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Spending for the Environment: General Government Expenditure Trends in Europe

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Abstract Are European Union countries converging towards a similar model of public spending for environmental protection? National spending policies for environmental protection might be the result of country specific circumstances and priorities, but also of a shared vision towards the achievement of environmental goals as member of the European Union, in compliance with European Directives. This paper aims to empirically investigate models of environmental expenditures at European level, looking at the composition of public expenditure for environmental protection. It also contributes to the debate on the efficacy of public spending in the environmental domain. Results reject the existence of a homogeneous model of expenditure for environmental protection at European level. Furthermore, higher level of environmental performance seem to be positively correlated with the public expenditures in the environmental domain and partially with the different composition of the expenditure.

Keywords Environmental expenditures · Spending behaviour · Principal component analysis · Cluster analysis

JEL Classification H50 · N50 · Q58

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1 Introduction

Environmental degradation overcomes national boundaries. Hence, common transnational efforts are required to cope with it. This is at the core of the numerous agreements, treaties, international laws and regulations that since the 1970s have increasingly been concerned with environmental protection. At last, the Sustainable Development Goals and the Paris Agreement represent global commitment towards tackling the effects of climate change and negative impacts from anthropogenic activities on the natural environment. In Europe, sectorial Directives and strategies such as Europe 20 20 20, contributed to align environmental policies and stimulate efforts towards greater water quality, less waste production and energy savings, amongst others.

Cross-national policy convergence among industrializsed countries has been investigated over recent years (Heichel et al. 2005). Policy convergence is defined as "any increase in the similarity between one or more characteristics of a certain policy (e.g. policy objectives, policy instruments, policy settings) across a given set of political jurisdictions over a given period of time" (Knill 2005). In the environmental protection domain, policy convergence has translated into a wide range of environmental programmes, of similar institutions, such as environmental ministries and agencies, and of comparable policy instruments, such as incentives and tariffs within industrialised countries (Busch and Jörgens 2005; Holzinger and Sommerer 2011; Holzinger et al. 2008; Holzinger and Knill 2008).

Does this policy convergence translate into cross-national similitudes in public expenditure? In other words, does it generate similar levels of public expenditure for environmental protection and, more specifically, a similar composition of this expenditure, i.e. comparable levels of expenditure devoted to specific activities linked to environmental protection?

On the one hand, a negative answer to this question is expected, since cross-national divergences in public expenditure for environmental protection would be likely to arise due to socio-economic, morphological and geographical differences among countries: how many public goods (and which ones) to provide depends on country-specific circumstances, whether as a reflection of policies (e.g. competition regulations), of objectives (e.g. income distribution), or of other features (e.g. cultural ones) (EC 2009). On the other hand, it is possible to assume that to comply with common international standards, similar expenditure behaviours in the environmental domain may be adopted.

In order to answer this question, the paper examines the cross-national evolution of public spending for environmental protection and its composition. The analysis focuses on European member countries, and is based on available data over the years 2002 and 2010, encompassing periods both before and after the economic crisis.

The analysis proposed goes beyond public spending aggregates and considers spending for specific environmental protection-related functions as identified by the international classification of the functions of government (COFOG). This classification splits government expenditure on environmental protection into the following six subdomains: waste management, waste-water management, pollution abatement, protection of biodiversity and landscape, research and development for environmental protection, and expenditures linked to environmental protection but not classified elsewhere.

Public spending for the environment is not very high in Europe: in 2014, the EU28 average general government expenditure for environmental protection amounted to 0.8% of GDP (0.9% in 2010) with the highest value reported by Greece and Malta (1.6% of

GDP) and the lowest by Cyprus, Finland and Sweden (0.3% of GDP).[1] However, the size of the public sector ultimately reflects political choices (EC 2008), but is not necessarily correlated to effectiveness in reaching specific goals, such as protecting the environment (Eurostat 2013). In Europe, the North–South dichotomy has traditionally been at the core of the literature on heterogeneity among member states concerning compliance with EU environmental regulations. Typically, southern countries have been characterised by a weak political culture and low public support for environmental protection, an attitude described as the "Mediterranean Syndrome" (La Spina and Sciortino 1993). More recently, the dichotomy has shifted towards Eastern European countries (seen as laggards), opposed to the Western and Northern Europeans (leaders) (Magone 2010).

Environmental protection expenditure generates improvements that benefit large numbers of people simultaneously (joint consumption) (Pearce and Palmer 2001) and deals with market failures linked to environment-related externalities (EC 2009). It is justified, then, in view of a more efficient allocation of resources, which requires removals of political distortions, so to avoid, in turn, policy failures (Gupta and Miranda 1995). Despite being largely neglected, expenditure for environmental protection[2] is crucial for improving social welfare (Pearce and Palmer 2001) and this motivates the interest for its analysis.

The empirical investigation provided by this paper relies firstly on a sigma convergence analysis which, despite being originally developed for the analysis of convergence of countries' per capita income (Barro and Sala-i-Martin 1992), is also commonly used to investigate the emergence of similarities in the distribution of public spending across basic functional categories (Sanz and Velázquez 2004; Ferreiro et al. 2010, 2012, 2013). Furthermore, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (CA) are used in order to inspect the evolution of cross-national variability in the composition of public spending for environmental protection over the period considered.

Results suggest that over the eight years investigated in this analysis, countries do not show trends of convergence in public spending concerning environmental purposes.

The remainder of the paper is organised as follows: the next section is devoted to a review of the main contribution regarding the issue of policy convergence and policy mix in the environmental domain. Data used in the analysis are presented in Sect. 3, while methodologies adopted for data analysis are discussed in Sect. 4. Section 5 illustrates the results. Section 6 proposes some hints regarding how public expenditure for environmental protection is correlated with the environmental performance. Finally, conclusions are reported in Sect. 7.

2 Literature Review

According to Pearce and Palmer (2001) the environmental protection is a classic case of a public good: expenditure generates improvements that benefit large numbers of people simultaneously (joint consumption) and it deals with market failures linked to environment-related externalities (EC 2009). How much public goods (and which ones) to provide depends on country-specific circumstances, as a reflection of policies (e.g. competition

[1] http://ec.europa.eu/eurostat/statistics-explained/index.php/Government_expenditure_on_environmental_protection.

[2] Environmental protection expenditure includes "all activities directly aimed at the prevention, reduction and elimination of pollution or any other degradation of the environment" (Eurostat 2016, available at: http://ec.europa.eu/eurostat/cache/metadata/en/env_ac_exp1r2_esms.htm).

regulations) of objectives (e.g. income distribution) or other features (e.g. geopolitical, socio-cultural ones).

Imposition of policies, harmonization of national policies through international or supranational law, transnational communication are, in fact, among the causes of cross-national policy convergence, defined as ‘any increase in the similarity between one or more characteristics of a certain policy (e.g. policy objectives, policy instruments, policy settings) across a given set of political jurisdictions over a given period of time’ (Knill 2005). Policy convergence thus describes the end result of a process of policy change over time towards some common point, regardless of the causal processes and in this differs from policy transfer and policy diffusion that typically refers to processes (Knill 2005).

