



**HAL**  
open science

## Environmental expenditure interactions among OECD countries, 1995-2017

Julie Le Gallo, Youba Ndiaye

► **To cite this version:**

Julie Le Gallo, Youba Ndiaye. Environmental expenditure interactions among OECD countries, 1995-2017. *Economic Modelling*, 2021, 94, pp.244-255. 10.1016/j.econmod.2020.10.006 . hal-02974683

**HAL Id: hal-02974683**

**<https://hal.science/hal-02974683>**

Submitted on 22 Oct 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Environmental expenditure interactions among OECD countries, 1995-2017<sup>1</sup>

Julie LE GALLO and Youba NDIAYE

CESAER UMR 1041, AgroSup Dijon, INRAE Dijon, Université de Bourgogne Franche-Comté, France

September 28, 2020

## Abstract

How do countries respond to other countries when setting the level of their environmental expenditures? Using data from 1995-2017 on a sample of 28 OECD countries, we examine the nature and extent of strategic interactions in environmental expenditures among OECD countries using a spatial Durbin model including economic and political control variables and both economic and spatial weight matrices reflecting several interaction mechanisms. The results show the existence of significant positive spatial dependence in environmental spending suggesting that OECD countries consider their neighbors' behavior when making policy choices related to environmental expenditures. We also find that the most populous countries or those with high unemployment tend to spend less for environment while countries with a large urban population set higher levels of environmental expenditures. The results are robust to the inclusion of strong cross-sectional dependence under the form of common factors.

**Keywords:** Environmental expenditure, Strategic interaction, Spatial econometrics, Common factors

**JEL codes:** C33, H77, Q58

1

---

<sup>1</sup> We thank the editor and the two reviewers for helpful comments. The usual disclaimers apply.

# 1 Introduction

In face of the growing environmental challenges, governments have a range of tools at their disposal, including regulation, information programmes, innovation policies, environmental taxes, subsidies and environmental expenditure. According to Pearce and Palmer (2001), expenditure for environmental protection is crucial for improving social welfare. Nevertheless, its share in Gross Domestic Product (GDP) remains low: in 2016, the EU28 average general government expenditure for environmental protection amounted to 0.7% of European GDP (Source: Eurostat<sup>1</sup>).

When countries set their policy choices, three types of externalities might arise (Millimet, 2014): resource, pecuniary and fiscal externalities<sup>2</sup>. We focus on the latter and test the existence of strategic interactions in environmental expenditures. In other words, we test whether the policy choices of a country in terms of environmental expenditures impact the policy choices of other countries through strategic policy making (Wilson, 1999). This issue is important as environmental degradation overcomes national boundaries, common transnational efforts are then necessary. The Sustainable Development Goals and the Paris Agreement represent global commitment and steps towards tackling the negative effects of climate change on the environment. In Europe, sectorial directives and strategies such as Europe 20 20 20 contribute to align environmental policies and stimulate efforts towards greater water quality, less waste production and energy savings, amongst others (Ercolano and Romano, 2018).

The impact of strategic interactions among governments on the provision of public goods has been extensively studied. However, interactions in environmental issues have received rather scant attention. Not only are there few studies focusing on environmental strategic interactions among governments but the extent and direction of strategic interactions in environmental policies are also ambiguous. Indeed, some authors advocate the idea that decentralized environmental policies lead to a "race to the bottom" with overly lax environmental standards, while other authors rather favor the occurrence of a race to the top. Uncovering the possible existence of environmental expenditures interactions among countries is important for various reasons. Firstly, it allows to compare efforts that countries make for environmental protection. In the context of the climate change challenge, developed countries play a major role in environmental protection through setting environmental regulations and environmental protection expenditure. Hence, countries can be tempted to adopt a mimicking behavior for their expenditures in environmental protection in order to promote their self. Secondly, as mentioned above, due to the potential existence of expenditure externalities, countries' policy choices are not independent. In terms of environmental expenditures, these externalities could be the amount of public investments in environmental infrastructures in a country whose benefits spill over in neighboring countries, and therefore affect the level of investments in the latter countries. Another type of interdependence regarding environmental expenditure policy is based on the idea that citizens can evaluate the performances of their policy makers by comparing the

---

<sup>1</sup> Government expenditure on environmental protection (<http://ec.europa.eu/eurostat/statistics-explained/index.php>)

<sup>2</sup> For more details, see the survey by Millimet (2014). Resource externalities refer to the case where the actions of one jurisdiction affect the resource quantity or quality available to other jurisdictions. The canonic example related to this externality is transboundary pollution. Pecuniary externalities refer to the situations where the actions of one jurisdiction affect prices in other jurisdictions.

same policy choices taken by the neighboring countries. Environmental expenditure policies can also affect business location decisions: countries that impose higher environmental standards (in terms of investments for environmental protection) can encourage businesses to relocate to countries with lower environmental standards.

Two approaches have been implemented in the empirical literature to assess the presence and direction of strategic environmental interactions. The first approach examines directly pollution levels, using temporal variation while the second approach estimates so-called spatial reaction functions in order to determine if environmental policy choices in one jurisdiction are affected by the choices of other jurisdictions. Our paper is in line with the second strand of literature and is the first to consider the issue of strategic interactions in environmental expenditures at the level of countries. To test for strategic interactions in environmental expenditures between OECD countries, our approach is then threefold. First, using a panel dataset of 28 OECD countries over the period 1995-2017, we estimate a spatial Durbin model as our benchmark, including temporal and individual fixed effects and a range of control variables. Second, we check the validity of our results by taking into account strong cross-sectional dependence in the form of common factors, which, to the best of our knowledge, have never been considered in the literature on interactions in environmental policies. Third, to define the neighborhood, we consider criteria based on both geographic and economic proximity to reflect various interaction mechanisms. Our results tend to confirm the existence of mimicking between geographic and/or economic neighbors: OECD countries increase their environmental expenditures in response to the rise of neighbors. Results remain robust when common factors are included. We also find that the most populous countries or those with high unemployment rate tend to spend less on the environment. In addition, countries with a large urban population set higher levels of environmental expenditures.

