna, though possessing a regional inventory, has encountered regarding the integration of NACE (statistical classifications of economic activities) sectors with emission SNAP codes (developed by the European Environment Agency's European Topic Centre on air emissions), which constitute the origin of sector emissions data.[8]

It is interesting to comment on and compare the set of ecological-economic indicators Stauvermann proposes, as an alternative, or perhaps better a first step embedded in a proper shift-share analysis, which, in this case, compares regional and national data. First, sector environmental impact indicators and environmental efficiencies are compared by means of normalising to the regional average, to highlight which sectors are more or less eco-efficient than the regional average. This analysis is first carried out on emissions-ecological factors and then incorporates economic-environmental indicators (emissions/value added ratio)[9] as in our paper. In all cases the comparison is merely between the regional average of the indicator and the sector specific values, or eventually regional eco-efficiency and national eco-efficiency per sector. Finally, a synthetic index can be compiled by relating the emissions share and the economic share of a sector, to the respective regional average shares.[10] The use of such a relative indicator, which captures the extent to which the sector's contribution in terms of emissions is more or less proportional to its economic impact (if the emission shares is lower than the value added, the index is lower than unity), leads the analysis towards conceptual frameworks which have a strict connection with shift-share (this may be an embryonic component of it) and delinking/environmental efficiency oriented dynamic assessments.[11]

What is lacking from this, and constitutes the core value of our paper, is analysis of the drivers from decomposition of the emissions/value added index into its potential sources.

The Dutch study, however, is based on the three years, 2001–2003, which makes it impossible for us to conduct a decomposition analysis although this should become possible with the next evolution of regional NAMEA for Italy. Thus, we conduct a 'dynamic shift-share' analysis for 2001 and 2003 (following a static analysis for 2002) by identifying the three components of 'national share', 'regional shift' and 'industry mix', in order "to account for the regional ecological competitiveness". We note both ecological *and* economic competitiveness, given that 'environmental efficiency', calculated in terms of emissions/value added, is a real component of the economic

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[7] We thank Michele Sansoni (ARPA, regional environmental agency, Emilia-Romagna) for this comment. See for references www.arpa.emr.it/pubblicazioni/ramea/generale_869.asp (see especially the 'Construction manual' and the 'Case studies manual') and the document by Bonazzi and Sansoni (2008), who present a shift-share analysis for Emilia-Romagna and a methodological discussion of RAMEA accounting systems.

[8] The region used a 'regionalised' national APAT data (top-down approach), in line with Stauvermann's analysis. The differences related to the regional possibilities of using bottom-up approaches constitute the main constraints to achieving a full reliable and robust RAMEA at country and EU levels. It would also be interesting to match RAMEA datasets with real I-O datasets, which in Italy are managed and provided by IRPET (Regional Institute for Economic Planning of Tuscany). This would be another fruitful avenue for future research.

[9] Interestingly, emissions/value added and emissions/employee ratios, both derivable from NAMEA, are used. For comparison, Mazzanti and Zoboli (2009) exploit the former indicator in order to assess the dynamic (1990-2001) correlation between environmental and economic productivities in Italy using NAMEA, while Mazzanti et al. (2008) use the latter per head indicator, for the same period and applied to the same data, which is more in line with the EKC framework which frequently specifies an emission per capita ratio as the objective variable.

[10] Which also links to the idea of elasticity between environmental impact and value added if placed in a multivariate statistical framework.

[11] It remains true that the two levels – regional and national - are interconnected by definition and there may be some bias depending on correlation, as highlighted again by the author in the conclusion.

competitiveness of a region, and is at the basis of both private (as a component of productivity)[12] and public (non-market) benefits. The utility of NAMEA analysis stands out as a stimulus for shaping the future efforts of both private profit making agents and policy makers.

3. Objectives of the study and the empirical model

The first empirical objective of this paper is to measure the role of the regional productive structure in explaining the emissions efficiency gap between Lazio and Italy, using shift-share analysis. Generally, shift-share analysis decomposes the source of change of the specified 'dependent variable' into regional specific components (the shift) and the portion that follows national growth trends (the share). This shift-share methodology emerged in the 1960s as a tool for analysing the indicators of regional productivity and employment (Dunn, 1960). It has been applied since to other issues, such as international trade and, more recently, tourism economics, but, to our knowledge, with the exception of Stauvermann (2007) it has been used only rarely for environmental economic analysis. The specific methodology used here was introduced by Esteban (2000, 1972). The decision to use shift-share analysis was to determine the effects and factors that synthetically explain the relative efficiency/inefficiency of the regional system compared to the (national) average. Our aim is to examine and test whether the gap between the region under consideration and the benchmark average depends on an overall higher/lower productivity differential for all sectors, and/or on a higher/lower regional specialization in sectors with higher/lower productivity.