Most of the Europeanisation studies agree that political pressures within the EU determine heterogeneous choices in terms of institutions, policy styles and instruments, rather than leading to homogeneous actions at the level of member states (Héritier et al. 2001; Jörgens et al. 2014). Instead, path dependency, domestic politics and country-specific problem pressures are seen as crucial dimension to explain the persistence of the existing policy variation or even as forces making for further welfare state divergence (Starke et al. 2008). Heterogeneities among EU member states are also explained by studies on compliance with EU environmental regulations that show how divergences have traditionally characterized the European context. Other studies underlines differences based on specific environmental domains rather than on geographical characteristics. For instance complying with the regulation on biodiversity is far more difficult for member states than complying with the air pollution control regulation (Börzel 2000, 2003).

More in particular, concerning the environmental protection expenditure, the cluster analysis run by Ferreiro et al. (2010) suggests that 12 countries (the second biggest group of the sample) show a national social preference for environmental protection. However their overall conclusions are that there is not a single model of fiscal policy that fosters the economic growth and competitiveness, and that, simultaneously, maximizes the social welfare of a nation. The constituencies of EU countries rejects the aim of universality, conversely leading to the divergence both in the size and in the composition of public expenditures (Ferreiro et al. 2010, 2013).

On the other hand, Apergis et al. (2013), analysing whether public spending differences across European countries decrease or increase through a convergence approach for the time span 1990–2012, find non convergence in public policies in the EU related to environmental protection. They conclude that although the EU has enacted several directives with key environmental implications, results clearly demonstrate that convergence is far from being a reality; therefore it is crucial that such public expenses policies are better coordinated, so as to support common regulatory requirements.

Beyond the conclusions on the existence of convergence or divergence in environmental expenditures, at the best of our knowledge no contributions have investigated how environmental expenditures are distributed among several programmes.

The analysis of the composition of public expenditures in environmental domain could open an interesting field in the environmental economics literature, shedding light on how a specific composition of the expenditure could foster different environmental goals. In fact, if path dependency is not detected in the composition of public expenditures for environmental protection, it seems reasonable to suppose the existence of a margin for manoeuvre for the governments in financing different expenditures programmes. In this perspective, different choices of governments could be addressed to identify the best composition in order to reach several targets. Different “mix” of public expenditures can represent the macro aspect of the literature on “policy mix”. This branch of environmental economics highlights that the combination of different and multiple policy instruments like command and control strategies and economic instruments can reach solutions that are pareto-superior compared with a single instrument approach (Gunningham and Sinclair 1999). In more detail, a specific policy mix can be addressed to reach multiple goals in environmental domain (Kern and Howlett 2009), such as investments in R&D and eco-innovation (Costantini et al. 2017), the control of pollution (Lehmann 2012), the conservation of biodiversity and ecosystem (Ring and Schröter-Schlaack 2011).

3 Data

In order to investigate on the relative weight of public expenditure for environmental protection and its composition, we used general government expenditure data classified according to the international COFOG classification, which divides general government expenditure into ten main spending categories that correspond to specific government activities: general public services; defence; public order and safety; economic affairs; environmental protection; housing and community affairs; health; recreation, culture and religion; education; social protection. The data source is the Eurostat Government Finance Statistics website.

We first employed data on the general government expenditure for environmental protection, expressed as a share of GDP, in order to measure the importance of environmental protection relative to overall economic activity carried out in each country. Next, we considered the sub-categories of spending that fall within the main category of environmental protection. More specifically, the breakdown of environmental protection spending is based upon the classification of environmental protection activities that has been elaborated in the European system for the collection of economic information on the environment of the Eurostat.

According to this classification, general government expenditure for environmental protection is divided into 6 sub categories.[3]: (1) expenditure for waste management that covers collection, treatment and disposal of waste (hereafter labelled WASTE_MAN); (2) expenditure for waste-water management that covers sewage system operation and waste water treatment (WASTE_WATER); (3) expenditure for pollution abatement that includes a wide range of activities relating to ambient air and climate protection, soil and groundwater protection, noise and vibration abatement, and protection against radiation (POLLUTION_ABAT); (4) expenditure for protection of biodiversity and landscape that covers activities relating to the protection of fauna and flora species, the protection of habitats and the protection of landscapes for their aesthetic values (BIO_PROT); (5) expenditure for research and development that considers the financial resources for the management of government agencies engaged in applied research and experimental development related to environmental protection, and any grants, loans or subsidies to support applied research in environmental protection (RD); (6) expenditure for environmental protection not elsewhere classified that includes three different kinds of activities: (a) formulation, administration, coordination, and monitoring policies for the promotion of environmental protection; (b) preparation and enforcement of legislation and standards for

[3] The detailed structure and explanatory notes for the General Expenditure classified according to COFOG categories are described by the Statistics Division of the United Nations at the following link: http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=4.

the provision of environmental protection services; (c) production and dissemination of general information, technical documentation and statistics on environmental protection (GEN_NEC).

For each of these specific spending categories, we considered the expenditure data expressed as a ratio of GDP, in order to measure the importance of that specific spending relative to the overall economic activity of each country.

Due to limited data availability, our analysis covers the timespan from 2002 until 2010, and looks at 21 European countries: the Czech Republic, Germany, Ireland, Greece, Spain, France, Italy, Cyprus, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Slovenia, Finland, Sweden, the United Kingdom, Iceland, and Norway.

4 Methodology

In the first part of the analysis we relied on the sigma-convergence approach and investigated the evolution over time of the cross-national dispersion in environmental spending. Indeed, a reduction of spending variability across countries would suggest that convergence towards similar general government spending is observed.

The investigation of this variability is carried out by alternatively looking at two indices: the interquartile range and the coefficient of variation (CV). The interquartile range is calculated as the difference between the 1st and 3rd quartiles in a distribution; it considers only the dispersion of the central 50% of the data, and does not consider extreme values (Berenson et al. 2012). The CV is instead a normalized measure of data dispersion calculated as the ratio between the standard deviation and the mean of a distribution. This index allows us to measure the variability of a series of numbers independently of the unit of measurement, and is commonly used to compare distributions based on different units (Abdi 2010).

In the first step of the analysis, both the interquartile range and the CV were calculated by using cross-national yearly data on the total general government expenditure for environmental protection as a share of GDP. In the same step of the analysis, the calculation of the interquartile range and the CV was replicated by using spending data referring to the six specific spending categories that fall within the main environmental protection category.

In the second step of our investigation, we carried out a principal component analysis (PCA) (Pearson 1901; Jolliffe 1986; Stathis and Myronidis 2009; Shlens 2005; Cooley and Lohnes 1971) and a subsequent hierarchical cluster analysis (CA), in order to examine in greater detail public spending choices across the six specific categories that constitute the total environmental protection expenditure. The CA was performed in the subspace determined by the components extracted.

The PCA is a non-parametric statistical technique that permits us to reduce the dimensions of data by finding those few orthogonal linear combinations (named principal components) of the original variables, which account for as much of the variability in the data as possible. Assuming a *p*-variable problem, we may have the following covariance matrix, which represents the starting point of PCA (Jackson 2003):

$$S = \begin{bmatrix} s_1^2 & s_{12} & \cdots & s_{1p} \\ s_{12} & s_2^2 & & s_{2p} \\ \vdots & & \ddots & \vdots \\ s_{1p} & s_{2p} & \cdots & s_p^2 \end{bmatrix}$$

In this matrix, s_i^2 represents the variance of the original variable x_i $(i = 1\ldots p)$, s_{ij}. represents the covariance between the i-th and j-th variables.