Given the environmental challenges at hand, implementing effective environmental policies is crucial in order to fight climate change, preserve biodiversity, and reduce water and air pollution. Few empirical studies analyze spatial interactions via environmental spending. Therefore, our paper is important as it aims to fill this gap by analyzing policies on environmental spending both at the country level and from the perspective of spatial interactions. Our findings support the conjecture that countries act interdependently when they formulate policy choices related to environmental expenditures. In other words, there are mimicking behaviors of OECD countries when determining their environmental efforts according to their neighbors. This finding has important implications for environmental policy among countries. In particular, the location decisions of companies often, and in an important extent, guides the decisions of the public authorities in deciding the amount of environmental expenditures: when a country adopts a strict environmental policy, it creates *de facto* external effects on the environmental policy of its neighbors as strict environmental standards in terms of investments may encourage some companies to relocate and settle in countries where environmental standards are less stringent.

The remainder of this paper is organised as follows. The next section reviews the main contributions regarding environmental strategic interactions. Section 3 presents the econometric specification and estimation method. Section 4 describes the data and Section 5 reports the estimation results. The final section concludes with a summary of the main

findings and policy implications.

## 2 Literature review

Strategic interactions between governments in public spending decisions have received considerable attention in the applied public economics literature.

From a theoretical point of view, there are at least two mechanisms explaining potential strategic interactions in government expenditures (see for instance Brueckner (2003) for a survey). First, strategic interactions might arise from the interdependence amongst governments due to expenditure competition that may be associated with the mimicking behavior or yardstick competition. The second source is the presence of spillover effects: the benefits of public spending in domestic regions can easily spill over to neighboring regions (Gordon, 1983).

Empirically, in the context of environmental strategic interactions, there is no consensus. Some authors put forward the hypothesis that the decentralization of environmental policy leads to a "race to the bottom" while others rather highlight the occurrence of a "race to the top" (Millimet, 2003). Three main reasons may explain the race to the bottom in the context of environmental policy. First, resource externalities relate to transboundary pollution (Fredriksson and Millimet, 2002) producing negative externalities which are transmitted between neighbors. Thus, governments are encouraged to capture the economic benefits of industrial production within their borders while forcing their neighbors to bear the costs resulting from the resulting pollution. Environmental protection can then be left stranded and governments set the lowest environmental standards. Second, fiscal externalities, in particular tax competition, may induce local governments to adopt low standards of environmental regulation in order to improve the attractiveness of capital (Millimet, 2003 ; Fredriksson and Millimet, 2002). According to Konisky (2007), the consequence of lax environmental standard is similar to the prisoner's dilemma situation as the governments could have gained collectively by maintaining their environmental levels instead of reducing them. In addition, in the context of yardstick competition, jurisdiction leaders may have electoral incentives that justify lowering environmental regulation (Konisky, 2007). The third factor that can influence states to adopt lax environmental regulation is business interest groups (lobbies) that may try to persuade governments to reduce the costs of regulation to do business in their country. Alternatively, the race to the top may result from a desire by local governments to discourage firms located in their territories from generating pollution or to promote environmental protection (Millimet, 2003). Some papers indeed find some evidence of the existence of a race to the top in setting environmental regulation. For instance, Holzinger and Sommerer (2011) analyze the development of 17 environmental regulations in 24 countries over a period of 35 years. They find a clear 'race to the top' of environmental regulation and provide indications of an active search for European environmental harmonization.

Yet, environmental regulation *per se* is a difficult concept to measure (Millimet, 2014) as it encompasses on the one hand the regulatory aspects, linked to legislation called "de jure regulation" and the enforcement aspects, i.e "de facto regulation", on the other hand.

Hence, some empirical studies use environmental regulation as "de jure regulation" in order to analyse strategic interaction among governments. For instance, some papers employ state US data (Fredriksson and Millimet, 2002; Levinson, 2003; Galinato and Chouinard, 2018). Fredriksson and Millimet (2002) examine whether the US has engaged in strategic behavior in terms of environmental policies. Using two environmental measures of stringency on panel data (Levinson index and pollution abatement and control expenditures, PACE), they find that the states take into account the choices of neighboring states in the form of a positive association between the environmental abatement costs incurred by manufacturing industries in neighboring states, even after controlling for the non-uniform distribution of industries within the U.S. Furthermore, the response is asymmetrical. Indeed, states are driven by high levels of abatement costs when neighboring states adopt strict regulation levels. Galinato and Chouinard (2018) examine whether there is strategic interaction of implemented environmental regulations among neighboring countries. They also determine the role of institutional factors within a country in affecting the implemented environmental regulations stringency. However, they find no evidence of strategic interaction in environmental regulations after controlling for institutions.

The second branch focuses on enforcement, i.e. 'de facto regulation' when studying reaction functions of environmental policy. Instead of using pollution data, several studies test for cross-state strategic interaction using measures of environmental enforcement (Woods, 2006; Konisky, 2007). For instance, Konisky (2007) estimate a series of strategic interaction models to study the behavior of states in terms of environmental regulation. Using data on enforcement of three federal pollution control programs (Clean Air Act CAA, Clean Water Act and Resource Conservation and Recovery Act RCRA), he shows that states respond strategically to economic competitors. Woods (2006) assesses the effects of competition among states to determine if the enforcement gap between a state and competitor states affects the stringency of state enforcement. The results suggest that the enforcement of states is systematically affected by the behavior of regional competitors: states adjust their enforcement in response to competitor states when their enforcement stringency exceeds that of their competitors. Furthermore, some governments may pursue several environmental policy objectives in order to attract investments. In this perspective, Fredriksson et al. (2004) integrate the multidimensional dimension in strategic interactions of environmental policy and they indeed find evidence of cross-policy strategic interactions. Davies and Naughton (2014) take into account both international competition in environmental policy and the relationship between FDI and the environment. On a data set of 110 multilateral environmental agreements (treaties) and 139 countries between 1980 and 1999, they find that policies are strategic complements, which is a key requirement for an inefficient race to the bottom in the environmental policy field.

We contribute to a limited third strand of papers, which considers environmental expenditures as an appropriate instrument to analyse the behavior of governments in their choice of environmental policy. For instance, at the city-level, Deng et al. (2012) find that city governments behave strategically in making spending decisions regarding environmental protection. A city government appears to cut its own spending as a response to the rise in environmental protection spending by its neighbors so that environmental protection tends to be underprovided. Ercolano and Romano (2018) investigate environmental expenditures interactions among European countries and show that higher level of environmental

performance seem to be positively correlated with public expenditures in the environmental domain and partially with the nature of the expenditure. In particular, countries seem to show greater similarities when the environmental expenditure is devoted either to waste management or to pollution abatement. Using Chinese provincial data from 2000 to 2015, Cheng (2015) estimates the degree and direction of intergovernmental strategic interaction at three levels: the whole country, the southeast and the northwest. In order to take into account the inequalities among various regions in China, he also integrates the asymmetrical interaction between China's inter-provincial environmental protection expenditures (EPE) strategies by using a two-regime spatial econometric model and finds significant mimicking strategic interactions in inter-provincial EPE.