In our analysis, the primary attention is on the intensity of emissions, in other words, on the indicators of emissions per value added, at sector level, given that this variable provides insights into the efficiency of the productive sectors, which is very useful information for the formulation of actions to support environmental innovation at sector level.

More specifically, we develop an analysis of the relative environmental efficiency of the Lazio economic system with respect to the national average, referring to a vector of ten pollutants, which encompass GHG, regional pollutants and local pollutants, and to the economic sector included and specified by NAMEA.

Our starting point is the aggregate indicator of emissions intensity, represented by 'total emissions on value added', defined as E/VA for Italy - the benchmark, and as E_l/VA_l for Lazio. This indicator is decomposed as the sum of $(E^s/VA^s)*(VA^s/VA)$, where VA^s/VA is the share of sector value added on total value added, for all sectors s, with the value of s defined from 1 to j (j = 24 - the number of NACE sectors included in the regional NAMEA).

For clarity, we redefined the index of emissions intensity as X for the national average ($X=E/VA$), as X_l for Lazio ($X_l = E_l/VA_l$), and as X^s for each sector (for Lazio $X^s_l = E^s_l/VA^s_l$, for Italy $X^s = E^s/VA^s$). We then defined the share of sector value added as $P^s=VA^s/VA$ for Italy and $P^s_l=VA^s_l/VA_l$, for Lazio.

In other words:

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[12] See the interesting applied papers by Bruvoll and Medin (2003), and Mazzanti and Zoboli (2009) for an extensive discussion of market and non-market productivities associated with environmental inputs and outputs.

$$X = \sum_s P^s X^s$$

$$X_l = \sum_s P^s{}_l X^s{}_l$$

On this basis we can easily identify three effects, as prescribed by the *shift-share decomposition*. These three effects explain the gaps in terms of aggregate emissions efficiency between Lazio and Italy.

The first effect ('structural' or *industry mix*) is given by:

$$m_l = \sum_s (P^s{}_l - P^s) X^s$$

m_l assumes a positive (negative) value if the region is 'specialised' ($P^s{}_l - P^s > 0$) 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_l assumes lower values if the region is specialised in (on average) more efficient sectors.

The second factor, defined as the 'differential' or 'efficiency', is:

$$p_l = \sum_s P^s (X_l^s - X^s)$$

p_l assumes a positive (negative) value if the region is less (more) efficient in terms of emissions (the "*shift*" between regional and national efficiency), under the assumption that ('as if') value added sector shares were the same for the region, and for Italy ($P^s{}_l - P^s = 0$).

Finally, the effect of 'covariance' between these two equations, or the 'allocative component', is given by:

$$a_l = \sum_s (X_l^s - X^s)(P_l^s - P^s)$$

The a_l factor is positive (negative) if the region is specialised, relative to the national benchmark, in sectors characterised by higher (lower) emissions intensity.

It assumes a minimum value, in our case if the region is specialised in sectors where it presents the highest 'comparative advantage' (low intensity of emissions), then the covariance factor is between m_l and p_l.

Thus, the total difference in emissions intensity between the region and Italy, for each pollutant, can be decomposed with the sum of the aforementioned factors[13]:

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[13] As a comparison to the Stauvermann approach presented above, we note that, the former element of the Dutch shift-share experiment shows which part of the regional emissions decreases or increases is dependent on the respective trends in

$$X_l - X = m_l + p_l + a_l$$

This decomposition in three factors allows a quantitative and synthetic measure of the underlying reasons for the differences in emissions intensity. It allows assessment of the aggregate differentials we observe. For example, it may be that a higher value for regional emissions intensity depends only on productive structural motivations, on which environmental and energy policy can have no direct impact. Such policy would be more effective in altering the dynamics if the gap were due relatively more to a specific sector inefficiency, attributable to technological factors or/and inadequate organisational and regulatory frameworks.