Tsity of the linear association between the i-th and j-th variables is represented by the correlation coefficient r_{ij}.

Starting from the original variables x_i. $(i = 1\ldots p)$, by means of the principal axis transformation we obtain new uncorrelated variables z_i. $(i = 1\ldots p)$, which represent the principal components of x variables.

The i-th z variable (principal component) can be formalized as follows:

$$z_i = u_i'[x - \bar{x}]$$

where x and $\bar{x}$ represent the p * 1 vectors of observations on the original variables and their means.

This technique is useful in discovering which original variables form coherent subsets that are relatively independent of one another. More specifically, the factors extracted from the analysis (the principal components) tend to reflect the processes that generated the correlation among the original variables (Tabachnick and Fidell 2007). In our specific case, the application of this technique allows us to reduce the information on general government spending across the six environmental protection categories presented above into synthetic indexes, resulting from the principal components that measure the underlying structure of our data.

The PCA is widely employed for the study of the evolution of the welfare state and spending for social protection (De Simone et al. 2012). Furthermore, this methodology is suggested by international organizations as a means to build composite indicators for complex phenomena (OECD 2008a), and has been adopted in previous contributions that try to build composite indicators for environmental policies (Ercolano and Romano 2013).

While the PCA is usually run by using a two-way (observations × variables) matrix and cross-sectional data, previous studies suggest that a three-way data matrix, which also includes time, can be analysed by considering observations recorded in different years as independent statistical units (De Simone et al. 2012). We followed this approach by running our PCA analysis using data on European countries' expenditure for each of the six components of general government expenditure for environmental protection, covering the 2002–2010 period. In order to ease the interpretation of our results, the following sections present the results achieved by PCA run on country data for each of the selected categories of public spending reported in three years 2002, 2006 and 2010, representing the first, median and final year of the considered period.

The next step of the empirical investigation proposed in this paper is represented by a cluster analysis (CA). CA techniques classify a set of observations in such a way as to form groups (clusters) each one characterized by a high and significant similarity in the variables that define it and, at the same time, by a significant difference to others. Our application of the CA is based on data concerning government expenditure across six specific environmental-protection related purposes. This CA allows us to identify similarities and differences among countries in their spending choices.

The CA can be performed through different methods that allow us to build clusters. Our analysis is based on a hybrid procedure (PARTI-DECLA) developed in the statistical package DECISIA SPAD 5.6. This method clusters the original observations without any *ex ante* definition of the number of clusters to be generated. As pointed out by Awasthi et al. (2006) the hybrid procedure requires PCA to be carried out before proceeding with a clustering procedure. Then, after implementing a K-means cluster analysis (Everitt 1974; Meila and Heckerman 1998; Hansen and Jaumard 1997; Klein and Aronson 1991), we are able to classify the data according to the data point obtained in the PCA. Finally, by using Ward's method (Ward 1963), it is possible to cluster the cases through a hierarchical agglomerative clustering, consequently grouping the clusters close to each other (Abraham et al. 2009).

This two-step procedure (PCA + CA) has been employed by previous contributions to the study of the composition of public expenditure in the EU (Ferreiro et al. 2013), and more specifically for the cross-country analysis of social expenditure and its composition in some OECD countries (De Simone et al. 2012). According to some authors, the use of multidimensional techniques, such as those proposed in the second step of our empirical investigation, can be helpful in order to integrate the main findings provided by standard convergence analyses (Ferreiro et al. 2010).

5 Results

5.1 The Evolution over Time of Size and Cross-Country Variability of Public Expenditure for Environmental Protection

Figure 1 shows nine box plots built by using cross-country yearly (2002–2010) data concerning total general government expenditure for environmental protection as a share of GDP. Box plots are graphical representations that simultaneously display the lowest and highest values in a distribution alongside the median value and the 1st and the 3rd quartiles, whose difference (the interquartile range) shows how the data is spread around the median. This representation allows us to visualize the centering and variability of data under scrutiny, and also provides hints as to the identification of outliers, since any value greater (lower) than the 3rd quartile (1st quartile) for an amount of 1.5 times the interquartile range, is a suspected outlier in a distribution.

The median value of public expenditure for the environment remained fairly stable in the sample and over the period analysed. The Netherlands, whose expenditure for environmental protection is permanently higher than 1.5% of GDP, with the exception of 2010, turns out to be a possible positive outlier in most of the years considered, and the same applies to Malta from 2005 to 2008 and in 2010.

Looking at the information in Fig. 1 that allows us to examine the variability of the data, the min–max range appears to increase starting from 2005, and this rise looks even more remarkable over the final two years examined. The same applies to the interquartile range. Figure 2 provides additional information by presenting a graphical representation of the CV as calculated for each of the years investigated. Consistently with data reported in

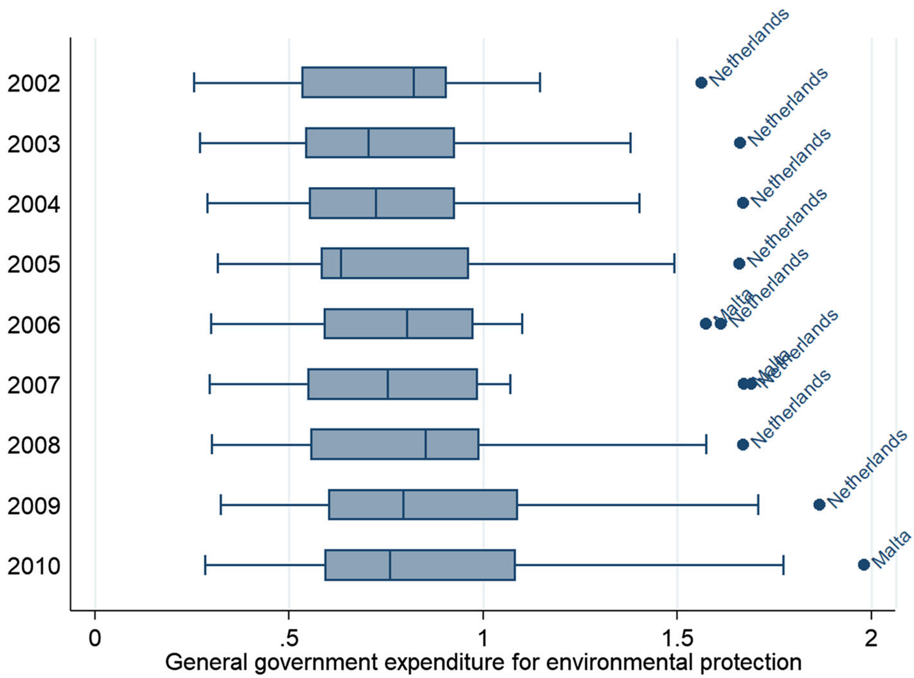

Fig. 1 General government expenditure for environmental protection in 21 European Countries (% GDP), 2002–2010. See Sect. 3 for the complete list of countries considered