However, these studies are set within a local level so that the relevance of all these issues regarding environmental public expenditures among OECD countries remains untested. This study fills this gap using a new dataset that combines information on environmental spending varying over time (23 years) across a sample of OECD countries. Note that while the sample used in the paper by Tang et al. (2017) is similar to ours, we differ in various aspects. First, Tang et al. (2017) use the index of environmental stringency as the dependent variable to analyze strategic interactions while we focus on environmental expenditure. Our approach then allows to compare in absolute terms the efforts made by countries in environmental decisions, and not through a composite indicator. In addition, it also allows recovering the determinants of environmental expenditures. Finally, to the best of our knowledge, our study is the first to test strong dependence hypothesis' when analysing horizontal strategic interaction in environmental policy while all the papers mentioned above use a variant of a standard spatial autoregressive model. We now turn to the specificities of our identification strategy below.

### 3 Methodology

In this section, we present the econometric specifications and weights matrices used for estimating environmental expenditures strategic interactions between countries.

#### 3.1 Econometric specifications

Our identification strategy is based on a panel spatial Durbin model (SDM) with individual and time fixed effects with environmental expenditure as dependent variables. This model is written formally as:

$$E_{it} = \rho \sum_{j=1, j \neq i}^N w_{ij} E_{jt} + \sum_{k=1}^K x_{k,it} \beta_k + \sum_{k=1}^K \theta_k \sum_{j=1, j \neq i}^N w_{ij} x_{k,jt} + \mu_i + \eta_t + \varepsilon_{it} \quad (1)$$

where  $E_{it}$  is the environmental expenditure in country  $i$  and year  $t$ .  $w_{ij}$  corresponds to the spatial and/or economic connectivity structure between country  $j$  and country  $i$  ( $j \neq i$ ) and is an element of  $W$ , an  $N * N$  pre-specified row-normalized weights matrix with zeros on the diagonal. Then,  $\sum_{j=1, j \neq i}^N w_{ij} E_{jt}$  represents the weighted average of environmental expenditures of country's  $i$  neighboring countries, where the notion of neighbor is defined by  $W$ . This term is called the (endogenous) spatial lag in the spatial econometrics literature. Because we don't use time-varying weight matrices, there is no

index  $t$  for an element of the weight matrix.  $x_{k,it}$  is the observation  $(i, j)$  of control variable  $k$  with  $\beta_k$  as the associated coefficient to be estimated and  $\sum_{j=1, j \neq i}^N w_{ij} x_{k,jt}$  corresponds to its spatial lag, with  $\theta_k$  as the associated coefficient to be estimated.  $\varepsilon_{it}$  is a spatially correlated error term (corresponding to weak spatial dependence) such as:  $\varepsilon_{it} = \lambda \sum_{j=1, j \neq i}^N w_{ij} \varepsilon_{jt} + u_{it}$  and  $u_{it}$  represent idiosyncratic shocks uncorrelated across countries and over time. In addition, we include country fixed effects  $\mu_i$ , which capture time invariant country-specific attributes such as natural endowment, and time fixed effects.

We base our empirical analysis on panel SDM with individual and time fixed effects for two reasons. First, the spatial autoregressive model containing an endogenous spatial lag is the preferred reduced form used in the literature on fiscal federalism (Brueckner, 2003) as it allows capturing the presence and the extent of spatial/economic interactions in the dependent variable, environmental interactions in our case. Second, we add spatial lags of the explanatory variables in the specification, since LeSage and Pace (2009) show that a SDM model allows obtaining consistent estimates of the regression coefficients in the presence of spatially autocorrelated omitted variables. Using Monte-Carlo simulations, Fingleton and Le Gallo (2009) show that SDM models also allow reducing the finite-sample bias of endogeneity implied by measurement error and simultaneity. Although we include a range of control variables (see below), there is always the possibility of omitted variables correlated with the error terms implying endogeneity. Simultaneity between environmental expenditures and some of our control variables might also arise. Using a SDM model then allows to mitigate the endogeneity bias.

The explanatory variables  $X_{it}$  are described in the next section and aim at controlling the socioeconomic conditions in a country which impact residents policy preferences and policy choices for environmental expenditures. The spatial scalar parameter,  $\rho$ , is our coefficient of interest and reflects the endogenous spatial and/or economic interaction between country  $i$  and its neighboring countries. When  $\rho = 0$ , there is no strategic interaction. If  $\rho > 0$ , the environmental expenditure provision in a country tends to be more similar to the environmental expenditure provided in neighboring countries, and therefore the neighboring countries follow a mimicking strategy. On the other hand,  $\rho < 0$  would suggest that the environmental expenditure provision in nearby countries tends to be more diverse and demonstrates dissimilarity. In that case, countries follow a substituting strategy involving possible free-riding behaviors between countries (Brueckner, 2003).

The econometric estimation of Eq. 1 presents a number of challenges. Firstly, the neighboring countries' environmental expenditure are endogenous. Therefore, the spatial lag variable is correlated with the error term and this will lead to biased estimates of the parameter  $\rho$  if estimated by Ordinary Least Squares (OLS). In order to deal with the endogeneity of neighboring countries' environmental expenditures on the right hand side, we use maximum likelihood estimation. Secondly, whenever the weights matrix  $W$  is defined with an economic criteria, there might be endogenous issues. We present in the next section how we mitigate this problem. The last issue is related to parameter interpretation of explanatory variables. Since the estimated coefficients from a spatial lag model of equation (1) cannot be interpreted directly because of spillover effects, we compute partial derivatives in line with LeSage and Pace (2009). We report in this paper the direct effects which measure the impact of the dependent variable of a change in one independent



variable in the own country (see LeSage and Pace, 2009, p. 38-39).