4. Empirical evidence

First, we look at the evidence for the aggregate efficiency indicator (X_l-X)[14]. It is clear that Lazio emerges as being relatively more efficient for all the pollutants and emissions considered (Table 2). The sector decomposition also shows the extent to which the comparative advantage in efficiency is derived from services (G-P branches), and some manufacturing branches (DE, DF-DG, DJ, and the aggregate DK-DL-DM), which do not show a gap which is unfavourable to the region for any emissions.

This empirical information is not sufficient, however, to identify the main drivers of the efficiency differential, or to provide major implications for policy. Therefore, we next analysed (Table 3) the factors and components (*m, p* and *a)* that contribute to explaining the (X_l-X) differential. We note that, in eight out of ten cases, including GHG and the main regional acid rain and local pollutants, the primary finding from the shift-share analysis is the efficiency factor (p), which favours Lazio. Its relevance is associated to a weight that is often more than the 50% of the difference we observe between the region and Italy.

Finally, some comments on the results of the shift-share analysis on the aggregates of the manufacturing sectors (D), services (G-P) and 'other industrial sectors' (C,E,F). Note that this investigation does not affect the regional comparative advantage for *all* NAMEA emissions.

The differences ($X_l - X$) are negative for all macro sectors and all pollutants. Also, we can verify whether this higher efficiency is higher or lower in the three macro sectors with respect to the average benchmark related to the region-Italy comparison. In other words, the analysis by macro aggregates shows the extent to which they contribute to the average advantage of the region.

This comparative assessment, which was made by comparing the results in Tables 3 and 4 (the table showing the actual comparison is omitted here, but is available upon request), indicates quite clearly that there are very few

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the national economy, the latter shows how much emissions depend on the regional industry mix, which captures the influence of regional features. The industry mix element is present in both approaches, while in our model the first factor is an 'efficiency' factor, and the third is the covariance between efficiency and the industry mix. Nevertheless, this shows the high flexibility of SDA and shift-share analyses, which may be shaped according to research objectives and data availability.

[14] Table 1 shows the variable P_l for Lazio and P for Italy, which is the decomposition for value added by each productive branch. Table 2 shows the variables X_l (Lazio) and X (Italy), which refer to emissions on value added, by each pollutant. These four variables are the basis of the shift-share analysis following the approach described above.

cases where the gap favouring the region in the overall analysis of the economic system, emerges as higher for manufacturing and services: four pollutants for manufacturing (CO, N_2O, NH_3 and, with minor emphasis, CH_4), and one for services (PM_{10}).

Services, in comparative terms, are the aggregate sector that is less efficient than the regional average, although we would emphasis that G-P sectors are always less intensive for emissions with respect to national averages.

Thus, it can be said that the Lazio region's environmental comparative advantage is mainly driven by "other industrial sectors" (extraction of materials, production and distribution of energy, construction). As before, we observe that the main driver explaining the differential (*p*) is related to sectoral efficiency. We note the heterogeneity across macro sectors: factor (*p*) in six cases is the main driver of manufacturing, while for services and other industries it is the main driver in nine and ten cases respectively.

5. Conclusions and policy insights

Our shift-share analysis aimed to demonstrate the relative performance of Lazio region and Italy, in terms of environmental efficiency, as defined in the paper. We summarise some key critical outcomes and some policy considerations linked both to the current analysis and to extensions for future research using updated NAMEA datasets.

We showed that for all emissions included in NAMEA the sum of the three shift-share factors indicates that Lazio is comparatively more environmental efficient than the national average. For most emissions, we can claim from our knowledge of the Italian framework (ENEA, 2006)[15] that the main source of this difference is lower energy consumption per capita and lower energy intensity (electrical energy) on GDP, compared to the national averages. Lazio in 2003 had a value of 99.7tep/million€ GDP, the third lowest value in Italy (Italian average is 126, with Lombardy, the most industrialised and richest region, at 121). Electricity intensity was around 201.9 MWh/Million€ GDP, the lowest in Italy (288.4 is the average, with Lombardy registering 301). Finally, energy and electrical energy intensity in Lazio's manufacturing sector is the lowest in Italy.

However, starting from relative efficiency and based on discussion of some structural factors behind this evidence, if we analyse specific components more deeply, some criticalities emerge for the region. We synthesise these elements in two main categories: the role of energy intensity and the role of services.