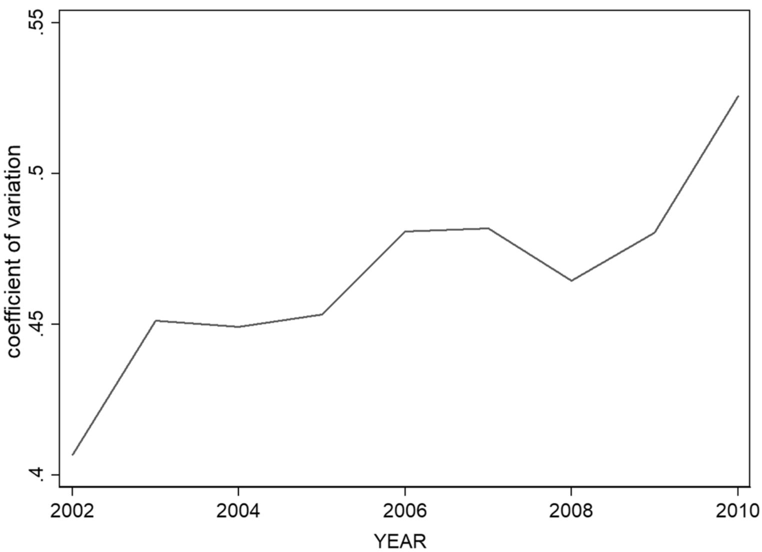

Fig. 2 Coefficient of variation calculated on yearly cross-national data of general government expenditure for environmental protection (% GDP) by year

Fig. 1, the CV shows an increasing trend over the period considered, with only two slight decreases registered in 2004 and 2008.

Overall, an inspection of Fig. 1 suggests that the size of expenditure devoted to environmental protection by European countries remained largely unaltered from 2002 to 2010. However, Figs. 1 and 2 suggest that cross-country variability in public expenditure for the environment increased slightly over the period investigated. According to this interpretation of the data, European countries do not show any trend of convergence towards a similar level of public expenditure for environmental purposes, but on the contrary retain significant differences.

Tables 1 and 2 report summary statistics concerning cross-country yearly data of public expenditure in each of the six spending categories that constitute the total general government expenditure for environmental protection (WASTE_MAN, WASTE_WATER, POLLUTION_ABAT, BIO_PROT, RD, GEN_NEC). In Table 1, data expressed as a ratio of GDP are considered while in Table 2 the expenditure allocated to each of the specific environment-related functions is measured as a ratio of total expenditure for environmental protection. Due to constraints of space, our tables only report the data recorded for three years, 2002, 2006 and 2010, respectively the first, median and final year within the considered period.

The inspection of minimum, maximum, and mean values allows us to identify WASTE_MAN as the most important spending category among those considered. Indeed, on average, 40% of the total expenditure on environmental protection is devoted to this specific activity in the European countries considered. WASTE_WATER is the second largest expenditure category on average, followed by BIO_PROT and GEN_NEC.[4] According to the figures, RD turns out to be the spending category that reports the lowest amount of general government expenditure.

An inspection of the interquartile range and CV, which are reported in the last two columns of Table 1, suggests that a reduction of cross-country variability in the level of expenditure is registered for BIO_PROT both when considering data expressed as a ratio of GDP, and as a ratio of total expenditure for environmental protection. The same partially applies to RD, for which the interquartile range inspection provides different results. According to these elaborations, then, cross-country differences in the public spending for these two specific domains decreased in the time period considered.

On the other hand, an increase in cross-country variability is registered for WASTE_WATER and GEN_NEC. Finally, a mixed result is found for POLLUTION_ABAT, which shows a significant reduction in variability when looking at data calculated as a ratio of GDP, and an increase in variability when looking at data expressed as a ratio of total expenditure. For these domains, cross-country differences in public spending are stable or increasing over the considered time period.

[4] Czech Republic presents some negative values for NEC category due to the sale of carbon trading rights in 2009. More detail on Eurostat metadata at http://ec.europa.eu/eurostat/cache/metadata/en/gov_a_exp_esms.htm.

Table 1 General government expenditure for each of the six categories building general expenditure for environmental protection. *Source*: Our elaboration on data provided by Eurostat Government Finance Statistics

Variable	Year	Min	Max	Mean	Interquartile range	Coeff. of variation
WASTE_MAN	2002	0.0000 (Ireland)	0.0054 (Netherlands)	0.0028	0.003	0.5850
	2006	0.0002 (Ireland)	0.0090 (Malta)	0.0032	0.002	0.6899
	2010	0.0004 (Finland)	0.0078 (UK)	0.0032	0.003	0.6692
WASTE_WATER	2002	0.0000 (Finland)	0.0077 (Ireland)	0.0024	0.003	0.8929
	2006	0.0000 (Finland)	0.0074 (Ireland)	0.0023	0.003	0.8998
	2010	0.0000 (Finland)	0.0090 (Malta)	0.0027	0.003	0.9919
POLLUTION_ABAT	2002	0.0000 (Iceland + Greece)	0.0034 (Netherlands)	0.0005	0.001	1.4576
	2006	0.0000 (Iceland + Greece)	0.0035 (Netherlands)	0.0006	0.001	1.3427
	2010	0.0000 (Iceland + Greece)	0.0036 (Netherlands)	0.0007	0.001	1.3873
BIO_PROT	2002	0.0000 (Greece)	0.0030 (Slovenia)	0.0009	0.001	0.9995
	2006	0.0000 (Greece)	0.0027 (Italy)	0.0010	0.001	0.9415
	2010	0.0000 (Greece)	0.0031 (Czech Rep)	0.0011	0.001	0.8617
RD	2002	0.0000 (Hung, Mal, Cyp, Gr,)	0.0004 (Germany)	0.0001	0.000	1.0839
	2006	0.0000 (Hung, Mal, Cyp, Gr,Por)	0.0004 (Germany)	0.0001	0.000	0.9934
	2010	0.0000 (Mal, Cyp, Gr,Pol, Por)	0.0005 (Germany)	0.0001	0.000	0.9073
GEN_NEC	2002	0.0000 (Cyprus)	0.0013 (France)	0.0007	0.000	0.4929
	2006	0.0000 (Cyprus)	0.0013 (France)	0.0007	0.001	0.5669
	2010	−0.0008 (Czech Rep)	0.0013 (UK)	0.0006	0.001	0.7806

Data are expressed as a ratio of GDP

Table 2 General government expenditure for each of the six categories building general expenditure for environmental protection. *Source*: Our elaboration on data provided by Eurostat Government Finance Statistics