The previous specification is the benchmark model used by all papers to uncover strategic interactions in environmental expenditures in general and strategic interactions in expenditures and taxes in general. Here, we check the validity of the results by allowing for strong cross-sectional dependence under the form of common factors (Chudik et al, 2011 ; Pesaran, 2006):

$$E_{it} = \rho \sum_{j=1, j \neq i}^N w_{ij} E_{jt} + \sum_{k=1}^K x_{k,it} \beta_k + \sum_{k=1}^K \theta_k \sum_{j=1, j \neq i}^N w_{ij} x_{k,jt} + \Gamma_1 \bar{E}_t + \sum_{k=1}^K \Gamma_{k,2} \bar{x}_{kt} + \mu_i + \varepsilon_{it} \quad (3)$$

where  $\bar{E}_t = 1/N \sum_{i=1}^N E_{it}$  and  $\bar{x}_t = 1/N \sum_{i=1}^N x_{it}$  are the cross-sectional averages of the dependent and independent variables at time  $t$ . These common factors therefore enter the equation as unit-specific coefficients. To the best of our knowledge, this model has never been used in the literature pertaining to environmental strategic interactions.

### 3.2 Weighting matrices

Our specification implies the specification of a weights matrix  $W$ . We define several weights matrices in order to reflect different mechanisms for environmental strategic interactions. In general, for a specific country  $i$ , the weight it assigns to country  $j$ ,  $w_{ij}$ , should reflect the degree of importance that country  $i$  assigns to country's  $j$  environmental policy in setting its own environmental policy. This importance depends on the underlying mechanism of government policy interaction.

The first weight matrices are simple spatial matrices commonly used in spatial econometrics: a contiguity matrix based on Gabriel neighbors<sup>2</sup>, noted  $W_{\text{cont}}$ , a  $k$  nearest matrix with  $k = 3$ :  $w_{ijt} = 1$  if  $j$  is one of  $i$ 's three nearest neighbors and 0 otherwise, noted  $W_{\text{nn3}}$  and an inverse distance matrix, noted  $W_{\text{inverse}}$ . These spatial weight matrices are then row-standardised.

We also use three economic matrices. In the first economic weight matrix, labelled  $W_{\text{GDPpc}}$ , the weight that country  $i$  assigns to country  $j$  is equal to  $w_{ijt} = \overline{GDPpc}_j / \sum_{k \neq i} \overline{GDPpc}_k, \forall t$ , where  $\overline{GDPpc}_j$  is the average of country's  $j$  GDP per capita over the period. This specification reflects interjurisdictional competition: when two countries compete for mobile resources with environmental policies, then they assign more weight to their wealthiest competitors. The second economic matrix,  $W_{\text{open}}$ , takes the same form but by using openness rather than GDP per capita:  $w_{ijt} = \overline{Openness}_j / \sum_{k \neq i} \overline{Openness}_k, \forall t$ , where  $\overline{Openness}_j$  is the average of country's  $j$  openness over the period. Openness is defined as the sum of exports and imports as a fraction of GDP. It is a common proxy for the inverse of trade costs. The third economic weight matrix,  $W_{\text{simi}}$ , measures economic

<sup>2</sup> We use Gabriel neighbors rather than a simple contiguity matrix in order to avoid a block diagonal structure of the weight matrix.

similarity between countries. The weights are constructed as the inverse of GDP per capita difference :  $w_{ijt} = (1/|\overline{GDPpc}_j - \overline{GDPpc}_i|) / (\sum_{k \neq i} 1/|\overline{GDPpc}_k - \overline{GDPpc}_i|), \forall t$ . These weights are consistent with yardstick competition, i.e. interactions due to voters' pressure. In this case, countries that have more similar conditions are expected to interact more. Note that Fredriksson et al. (2004) or Chen et al. (2019) use time-varying economic weight matrices by using GDP per capita or openness for each year rather than an average. However, economic weights may suffer from endogeneity, an issue that has been overlooked in the empirical literature dealing with environmental expenditures interactions. In the absence of convincing instruments that would allow implementing the instrumental variable strategies proposed for instance by Kelejian and Piras (2014) for a spatial autoregressive model or Shi and Lee (2018) for a spatial autoregressive model with common factors, we use period average to mitigate the endogeneity of the economic weights.<sup>3</sup> Results for these weight matrices should however be considered with some caution but they are consistent with those obtained with geographic weights, as we show below.

## 4 Data

Our sample consists of a subset of OECD countries over the period 1995-2017, namely Australia, Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland and United Kingdom. Several OECD countries were not included because of missing data with respect to our measure of environmental protection expenditures. In particular, data were totally or almost completely absent for Canada, Chile, Iceland, Mexico, New Zealand, Slovak Republic, Turkey and United States. As a robustness check we also consider a restricted sample of the countries in Europe (i.e. excluding Australia, Japan, Korea and Israel).

The main variable of interest comes from the OECD data and measures government spending related to environmental protection in terms of thousand USD in % of GDP, according to the 2008 System of National Accounts (SNA). There are wide cross-country variations in the level of this indicator, labelled ENVPROT, as shown by Figure (1), with values ranging from 28% (Sweden) to 151% (Netherlands) of expenditures related to environmental protection in % of GDP (mean values by country for the period 1995-2017). There are also some significant variations over time of environmental protection expenditures as shown by Figure (2) : after some stagnation until 2000, these expenditures globally increased until 2010 to reach a mean of over 80% in 2010 and fell again until the end of the period.

---

<sup>3</sup> Using period averages rather than time-varying weights reduces the pairwise correlation between the explanatory variables and the economic weights by 36% on average.

Figure 1: Distribution of environmental protection expenditures in % of GDP by country, mean over 1995-2017