First, if we consider sector composition, this does not favour Lazio for CO_2, SO_x e NOx, the main environmental pollutants at supranational level. In other words, the situation regarding these three environmental externalities in the regional economic system is not favourable. This may be due to the strong role and weight of regional production of electricity based on fossil fuel sources, which compensate for the low energy intensity. The region is highly dependent on oil (59%), with natural gas at 21%. Renewable energy, including hydroelectric power, where Italy has a comparative advantage (two-thirds of total renewable energy in Italy comes from hydroelectric power stations, mainly located in the north), plays a very minor role. This may point to a rather negative future scenario in terms of GHG emissions trends.

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[15] ENEA is an Italian public agency operating in the fields of energy, the environment and new technologies to support competitiveness and sustainable development (www.enea.it).

This unfavourable situation should be targeted by environmental policies aimed at integrating the region into the national efforts towards achieving the EU policy targets of a 20% decrease in GHG by 2020 and a minimum 20% threshold for the renewable content of energy production. This is challenging for the region, given that innovation dynamics in services are on average low, and EU policy does not directly target services with environmental regulations that could be the drivers of innovation. Also, the low performance in renewable energy means that, on the one hand the region has strong incremental possibilities, but no specialisation, given the almost total absence of hydro and wind power generation sites.

Second, although Lazio is relatively more specialised than Italy on average in services, it seems that services are relatively 'less efficient' compared to the performances of other branches within the region, although they still benefit the region in comparison with Italy.

Evidence on energy intensities could provide some explanation for these structural facts. Services intensity in 2003 was on a level with the average for Italy (18.6 tep/million€ GDP), as was electrical energy performance. The relevant services orientation of the region, and of Rome in particular, is on the one hand helpful in terms of environmental performance (productive specialisation effect), but on the other hand is partially balanced by a relatively 'high' (at least not lower than the average) energy intensity of the sector[16]. This reflects an important point, mostly for local (regional, municipality of Rome) policy actions: the high energy intensity of transport systems, which is related to the high ratio of cars/per head. Using ENEA (2006) data, as above, we note that the region in 2003 had an intensity of 50.7 tep/million€ GDP, one of the highest in Italy (33.4 for Lombardy). Environmental and transport policies should incorporate complementary actions to tackle the relative low performance of the transport sector and poor household behaviour towards transport, especially in the critical hot spot of Rome.

Thus, regional environmental performance does not depend *strongly* on the bias towards services, which is historically typical of the region and of Rome, and on which the region's recent strong economic growth, compared to Italy, is mainly based. For the majority of pollutants, in fact, it is the second factor in shift-share, the differential/sector efficiency component, that quantitatively dominates first effect of sector composition.

The shift-share analysis disaggregated for the three macro sectors highlights additional interesting insights. Total efficiency differentials still favour the region for all pollutants and for all sectors. Nevertheless, relative to the gap observed in the aggregate analysis, we note that the ranking of macro sectors for their contribution to regional environmental performance is as follows: (1) 'other industrial sectors' (C,E,F); (2) manufacturing; (3) services. Services do not present cases of emissions where their efficiency is higher than the average regional efficiency, compared to Italy. Within the region, and this is a somewhat counterintuitive result with respect to qualitative 'at first sight' assessment, environmental performances is not *primarily* driven by the structurally strong weight of services, and the dynamic evolution that produced an increasing share of the sectors that characterise Lazio more than Italy. This evidence may have implications for a region such as the one investigated here, where the City of Rome plays a crucial role in economic and environmental performances.

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[16] In addition, the analysis shows that while the region is specialised in services, this specialisation occurs in those sub sectors with higher emission intensities.

Overall, then, relative environmental efficiency with respect to Italy is primarily explained by an actual lower emissions intensity per unit of value added, more than by sector composition and specialisation. Thermo-electric production fuelled by oil, an energy intensive transport sector, and a service sector which on average is not performing below the Italian average level in terms of emissions intensity are the 'hidden' negative elements, which national and especially local policy makers should be tackling to achieve future emissions reductions and environmental efficiency increases in the broader context.

This paper thus shows that even with a single regional NAMEA and a national average NAMEA, it is possible to identify a series of facts that help our understanding of the structural basis of the income-environment relationship, with a focus on energy issues, to help to define future national and regional policies. Panel data would provide a better basis for such an analysis, although we note that structural differences will be affected in the medium to long run. Our analysis would provide further value added with either very long panel data, which are unlikely to be available in the near future, or the extension of cross section analysis to more regions. A cross regional panel dataset could offer the possibility of more detailed investigations regarding the dynamics of the three pillars of the shift-share analysis. This could create links with the policy making frameworks and might allow a distinction between the evolution of (structural) production factors, the target of development-oriented regional policies, and pure efficiency effects, which have a stricter link to technological assets and to the set of environmental regulations existing at national and regional levels. Future research should aim at producing and analysing NAMEA for most (all) Italian regions. This should be enabled by ISTAT data to be published in 2009-2010,[17] which will allow more robust shift-share and other structural decomposition analyses. The complementary use of bottom-up approaches, relying on regional emissions inventory sources, and top-down approaches which 'regionalise' national emissions data might constitute a good compromise for the establishment of a robust framework allowing decomposition and (dynamic) shift-share analysis.