Variable	Year	Min	Max	Mean	Interquartile range	CV
WASTE_MAN	2002	0.0037 (Ireland)	0.9433 (Cyprus)	0.4005	0.274	0.5866
	2006	0.0254 (Ireland)	0.9499 (Cyprus)	0.4122	0.273	0.5490
	2010	0.0380 (Ireland)	0.9177 (Cyprus)	0.3994	0.295	0.5889
WASTE_WATER	2002	0.0000 (Finland)	0.8556 (Ireland)	0.2898	0.318	0.7980
	2006	0.0000 (Finland)	0.7623 (Ireland)	0.2688	0.285	0.8240
	2010	0.0000 (Finland)	0.7300 (Ireland)	0.2729	0.401	0.8070
POLLUTION_ABAT	2002	0.0000 (Iceland, Greece)	0.2983 (Austria)	0.0678	0.072	1.1922
	2006	0.0000 (Iceland, Greece)	0.3233 (Austria)	0.0741	0.082	1.1270
	2010	0.0000 (Iceland, Greece)	0.4690 (Austria)	0.0851	0.059	1.3723
BIO_PROT	2002	0.0000 (Greece)	0.3694 (Slovenia)	0.1103	0.116	0.9379
	2006	0.0000 (Greece)	0.3379 (Italy)	0.1141	0.126	0.8522
	2010	0.0000 (Greece, Cyprus)	0.3006 (Czech)	0.1223	0.078	0.7509
RD	2002	0.0000 (Greece, Hungary, Malta)	0.1067 (Finland)	0.0180	0.022	1.4280
	2006	0.0000 (Greece, Hungary, Malta, Cyprus, Portugal)	0.0959 (Finland)	0.0190	0.022	1.3128
	2010	0.0000 (Greece, Malta, Cyprus, Poland, Portugal)	0.1107 (Finland)	0.0211	0.025	1.2507
GEN_NEC	2002	0.0000 (Greece, Hungary, Malta)	0.3271 (Finland)	0.1138	0.109	0.7191
	2006	0.0000 (Greece, Hungary, Malta, Cyprus, Portugal)	0.3230 (Sweden)	0.1118	0.098	0.7900
	2010	−0.0803 (Greece, Hungary, Malta, Poland, Portugal)	0.3577 (Finland)	0.0994	0.100	0.9696

Data are expressed as a ratio of general expenditure for environmental protection

5.2 Principal Component Analysis and Cluster Analysis

In this section, results obtained through PCA and CA are presented and discussed.

Table 3 offers a preliminary inspection of correlations among the six categories of spending (% of national GDP) considered in the analysis: WASTE_MAN, WASTE_WATER, POLLUTION_ABAT, BIO_PROT, RD, GEN_NEC. Results reveal that there is not any strong positive or negative correlation ($p > 0.6$ and $p < -0.6$ respectively) in our sample. The highest positive correlation is found between RD and POLLUTION_ABAT ($p = 0.42$); the association of these types of expenditures may be explained due to a spillover effect between them. The highest negative correlation, meanwhile, is seen in BIO_PROT and GEN_NEC (−0.31). With the exception of the category RD, GEN NEC shows negative correlations with all the domains considered, and this suggest that expenditures included in this residual category are alternative to others.

Table 4 shows factors extracted through PCA run on the variables considered so far, and the corresponding eigenvalues. For each of the extracted factors, Table 4 also reports the percentage of the variability explained. The first three factorial axes report an eigenvalue higher than 1, and are able to synthetize more than 71% of variability in countries' choices of expenditure for the six spending categories under investigation.

In order to represent our results in graphical terms, the following analysis only considers the first two axes, which are able to explain more than 52% of the total variability. The factorial plan built by relying on these two axes is illustrated in Fig. 3. Here, the positioning of countries' observations with respect to factorial axes can be analysed. Nevertheless, before analysing it, it is useful to turn to Tables 5 and 6, which respectively present those variables whose coordinates on factorial axes 1 and 2 have the highest absolute values. Indeed, these variables are those that characterize these axes and permit us to interpret them.

Looking at the results reported in Table 5, the first axis (which is the horizontal one in Fig. 3) is highly positively characterized by GEN_NEC and highly negatively characterized by BIO_PROT. The second factorial axis (which is the vertical one in Fig. 3) is positively characterized by BIO_PROT, and highly negatively characterized by RD. This means that by moving to the top/left part of the factorial plan we find countries characterized on average by higher values of BIO_PROT; whereas in the bottom part of the factorial plan, we find countries characterized by higher values of RD. On the right are countries more characterized by GEN_NEC expenditures, while on the left are countries characterized by highest expenditures for BIO_PROT.

Turning back to Fig. 3, we can now examine the pattern followed by the countries in the three years (2002, 2006 and 2010) that were included in the PCA analysis. The first thing worth noting is that with few exceptions, most of the countries do not show significant movements on the factorial plan. This means that most of them retained their spending behaviour over time and did not substantially modify it. Countries whose movements on the factorial plan over the considered period seem to be worth noting are Malta, the Czech Republic and Slovenia. Specifically, Malta and the Czech Republic increase their negative coordinate on the first axis, changing their general government environmental expenditure composition in favour of BIO_PROT. Slovenia, meanwhile, shows an increasing negative coordinate on the second factorial axis and this suggests that it progressively changed the composition of its environmental protection expenditures by increasing RD.

Table 3 Pairwise correlations among WASTE_MAN, WASTE_WATER, POLLUTION_ABAT, BIO_PROT, RD, GEN_NEC expressed as a ratio of GDP

	WASTE_MAN	WASTE_WATER	POLLUTION_ABAT	BIO_PROT	RD	GEN_NEC
WASTE_MAN	1.00					
WASTE_WATER	−0.07	1.00				
POLLUTION_ABAT	0.08	0.27	1.00			
BIO_PROT	0.34	0.24	0.00	1.00		
RD	−0.01	−0.16	0.42	−0.04	1.00	
GEN_NEC	−0.05	−0.28	−0.16	−0.31	0.07	1.00

Table 4 Factors and related eigenvalues calculated through PCA run on WASTE_MAN, WASTE_-WATER, POLLUTION_ABAT, BIO_PROT, RD, GEN_NEC expressed as a ratio of GDP

Number	Eigenvalue	Percentage	Cumulated percentage
1	1.7061	28.44	28.44
2	1.4174	23.62	52.06
3	1.1709	19.51	71.57
4	0.7356	12.26	83.83
5	0.6217	10.36	94.19
6	0.3484	5.81	100.00

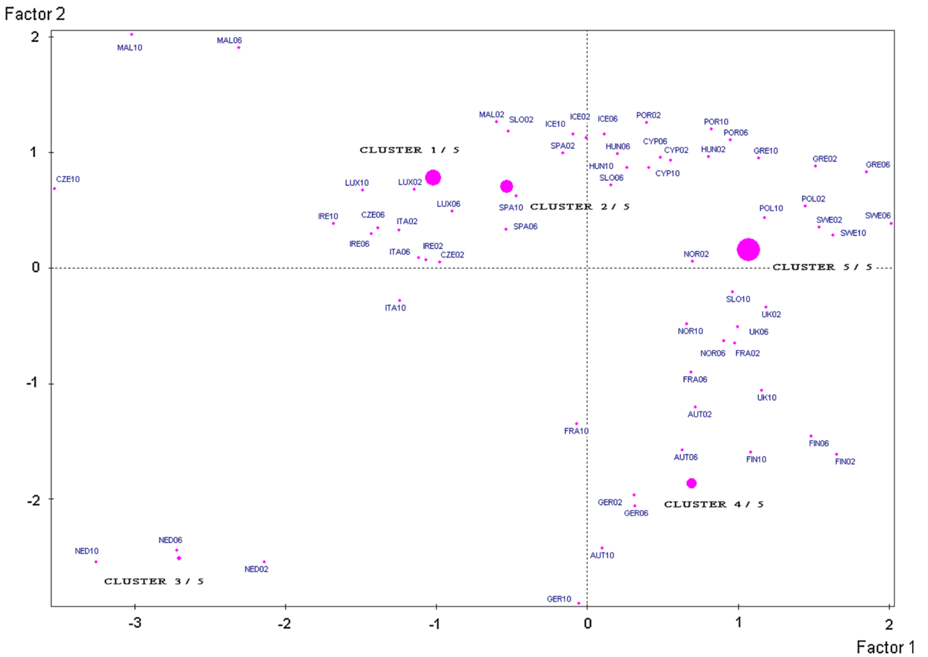

Fig. 3 Factorial plan resulting from the PCA analysis run on WASTE_MAN, WASTE_WATER, POLLUTION_ABAT, BIO_PROT, RD, GEN_NEC expressed as a ratio of GDP. Centres of cluster calculated through a subsequent CA are also reported