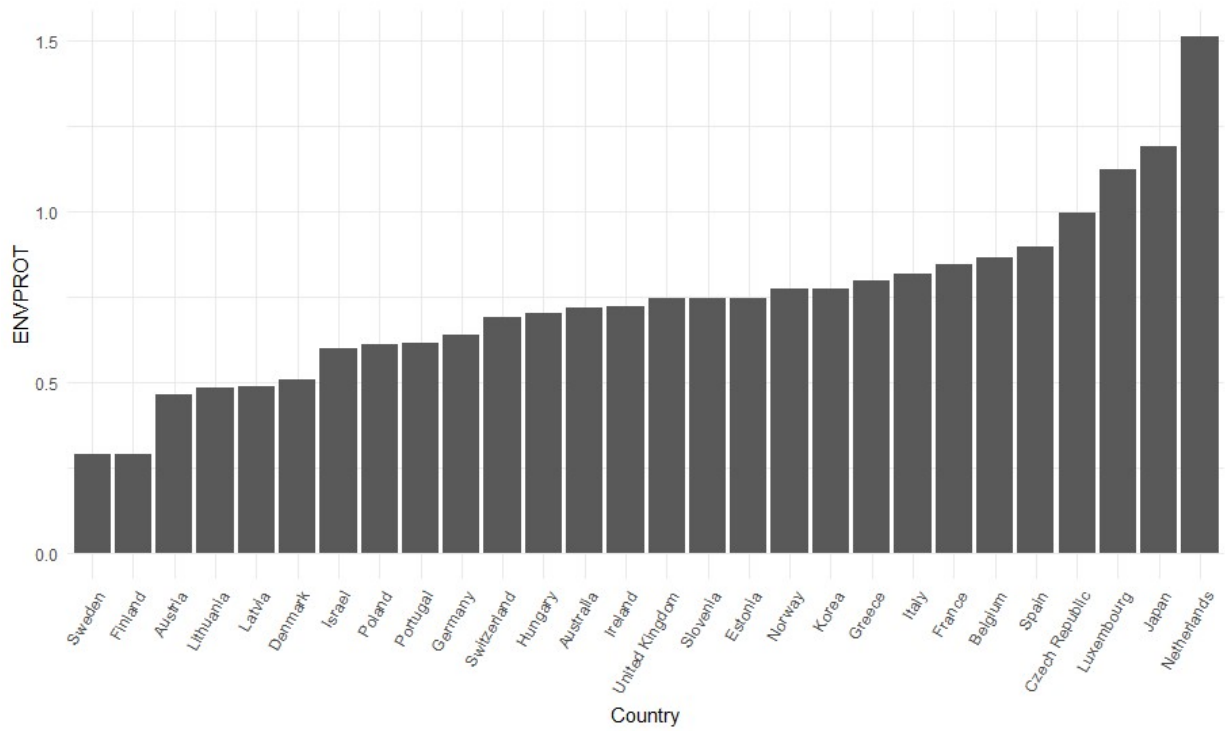
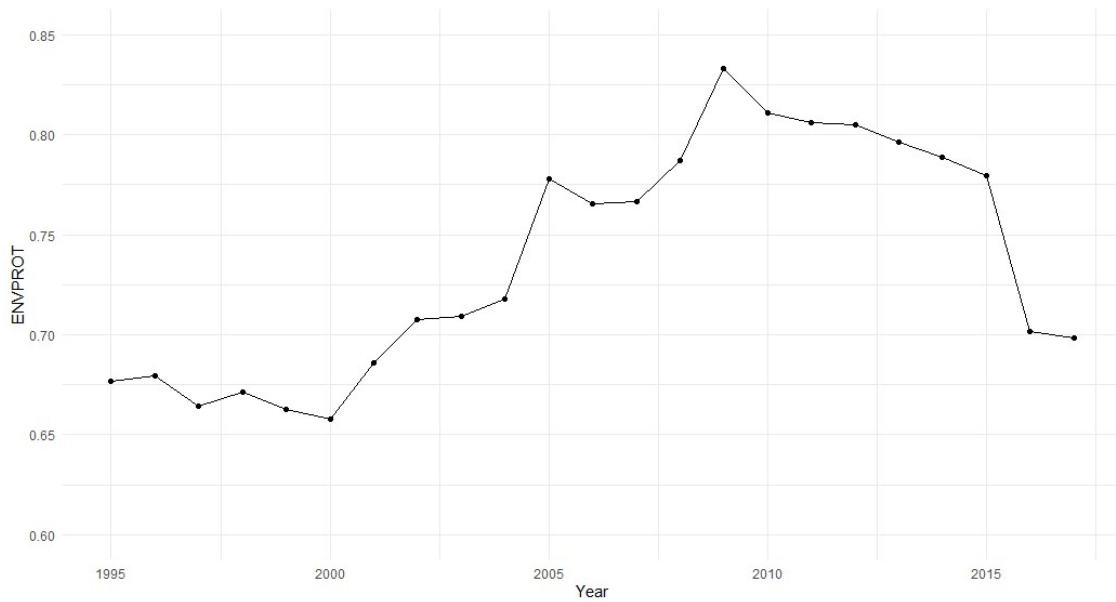


Figure 2: Evolution of environmental protection expenditures in % of GDP 1995-2017



We include a set of control variables to capture the relevant economic and population factors that are expected to influence the countries' environmental expenditures. These variables are drawn from the World Bank database and largely mirror those found as important in previous studies reviewed in section 2. With respect to population, we include the level of population to control for the scale of the country economy as well as the structure of population by age (share of population less than 14 years old and above 65 years old), the share of active population and the share of urban population to control for composition effects in population. The share of urban population is expected to be positive as high urbanization usually goes along with environmental degradation and requires more spending on environmental protection. We also include trade costs to control for the level of openness of countries, constant GDP per capita and unemployment rate as countries with poorer economic climates may face more political pressure to devote public expenditures to support the economy rather than environmental protection. With respect to GDP per capita, we expect a positive sign as, according to Wagner's law, government activities in general increase as economies grow which implies that as more developed economies should, everything else being equal, spend more on treating environmental pollution. All these control variables were drawn from the World Bank database.<sup>4</sup> Table (1) provide the descriptive statistics for these explanatory variables for the whole sample while Table (8) in the appendix provides these statistics for the restricted sample.<sup>5</sup>

Table 1: Descriptive statistics for the dependent and the explanatory variables; full sample

Variable	Description	N	Mean	St. Dev.	Min	Max
Envprot	Environmental protection (% GDP)	644	0.737	0.301	0.091	1.698
pop	Population	644	24,058,752	30,069,039	408,625	128,070,000
pop0014_pop	Share of pop below 14 (%)	644	0.172	0.030	0.128	0.290
popsup65_pop	Share of pop above 65 (%)	644	0.159	0.030	0.060	0.271
pop_active_pop	Share of active pop (%)	644	0.490	0.038	0.390	0.584
pop_urb_pop	Share of urban pop (%)	644	0.752	0.111	0.506	0.980
trade_costs	Trade costs	644	1.412	0.767	0.260	5.287
gdppc_constant	Constant GDP per capita (\$)	644	37,665.480	22,061.510	5,139.302	111,968.400
unemp_rate	Unemployment rate (%)	644	8.037	4.310	1.805	27.466

## 5 Results

We first investigate the potential for weak and strong spatial autocorrelation in the countries' distribution of environmental expenditures for the period 1995-2017. Figures (3) and (4) in the Appendix show the connectivity structure for the Gabriel and the 3 nearest neighbor weight matrices for our sample while Table (2) displays the evolution of the standardized value of Moran's  $I$  statistic over the period for the 3 spatial weight matrices and the 3 economic weight matrices. Table (7) in the appendix provides these statistics for the restricted sample. In general, the standardized values are the highest for the economic

<sup>4</sup> As a further robustness check, we also include political variables instead of individual fixed effects as they are usually very stable over time. These variables are described later in the text.