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[17] See www.istat.it/ambiente/contesto/namea.html., where the joint ISTAT-Ministry of Economic development research project 'environmental accounting and development' is described. The main aim is to develop a RAMEA national framework for all or most Italian regions starting from the consolidated NAMEA experience. 2005 regional emissions should be available for all regions by 2009, covering the usual 10 NAMEA emissions matched to value added and production.

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Table 1 – Value added by productive branches. Lazio and Italy – year 2000 *(shares)*

Productive branches (ATECO 2001)		Value added shares	
Title	NACE Code	Lazio	Italy
Agriculture, hunting and forestry	A	0.016	0.030
Fishing	B	0.000	0.001
Mining and quarrying	C	0.001	0.004
Manufacture of food products, beverages and tobacco	DA	0.011	0.020
Manufacture of textiles and textile products	DB	0.005	0.006
Manufacture of leather and leather products	DC	0.000	0.023
Manufacture of wood and wood products, Manufacture of rubber and plastic products, Manufacturing n.e.c.	DD-DH-DN	0.010	0.026
Manufacture of pulp, paper and paper products	DE	0.016	0.015
Manufacture of coke, refined petroleum products and nuclear fuel, Manufacture of chemicals, chemical products and man-made fibres	DF-DG	0.025	0.020
Manufacture of other non-metallic mineral products	DI	0.008	0.014
Manufacture of basic metals and fabricated metal	DJ	0.007	0.031
Manufacture of machinery and equipment n.e.c., Manufacture of electrical and optical equipment, Manufacture of transport equipment	DK-DL-DM	0.032	0.059
Electricity, gas and water supply	E	0.027	0.022
Construction	F	0.040	0.050
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	G	0.121	0.138
Hotels and restaurants	H	0.029	0.035
Transport, storage and communication	I	0.114	0.078
Financial intermediation	J	0.091	0.066
Real estate, renting and business activities	K	0.197	0.181
Public administration and defence; compulsory social security	L	0.085	0.051
Education	M	0.046	0.044
Health and social work	N	0.046	0.044
Other community, social and personal service activities	O	0.054	0.036
Household related activities	P	0.016	0.008
Total		1.000	1.000

Table 2 – Emission intensities. Lazio and Italy – Year 2000 *(emission tonnes per M€ of value added)*

NAMEA emissions/pollutants	Lazio	Italy
CH_4	1.148	1.769
CO	0.874	1.793
CO_2	221.860	381.072
N_2O	0.054	0.130
NH_3	0.179	0.435
NMVOC	0.470	0.750
NO_x	0.763	1.106
Pb	0.000211	0.000329
PM_{10}	0.069	0.165
SO_x	0.260	0.779

Table 3 - *Shift-share* coefficients regarding the total economic system (all productive branches)

NAMEA emissions/pollutants	X_l	X	X_l - X	Difference %	m	p	a	$m+p+a$	*Primary factor*	*Primary factor (%)**
CH_4	1.148	1.769	-0.621	-35%	-0.136	-0.471	-0.0130	-0.621	P	76%
CO	0.874	1.793	-0.919	-51%	-0.431	-0.770	0.283	-0.919	P	52%
CO_2	221.860	381.072	-159.212	-42%	26.429	-159.253	-26.388	-159.212	P	75%
N_2O	0.054	0.130	-0.076	-59%	-0.0272	-0.0428	-0.006	-0.076	P	56%
NH_3	0.179	0.435	-0.256	-59%	-0.186	-0.1105	0.041	-0.256	P	33%
NMVOC	0.470	0.750	-0.280	-37%	-0.162	0.0775	-0.194	-0.280	A	45%
NO_x	0.763	1.106	-0.343	-31%	0.0298	-0.297	-0.075	-0.343	P	74%
Pb	0.0002110	0.000329	-0.000118	-36%	-0.0002	-0.000040	0.0001	-0.000118	M	59%
PM_{10}	0.069	0.165	-0.097	-58%	-0.031	-0.0720	0.0072	-0.097	P	65%
SO_x	0.260	0.779	-0.519	-67%	0.118	-0.529	-0.108	-0.519	P	70%

Note: * share calculated on the sum of components in absolute values.