Table 5 Printout on factor 1 by the active continuous variables expressed as a ratio of GDP

Variable label	Coordinate	Weight	Mean	SD
BIO_PROT	−0.70	63.00	0.001	0.001
GEN_NEC	0.69	63.00	0.001	0.000

Only variables that report the highest absolute values of coordinates are reported

Table 6 Printout on factor 2 by the active continuous variables expressed as ratio of GDP

Variable label	Coordinate	Weight	Mean	SD
RD	−0.85	63.00	0.000	0.000
BIO_PROT	0.29	63.00	0.001	0.001

Only variables that report the highest absolute values of coordinates are reported

CA run after PCA reveals that the observations considered in the analysis can be grouped into five clusters whose composition is presented in Table 7, and whose characterization is shown in Table 8. In Fig. 3 the centre of these clusters is also reported on the factorial plan.

Looking at the characterization and composition of the clusters (see Tables 7 and 8), cluster 1 is positively characterized by BIO_PROT and WASTE_MAN; this cluster includes all the three observations (2002, 2006 and 2010) that concern Italy and Spain. Two out of three observations that concern Mediterranean countries such as Malta and Slovenia are also included in this cluster. Surprisingly, the same cluster includes observations that concern countries such as the Czech Republic and Iceland, which are supposed to be highly different from a geographical and morphological point of view.

Cluster 2 is positively characterized by WASTE_WATER and negatively by RD and GEN_NEC; this cluster includes Cyprus, Ireland and Luxembourg. Cluster 3 is highly positively characterized by POLLUTION_ABAT and weakly by WASTE_MAN; this cluster only includes Netherlands, meaning that the country has a very peculiar characterization in terms of the composition of its public expenditure for environmental protection.

Cluster 4 is strongly positively characterized by RD and lamely by POLLUTION_ABAT, while it is negatively characterized by WASTE_MAN. This cluster includes three countries: Germany, Austria and Finland.

Finally, cluster 5 is highly positively characterized by GEN_NEC and negatively by POLLUTION_ABAT and BIO_PROT. Other Mediterranean countries, namely France, Greece and Portugal, are included in cluster 5. Alongside these countries, this cluster also includes countries that theoretically show different geographical and morphological characterizations, such as the UK, Sweden and Poland.

Overall, the PCA and CA analyses reveal that the articulation of public expenditure for environmental protection is heterogeneous among the countries considered. Furthermore, existing spending differences among countries tend to persist over the time period considered. Indeed, most of the countries tend to permanently stay in the same cluster over the time period considered. This result is in line with the absence of substantial movements along the factorial plan, as shown above. There are limited exceptions to this consideration, with a few countries changing their cluster membership over the period analysed, e.g. Malta and Hungary, who change their position after 2002, moving respectively from cluster 2 to cluster 1 and from cluster 5 to cluster 2. In the case of Hungary, in 2006, in fact the big bulk of pollution abatement and control (PAC) investment expenditure was devoted to water protection (54%) and only 14% on air management (OECD 2008b).

As a robustness check, the same analysis was run by considering general government expenditure for each of the categories considered so far expressed as a share of total public spending for environmental protection. This analysis allows to take into account the

Table 7 Composition of clusters resulting from Cluster Analysis run on WASTE_MAN, WASTE_WATER, POLLUTION_ABAT, BIO_PROT, RD, GEN_NEC expressed as a ratio of GDP

Rank	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	Distance	Case	Distance	Case	Distance	Case	Distance	Case	Distance	Case
1	1.11299	ITA02	0.39345	LUX06	0.17695	NED06	1.07564	AUT06	1.05599	FRA02
2	1.17368	SPA10	0.86378	HUN10	0.34425	NED10	1.14406	FIN06	1.1314	SWE10
3	1.38096	SPA06	0.96426	HUN06	0.37761	NED02	1.16683	FIN10	1.25142	SWE06
4	1.5634	ICE10	1.34033	LUX02			1.30728	FIN02	1.54236	NOR02
5	1.62965	ICE02	1.34615	MAL02			1.56911	GER06	1.57322	SWE02
6	1.71651	CZE06	2.05269	LUX10			1.63159	GER02	1.71723	GRE02
7	1.7168	ITA06	3.49447	IRE06			1.86453	AUT02	1.93317	GRE06
8	1.88177	SPA02	3.92676	IRE02			2.32817	GER10	1.94167	NOR06
9	1.9067	CZE02	4.56711	CYP02			4.85131	AUT10	2.24618	NOR10
10	2.10253	ICE06	4.64262	CYP10					2.28332	FRA06
11	2.91059	ITA10	4.65356	CYP06					2.34339	SLO10
12	3.96287	SLO06	4.71862	IRE10					2.36226	POR10
13	3.99542	SLO02							2.36699	POL02
14	7.24627	MAL06							2.43681	POR06
15	12.2467	CZE10							2.47088	GRE10
16	12.4563	MAL10							2.47292	POL06
17									2.61601	UK02
18									2.86965	POR02
19									2.94917	POL10
20									3.37106	HUN02
21									4.54408	FRA10
22									6.7233	UK06
23									9.99919	UK10

Table 8 Characterization of the clusters presented in the previous table

	Characteristic variables	Cluster mean	Overallmean	Cluster SD	Overall SD	Test-value	Probability
Cluster 1	BIO_PROT	0.002	0.001	0.001	0.001	6.52	0
	WASTE_MAN	0.004	0.003	0.002	0.002	2.84	0.002
Cluster 2	WASTE_WATER	0.004	0.003	0.003	0.002	3.04	0.001
	RD	0	0	0	0	−2.95	0.002
	GEN_NEC	0	0.001	0	0	−4.22	0
Cluster 3	POLLUTION_ABAT	0.003	0.001	0	0.001	6.27	0
	WASTE_MAN	0.006	0.003	0	0.002	2.4	0.008
Cluster 4	RD	0	0	0	0	4.87	0
	POLLUTION_ABAT	0.001	0.001	0.001	0.001	2.45	0.007
	WASTE_MAN	0.001	0.003	0.001	0.002	−3.15	0.001
Cluster 5	GEN_NEC	0.001	0.001	0	0	5.48	0
	POLLUTION_ABAT	0	0.001	0	0.001	−2.4	0.008
	BIO_PROT	0.001	0.001	0	0.001	−3.17	0.001

relative preference that each country shows for the alternative categories that compose general government expenditure for environmental protection, without considering how large the dimension of each category with respect to the GDP is.

Results are not reported in order to save space; nevertheless they do not show any significant difference with the findings discussed in this section.

6 Environmental Performances and Public Expenditures

As pointed out in the previous section, the public expenditure for environmental protection and its composition among several programmes appear to be very different across the European countries analysed. As stressed by several authors, public expenditures need to be evaluated not only looking at the level but also in its efficacy. This point became very important over the last years when countries "had to deal with increased pressures on public balances, stemming from demographic trends and globalisation" (Mandl et al. 2008).