<sup>5</sup> We tried specifications including the income from environmental tax revenues (OECD database) and level of CO2 emissions (World Bank database), excluding Korea since the latter variable is not available for this country. These variables were included by lagging them of one year because of obvious simultaneity issues. In all specifications that we tried, the associated coefficients were never significant probably because their effects are already captured by per capita GDP. Complete results are available upon request.

weight matrices based on openness,  $W_{open}$ , and GDP per capita,  $W_{GDPpc}$ , and the 2 spatial weight matrices based on Gabriel neighbors,  $W_{cont}$ , and 3 nearest neighbors,  $W_{nn3}$ . The standardized values for  $W_{open}$  are higher at the beginning of the period while at the end of the period the values for  $W_{nn3}$  are highest. In general, the standardised values for the spatial matrix based on the squared inverse distance  $W_{dinverse}$  and the economic similarity matrix  $W_{simi}$  are the lowest. These results would suggest that immediate proximity matters more for environmental interactions. Interestingly, the evolution over time of Moran's  $I$  statistic follows an inverse pattern of that of the share of environmental expenditures in the GDP: the standardized values decrease until 2010 and then increase again. Furthermore, environmental expenditures are positively and significantly clustered at the beginning and at the end of the period whereas during the period of strong increase of the levels of these expenditures 2005-2010, Moran's  $I$  statistic are not significant. In other words, the levels of environmental expenditures are spatially/economically clustered when the levels are relatively low while the distribution of environmental expenditures is spatially/economically random when these levels are high. These results are similar for the restricted sample (Table 7).

Table 2: Standardised Moran's  $I$  statistics; full sample

Year	$W_{cont}$	$W_{nn3}$	$W_{dinverse}$	$W_{GDPpc}$	$W_{open}$	$W_{simi}$
1995	16.56***	17.74**	9.93**	16.80***	21.42***	7.58*
1996	11.90**	12.56*	7.77*	13.05**	17.58***	3.88
1997	14.70**	14.51**	9.52**	14.91**	19.11***	7.26
1998	13.97**	14.06**	8.66*	13.94**	18.05***	7.04
1999	11.95**	11.78*	8.75*	11.81**	15.73**	6.86
2000	15.94**	18.445**	13.97***	15.20**	19.84***	9.28*
2001	13.23**	13.01*	12.85**	14.46**	16.40***	8.30*
2002	13.81**	13.73**	13.61***	14.61**	16.57***	8.97*
2003	12.56**	11.79*	12.25**	12.86**	15.85**	6.64
2004	11.18*	10.16	9.88**	11.18*	13.94**	5.14
2005	3.01	8.89	4.11	3.46	5.17	0.07
2006	7.05	11.62*	7.97*	6.99	8.11	3.27
2007	3.19	11.18*	6.2	2.77	3.63	1.39
2008	4.13	12.51*	7.59*	3.38	4.14	2.52
2009	2.13	3.5	0.9	4.57	2.13	-2.44
2010	2.18	7.1	-0.24	3.82	2.25	-2.00
2011	15.19**	19.28***	12.04**	14.43**	16.10***	10.11**
2012	18.48***	25.91***	14.60***	17.04***	19.53***	12.70**
2013	13.96**	25.76***	10.68**	13.40**	15.06**	13.02**
2014	7.35	15.79**	4.47	6.76	8.15	8.69*
2015	6.55	14.65**	3.09	6.05	6.64	9.50**
2016	13.95**	25.26***	9.45**	12.64**	14.91**	10.52**
2017	17.62***	29.39***	12.84**	16.53***	19.43***	12.55**

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

We also find evidence for strong spatial dependence as the Pesaran's test of cross-sectional dependence (Pesaran, 2015), based on the correlation coefficients between the observations of each pair of spatial units and where the null hypothesis is that the values are only weakly cross-sectionally dependent, yields a statistic value of 6.143 which is strongly significant. Both weak and strong spatial dependence should therefore be included.

Next, we estimate equations (1) and (3) with all variables (dependent variables and explanatory variables) expressed in log using maximum likelihood. The estimation results for the spatial parameters  $\rho$  and  $\lambda$  are reported in Table (3) for the benchmark spatial autoregressive model (1) and in Table (4) for the spatial autoregressive model with common

factors (3). The associated direct effects for the explanatory variables are respectively in Tables (5) and (6), inference is based on a bootstrapping procedure. Tables (9) and (10) in the appendix provide the information for the restricted sample.

Looking at the results obtained for the coefficient of interest  $\rho$  in the benchmark spatial autoregressive model (Table 3), we see that there is a positive and statistically significant at the 1 % effect of other countries's environmental expenditures on one country's environmental expenditures. In other words, countries tend to increase their environmental expenditure as a response to a rise in environmental expenditure of its neighbors. The coefficients range from 19.50 % with W\_GDPpc to 39.11 % with W\_nn3. Immediate proximity therefore seem to matter most when setting environmental expenditures. However, the coefficient related to W\_simi is up to 36.82%, consistently with a strong mechanism of yarstick competition. Because we saw in the exploratory spatial analysis that the share of environmental expenditures in the GDP tend to be spatially autocorrelated when this share is lower, this result shows the existence of complementarity among OECD countries in determining the level of environmental spending. When including strong cross-sectional dependence under the form of common factors (Table 4), the results and implied hierarchy of autoregressive coefficients are unchanged. For the restricted sample to European countries (Tables 9 and 10) the estimated autoregressive coefficient for W\_simi is even higher (40.33%). Overall, our spatial interaction results are in line with the limited literature on public spending interactions among governments (Deng et al., 2012; Ercolano and Romano, 2017; Ermini and Santolini, 2010).