Legend:

X_l = (total emissions Lazio/total value added Lazio)

X = (total emissions Italy/total value added Italy)

m = sum by sectors s $((VA^s_l/VA_l)-(VA^s/VA))*(E^s/VA^s)$

p = sum by sectors s $(VA^s/VA)*((E^s_l/VA^s_l)-(E^s/VA^s))$

a = sum by sectors s $((VA^s_l/VA_l)-(VA^s/VA))*((E^s_l/VA^s_l)-(E^s/VA^s))$

$X_l - X = m + p + a$

Table 4 - *Shift-share* coefficients regarding the analyses for Manufacturing (D), other industrial sectors (C,E,F) and Services (G-P)

Manufacturing								
NAMEA emissions/pollutants	X_1	X	X_1-X	Difference %	m	p	a	$m+p+a$
CH_4	0.261	0.421	-0.160	-38%	0.154	-0.194	-0.120	-0.160
CO	0.541	2.883	-2.343	-81%	-1.190	-2.2618	1.109	-2.343
CO_2	426.282	469.605	-43.323	-9%	90.967	-104.519	-29.771	-43.323
N_2O	0.027	0.163	-0.136	-83%	0.1788	-0.136	-0.178	-0.136
NH_3	0.001	0.047	-0.0456	-97%	0.0567	-0.045	-0.056	-0.0456
NMVOC	1.836	1.974	-0.138	-7%	0.2039	0.621	-0.963	-0.138
NOx	0.964	1.091	-0.128	-12%	0.089	-0.146	-0.070	-0.128
Pb	0.001	0.001	-0.000003	-0.3%	-0.0005	-0.0001	0.0006	-0.000003
PM_{10}	0.146	0.273	-0.127	-47%	-0.039	-0.132	0.0447	-0.127
SOx	0.691	0.852	-0.161	-19%	0.329	-0.346	-0.144	-0.161
Non manufacturing industries (other industrial sectors)								
CH_4	2.850	3.739	-0.888	-24%	1.340	-1.645	-0.583	-0.888
CO	0.747	1.664	-0.917	-55%	0.454	-0.996	-0.374	-0.917
CO_2	1315.702	2529.417	-1213.714	-48%	930.408	-1556.852	-587.270	-1213.714
N_2O	0.057	0.102	-0.044	-44%	0.035	-0.057	-0.022	-0.044
NH_3	0.002	0.003	-0.0009	-31%	0.00075	-0.00137	-0.00035	-0.0009
NMVOC	0.929	1.329	-0.400	-30%	0.110	-0.423	-0.087	-0.400
NOx	1.693	2.764	-1.071	-39%	0.831	-1.385	-0.517	-1.071
Pb	0.00009	0.00011	-0.00002	-22%	0.00003	-0.00004	-0.00001	-0.00002
PM_{10}	0.204	0.363	-0.159	-44%	0.094	-0.189	-0.063	-0.159
SOx	2.009	6.576	-4.567	-69%	2.480	-5.115	-1.931	-4.567
Services								
CH_4	0.651	0.706	-0.055	-8%	0.1999	-0.1978	-0.0566	-0.0546
CO	0.697	0.936	-0.239	-26%	0.0619	-0.2585	-0.0427	-0.2392
CO_2	97.181	112.641	-15.460	-14%	8.895	-23.946	-0.408	-15.460
N_2O	0.010	0.013	-0.0035	-27%	0.0018	-0.0046	-0.0007	-0.0035
NH_3	0.008	0.011	-0.0033	-29%	0.0025	-0.0047	-0.0011	-0.0033
NMVOC	0.205	0.255	-0.0495	-19%	0.0065	-0.0395	-0.0165	-0.0495
NOx	0.575	0.784	-0.209	-27%	0.0732	-0.2616	-0.0209	-0.2093
Pb	0.000094	0.000117	-0.00002	-19%	0.000002	-0.000022	-0.000002	-0.00002
PM_{10}	0.024	0.067	-0.0427	-64%	0.0044	-0.0442	-0.0029	-0.0427
SOx	0.053	0.146	-0.0932	-64%	0.0326	-0.1021	-0.0237	-0.0932

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