This is the reason why we decide to investigate on whether or not public expenditures is correlated with some environmental outcomes. In more detail, in order to assess the efficacy of public expenditure in the environmental domain it could be useful to have a look to the different environmental performances of the selected countries. The evaluation of outcomes correlated with public programmes is a complex exercise since outcomes are often determined by external factors and it is not easy to select proper indicators able to provide adequate measurement. More specifically, looking at this last point, since the analysis of public expenditure deals with multidimensional impacts, composite indicators are recognised as useful tools in policy analysis and communication in order to asses and compare countries' performances in "complex and sometimes elusive issues in wide-ranging fields, such asenvironment, economy, society or technological development"

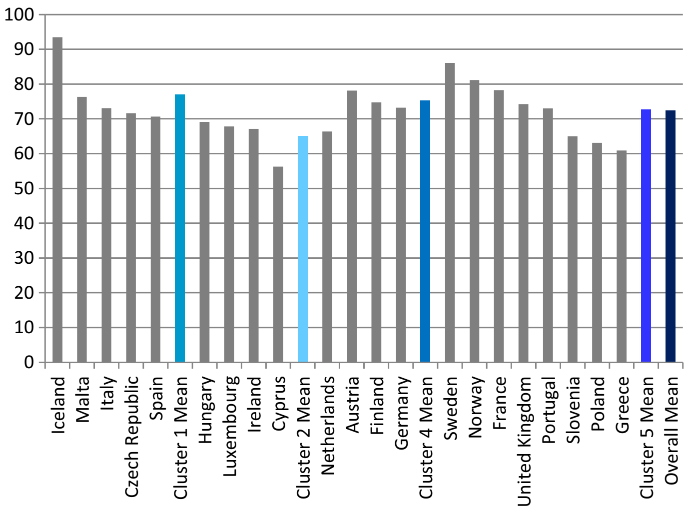

Fig. 4 EVI index at country level. The countries are groped by cluster (year 2010)

(OECD 2008c). The Environmental Performance Index (EPI)[5] represents an aggregate measure of a country's policy results to achieve targets towards protecting human environmental health and maintaining ecological vitality (Srebotnjak 2008). In more detail, EPI is actually built on the basis of measurable outcomes such as emissions or deforestation rates rather than policy inputs, such as program budget expenditures. Each sub-indicator of the EPI is linked to some policy targets. In Fig. 4 we report the EPI calculated over the 2010 for the countries considered in our previous analyses (grouped by cluster). In addition, the figure reports the mean value calculated for our sample.

By means of scatter plots in Figs. 5 and 6 it is possible to investigate on the bivariate correlations of EPI with two variables representatives of economic wealth and the public effort in the environmental domain.

1. Environmental Performance Index (EPI)
2. General Public Expenditure for environmental protection(EXP) expressed as a share of GDP.
3. Gross Domestic Product per capita (GDP).[6]

The figures show that in general there are not strong bivariate correlations among the selected variables. Nevertheless a positive feeble correlation seems to be detected between the EPI and GDP. This result could suggest that wealthier countries tend to report also higher values of environmental performances.

In order to investigate if public expenditure for environmental protection and its composition are correlated with environmental performance, a panel regression model was carried out. The results of our estimations are reported in Table 9. Unfortunately EPI does not allow any country comparison over time since it has been calculated with different

[5] The Environmental Performance Index is a project lead by the Yale Center for Environmental Law & Policy and Yale Data-Driven Environmental Solutions Group at Yale University, in collaboration with the Samuel Family Foundation, McCall MacBain Foundation, and the World Economic Forum.

[6] These variables have different sources. EPI is extracted by http://epi.yale.edu/; GDP and EXP are extracted from Eurostat database http://ec.europa.eu/eurostat/data/database.

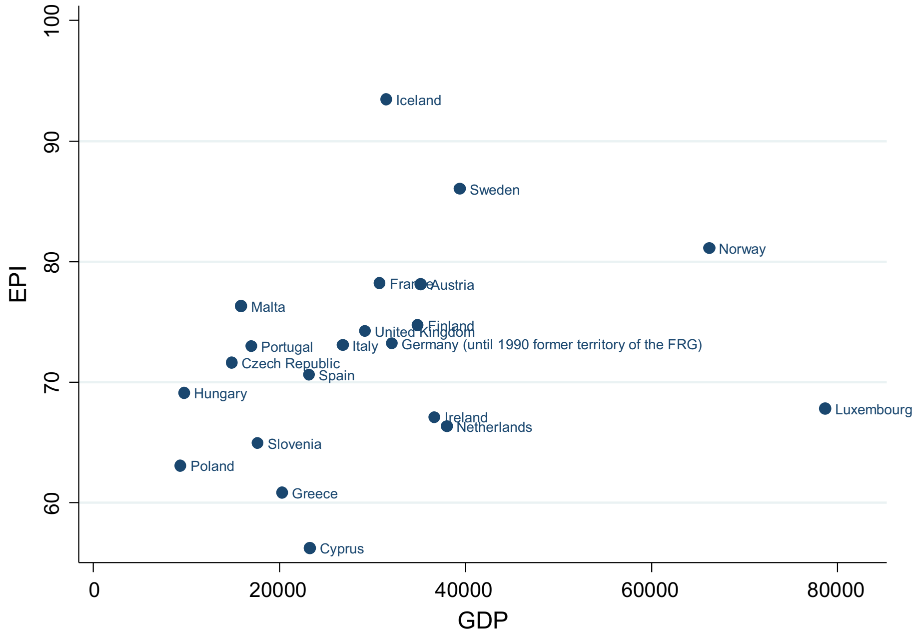

Fig. 5 Scatter plot reporting EPI and GDP (year 2010)

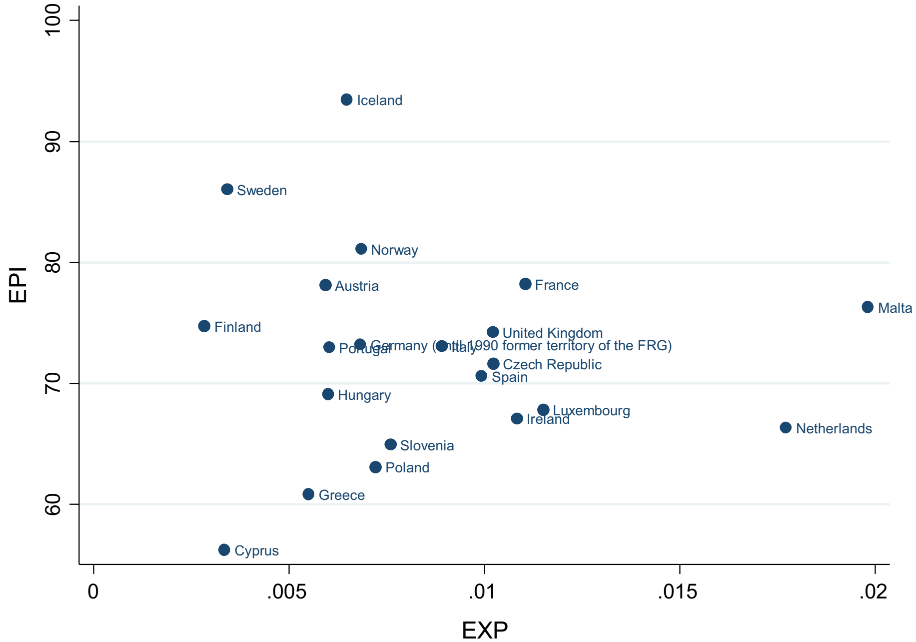

Fig. 6 Scatter plot reporting EPI and EXP (year 2010)