Table 3: Estimation results for the benchmark spatial autoregressive model; full sample

<i>Dependent variable: log(ENVPROT)</i>						
	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
$\rho$	0.2837*** (0.0827)	0.3911*** (0.0585)	0.2165*** (0.0812)	0.1950** (0.0795)	0.2635*** (0.0758)	0.3682*** (0.0553)
$\lambda$	-0.6117*** (0.0827)	-0.7065*** (0.0808)	-0.3783*** (0.0817)	-0.5133*** (0.0806)	-0.5144*** (0.0811)	-0.5739*** (0.0515)

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

Table 4: Estimation results for the spatial autoregressive model with common shocks; full sample

<i>Dependent variable: log(ENVPROT)</i>						
	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
$\rho$	0.2833*** (0.0806)	0.3920*** (0.0604)	0.2176*** (0.0819)	0.2079** (0.0836)	0.2649*** (0.0770)	0.3740*** (0.0559)
$\lambda$	-0.6109*** (0.0830)	-0.7053*** (0.0812)	-0.3798*** (0.0822)	-0.5233*** (0.0836)	-0.5151*** (0.0820)	-0.5768*** (0.0518)

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

Other variables also have an impact on the environmental expenditures (Tables 5 and 6) with estimated direct effects of all explanatory variables being very similar whether or not common factors are included.

Population and unemployment rate can be interpreted as indicators capturing expenditure needs with a negative impact on environmental expenditures. Indeed, larger population

and/or higher unemployment rate tend to (re)-direct spending toward social expenditures rather than environmental expenditures in order to reduce expenditure burden. Our findings are consistent with our expectation as the estimated direct effects for these two variables are significant and negative. Our results imply that the countries with larger population and higher unemployment rate tend to spend significantly less for the environment. With respect to the impact of population, our finding is in line with Davis (2013).

The intuition underlying the impact of population structure on environmental expenditures is different. On the one hand, including the share of the young and the elderly populations is based on the idea that these population categories are more vulnerable to environmental degradation and therefore more sensitive to measures taken by public authorities. To this end, assuming that OECD authorities are benevolent, then a larger share of young and elderly people can impact positively the amount of environmental expenditures decided by the governments. On the other hand, larger shares of these specific populations might also induce higher social expenditures and consequently less spending in favor of the environment. Our results favor the second interpretation since the estimated direct impacts corresponding to both the shares of young and elderly population are significantly negative. Tang (2019) finds the same results for the impact of population structures on a similar sample of OECD countries.

Regarding the other variables, GDP per capita has a positive and significant impact on environmental expenditures, which indicates growing awareness for these types of expenditures with economic development. Furthermore, we find, as expected, a significant and positive impact of the share of urban population on environmental expenditures. Indeed, a higher share of urban population means in particular more traffic to meet the needs in transport-related mobility, and therefore more pollution. Currently, OECD countries are positioned at the forefront of environmental defenders in order to improve air quality, reduce environmental degradation and restore biodiversity. This result is in line with Deng (2012). Conversely, the share of active population remains statistically insignificant.

Finally, including a measure of the degree of openness, here of a country in the analysis of environmental policy is relevant as it allows to control for the impact of the country's exposure to international trade on environmental policy. A positive sign implies that the more the country is open to the outside, the more stringent its environmental policy (the higher is the amount of environment expenditures). Contrary to Davis (2013), the estimated direct effect or our proxy measure of openness, i.e. trade costs, is significant and positive in most our specifications.

Table 5: Direct effects for the benchmark spatial autoregressive model;  
full sample

<i>Dependent variable: log(ENVPROT)</i>						
Variable	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
log(pop)	-1.384***	-1.088***	-1.403***	-1.525***	-1.293***	-1.275***
log(pop0014_pop)	-1.267***	-1.160***	-1.057***	-1.258***	-1.208***	-1.129***
log(popsup65_pop)	-0.424**	-0.364*	-0.711***	-0.482***	-0.408**	-0.406**
log(pop_active_pop)	-0.012	0.361	-0.216	-0.005	0.25	-0.855***
log(pop_urb_pop)	1.184**	1.649***	1.235**	1.259*	0.843	1.750***
log(trade_costs)	0.199	0.298***	0.274**	0.321**	0.262**	-0.005
log(gdppc_constant)	0.240**	0.199*	0.296***	0.349***	0.270***	-0.003
log(unemp_rate)	-0.098***	-0.086**	-0.064	-0.096	-0.081**	-0.135***

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

Table 6: Direct effects for the spatial autoregressive model with common shocks;  
full sample

Dependent variable: log(ENVPROT)						
Variable	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
log(pop)	-1.387***	-1.074***	-1.038***	-1.548***	-1.298***	-1.297***
log(pop0014_pop)	-1.270***	-1.158***	-1.234***	-1.266***	-1.210***	-1.144***
log(popsup65_pop)	-0.425**	-0.37*	-0.610***	-0.472***	-0.408**	-0.402**
log(pop_active_pop)	-0.016	0.385	-0.09	0.015	0.248	-0.868**
log(pop_urb_pop)	1.186**	1.632***	1.564***	1.277**	0.839	1.761***
log(trade_costs)	0.200*	0.298**	0.145*	0.318*	0.263***	-0.009
log(gdppc_constant)	0.237**	0.202**	0.357***	0.334***	0.264***	-0.011
log(unemp_rate)	-0.098***	-0.078**	0.003	-0.097	-0.082**	-0.140***

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

As a robustness check, we also include political variables instead of individual fixed effects as they are usually very stable over time. From the Freedom House database, we include PR, a variable capturing the extent of political rights.<sup>6</sup> The Database of Political Institutions also contains a large range of political variables that we considered. Among them, the variable gov1rlc describing the political orientation of the government had a significant impact in our results. This variable is a categorical variable with gov1rlc1 (right government) as the reference, gov1rlc2 for center government and gov1rlc3 for left governments. The presence and nature of interactions is not modified by the introduction of these variables (Table 7). Table (8) displays the direct effects for the former explanatory variables and the political variables. With respect to political variables, we find the stronger the political rights (PR), the higher the environmental expenditures. Regarding country policy orientation, our results suggest that a left-wing government tends to spend significantly more than a right-wing government on the environment. While we also find that there is no significant difference between a centrist government and a right-wing government. These results imply that left-wing policy-makers are more environmental-sensitive than right-wing ones, *ceteris paribus*.