Table 9 Results of the regression analysis

Dependent variable GHG Estimator	M1 Fixed	M2 Pooled	M3 Random
GDP	0.000670**	0.000167	0.000361
	(2.43)	(1.21)	(1.40)
VA_ind	1.396***	−0.758	0.673*
	(4.04)	(−1.64)	(1.79)
EXP	−1602.0**		
	(−2.60)		
Cluster1		18.57***	12.04*
		(3.03)	(1.82)
Cluster2		2.120	1.260
		(0.26)	(0.25)
Cluster4		9.053	0.545
		(1.52)	(0.06)
Cluster5		8.932*	7.473
		(2.01)	(1.34)
Constant	68.31***	102.3***	72.33***
	(5.00)	(12.97)	(5.27)
N	171	57	57
F test prob > F	0.0000		
Hausman prob > chi^2	0.0019		
Breusch Pagan LM test prob > chibar2			0.0000

The dependent variable is represented by the greenhouse gases index (GHG)

Standard errors are reported in parentheses

*, **, *** respectively indicate statistical significance at 10, 5 and 1% level

methodologies over the years 2006 (pilot edition), 2008, 2010, 2012 and 2014. This is the reason why the dependent variable of the model is represented by the GHG. In fact, differently from EPI index, there are available data for the time span considered in our previous analyses. Following OECD (2008) GHG emissions refer to the sum of the 6 gases of the Kyoto Protocol (CO2, CH4, N2O, PFCs, HFCs and SF6) with negative impact for the temperatures and the earth's climate, and consequences for ecosystems, human settlements, agriculture and other socio-economic activities.[7]

Our main variables of interest are represented by the public expenditures for the environmental protection (EXP) and four dummy variables that represent the belonging of the country to a specific cluster (Cluster 1, 2, 4, 5).[8] Since environmental performances can be also influenced by some economic factors, in order to get ceteris paribus correlations we include in the model the following covariates:

- Gross domestic product per capita (GDP) at constant price (2010)
- Value Added of Industry (VA_ind) as share of GDP[9]

[7] GHG is extracetd from OECD.stat https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG.

[8] The reference cluster is represented by the cluster 3 which includes Netherlands only.

[9] The source of the covariates is Eurostat.

In order to reduce multicollinearity issues we estimated different models including separately EXP (M1) and Cluster dummies (M2 and M3). It is worth noting that clusters are based on the analysis carried out in the previous section, where cluster composition has been built looking at three different years (2002, 2006 and 2010). However data on the total public expenditure for environmental protection are available for the whole period considered (2002–2010). As such, in the first model (M1) we are able to estimate a regression using 19 countries and 9 years (N = 171). Post-estimation tests suggest fixed estimator as the most appropriate for the first model. Instead models 2 and 3 (M2 and M3) consider only 3 periods for 19 countries,[10] obtaining a total sample of 57. Since for some clusters we have not variability over time, it is not possible to run a fixed effect model. Therefore, we had to select between pooled and random estimators. Post-estimation statistics suggest random estimator (M3) to be the most appropriate for this regression. Nevertheless, because of the size of the sample, we decided to report also the results of the pooled estimations.

Looking at the results of M1 reported in Table 9, the negative and significant sign of variable EXP allows to conclude that on average, controlling for the per capita GDP and the value added of the industrial sector, the higher the level of public expenditures for environmental protection are, the lower the level of GHG is. Moreover we noted a positive and significant correlation of GDP and VA_ind with GHG. This result suggests that wealthier countries, with a high incidence of the industrial sector, tend to show higher level of greenhouse gases index. Moreover, ceteris paribus, the share of public expenditure for environmental protection shows a positive robust correlation with environmental performance measured in term of greenhouse gases. Moving to the composition of the public expenditure for environmental protection, results reported in Table 9 (M2 and M3) seem to suggest that, ceteris paribus, belonging to some specific clusters characterized by specific environmental programmes implies positive correlations with different levels of GHG. In more detail, looking at the M2, the belonging to cluster 1 and 5 (with respect to the cluster 3) is positively correlated with higher level of GHG. However, the result reported for cluster 5 is not statistically significant if we look at the random effect model. In general we can conclude that different compositions of the public expenditure for environmental protection are just partially correlated, ceteris paribus, with different level of environmental performance measured through greenhouse gas index.

7 Conclusion

This paper has empirically examined trends in government expenditure for environmental protection in recent years at European level, analysing whether or not European countries significantly diverge in the composition of environmental public expenditure, and identifying those countries that display greater similarities in their spending behaviour concerning environmental protection. We first measured the yearly cross-country variability of environmental expenditures, and then employed principal component analysis (PCA) and a subsequent hierarchical cluster analysis (CA). Results deny the hypothesis of convergence in levels of public expenditure for environmental protection. Results show that the size of expenditure for environmental protection by European member countries remained largely unaltered over 2002–2010, and that cross-country variability in public expenditure for the environment slightly increased over the period investigated. While most of the countries

[10] OECD database does not report GHG index for Malta and Cyprus.

did not show changes in the composition of their environmental expenditure throughout the years, Malta, the Czech Republic and Slovenia increased expenditure for the protection of biodiversity and landscape, and for research and development. Over the years considered, countries were stable in their choices concerning public expenditure behaviour for environmental protection. However, these choices were heterogeneous from one country to another. Looking at the different domains, countries seem to show greater similarities when the environmental expenditure is devoted either to waste management or to pollution abatement.

This is in line with the literature demonstrating non-convergence in public policies in the EU related to environmental protection. In analysing public spending differences across European countries for the period 1990–2012, Apergis et al. (2013) concluded that although the EU has enacted several directives with important environmental implications, results clearly demonstrate that convergence does not occur, and therefore it is crucial that "such public expenses policies are better coordinated so as to support common regulatory requirements" (Apergis et al. 2013, p. 52).

These results lead to draw the following observations: (1) a geographical and institutional components are not accountable in the composition of the clusters: clusters are formed by countries located in different parts of Europe, meaning that the political choice in public spending is specific and not necessarily influenced by common geographical and institutional characteristics (i.e. Mediterranean vs. northern countries); (2) the correlation between R&D and pollution abatement shows that pollution abatement is certainly a more innovative dependent sector compared to the others, where long-term investments mainly characterise public spending and where market instruments might have a larger application for environmental protection purposes; (3) finally, with the exception of a small increase in the variability of the expenditure in the considered period, it seems that the recent economic crisis did not affect spending choices. The relative positions of the countries remain basically stable throughout the considered period.

In addition, the study contributes to the debate on the efficacy of public spending in the environmental domain. In more detail, our first results detect that higher level of environmental performance seems to be positively correlated with the public expenditures in the environmental domain and partially with the different composition of the expenditure. Although aware of the limits of this analysis, such as the difficulty in selecting the most appropriate indicators of environmental performance, it represents a first attempt to investigate how levels and composition of the public expenditure for environmental protection are correlated with different performances, opening a new and promising debate for further contributions.

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