Table 7: Estimation results for the spatial autoregressive model with political variables;  
full sample

Dependent variable: log(ENVPROT)						
	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
$\rho$	0.1606** (0.0745)	0.2849*** (0.0614)	0.2480*** (0.0681)	0.0873 (0.1096)	0.2039* (0.0827)	0.3110*** (0.0531)
$\lambda$	-0.3881*** (0.116)	-0.5182*** (0.0864)	-0.4097*** (0.0713)	-0.2623* (0.1202)	-0.3723*** (0.0949)	-0.5624*** (0.0518)

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

<sup>6</sup> This political variable range between 1 to 7, with 1 representing the greatest degree of freedom and 7 the smallest degree of freedom. In other words, countries with a rating of 1 enjoy a wide range of political rights, including free and fair elections while countries with a rating of 7 have few or no political rights because of severe government oppression, sometimes in combination with civil war. We also considered a variable capturing civil liberties but the associated coefficient was never significant.



Table 8: Direct effects for the spatial autoregressive model with political variables;  
full sample

Dependent variable: log(ENVPROT)						
Variable	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
log(pop)	-0.770***	-0.711***	-0.988***	-0.795***	-0.766***	-0.910***
log(pop0014_pop)	-1.267***	-1.310***	-1.126***	-1.071***	-1.306***	-1.189***
log(popsup65_pop)	-0.664**	-0.887***	-0.665***	-0.651**	-0.720***	-0.560**
log(pop_active_pop)	-0.749	-0.678	-1.004**	-0.739	0.52	-1.403***
log(pop_urb_pop)	1.075**	1.670***	1.709***	0.884*	0.926	1.963***
log(trade_costs)	0.398***	0.246**	0.321***	0.454***	0.380***	-0.088
log(gdppc_constant)	0.239*	0.215	0.198*	0.353**	0.174	-0.005
log(unemp_rate)	-0.078**	-0.079**	-0.072**	-0.056	-0.070*	-0.136***
PR	0.253***	0.266***	0.258***	0.279***	-0.237**	-0.257***
gov1rlc2	-0.052	-0.075	-0.041	-0.048	-0.060*	-0.008
gov1rlc3	0.074***	0.070***	0.081***	0.071***	0.072***	-0.056**

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

## 6 Conclusion

In this study, static spatial panel data models with weak and strong cross-sectional dependence are estimated to address the question of whether OECD countries engage in strategic interactions regarding environmental expenditures. Based on a panel dataset of 28 OECD countries over the period 1995-2017, clear evidence has been found in favor of significant and positive spatial interaction. In other words, countries act strategically regarding environmental spending by providing more environmental expenditure as a response to the increase of environmental expenditure of their neighboring, whether geographically or economically, countries. This mimicking behavior can compromise the determination of the optimal level of environmental protection spending. Indeed, countries mimic each other's environmental policies which could lead to similar environmental quality along the spatial dimension. Furthermore, if environmental performance is judged by consumers by making comparisons among countries, they may adjust their own environmental performance in response to that of other countries (yardstick competition). We also find that socio-demographic factors influence environmental expenditures. In particular, our results suggest that the most populous countries or those with high unemployment tend to spend less on the environment while countries with a large urban population set higher levels of environmental expenditures. Finally, a significant contribution of this study is related to the integration of strong dependence via common factors. Our results remain robust to their inclusion.

The contributions of our study can be summarized in three main points. Firstly, by using spatial econometric methods, we were able to analyze the strategic behavior of countries in environmental spending, a result that is robust to the inclusion of various sets of variables and strong dependence via common factors. Secondly, it allows to draw lessons on the potential negative effects of mimicking behavior of countries with respect to environmental policy. Finally, this work should incite public authorities to integrate these spatial interactions in environmental spending when deciding public policies in order to identify levers conducive for sustainable development.

We hope that this study triggers other research on the determinants of environmental

expenditures. There is indeed a need to facilitate international comparisons in environmental expenditure decisions by highlighting countries behaviors. Also, it may assist in the development of more effective environmental policies and regulations including national and regional budgetary decisions and the design of economic and administrative instruments for environmental protection. Indeed, such studies provide policymakers with indicators and economic mechanisms to monitor these determinants and interactions for strategic planning and policy analysis to identify more sustainable paths of development.

We faced some limitations while conducting this analysis. First, missing data for our dependent variables did not allow us to consider the full sample of OECD countries. Second, while we mitigate the issue by considering averages, our economic weights are probably endogenous. The results obtained with these weights remain however consistent with those obtained with exogenous matrices. It would also be interesting to include middle income, low income countries and climate affected countries and perform quantile regressions to investigate the outcomes for various conditional quantiles of environmental expenditure (see You et al., 2015 for an application focusing on the link between democracy and carbon dioxide emissions). Currently however, harmonized panel data on environmental expenditure are still lacking outside OECD countries.

## References

- Brueckner, J.K. (2003). Strategic interaction among governments: An overview of empirical studies. *International Regional Science Review*, 26(2): 175—188.
- Chen J.Y. (2015). When the wind blows: Spatial spillover effects of urban air pollution. *Journal of Environmental Planning and Management*, 62(8): 1359—1376.
- Chen, S., Song, Y., Ding, Y., Qian, X., and Zhang, M. (2019). Research on the strategic interaction and convergence of china's environmental public expenditure from the perspective of inequality. *Resources, Conservation U Recycling*, 145: 19—30.
- Chudik, A., Pesaran, M., and Tosetti, E. (2011). Weak and strong cross-section dependence and estimation of large panels. *The Econometrics Journal*, 14: C45—C90.
- Davies, R.B., and Naughton H.T. (2014). Cooperation in environmental policy: A spatial approach. *International Tax and Public Finance*, 21(5): 923—954.
- Deng, H., Zheng, X., Huang, N., and Li, F. (2012). Strategic interaction in spending on environmental protection: spatial evidence from Chinese cities. *China & World Economy*, 5: 103—120.
- Ercolano, S. and Romano, O. (2018). Spending for the environment: General government expenditure trends in Europe. *Social Indicators Research*, 138, 1145—1169.
- Fingleton B., Le Gallo J. (2009) Endogeneity in a spatial context, in: Páez A., Le Gallo J., Dall'ërba S., and Buliung R. (Eds.) *Progress in Spatial Analysis: Theory and Computation, and Thematic Applications*, Springer-Verlag Berlin, 59—73.
- Fredriksson, P.G., List, J.A., and Millimet, D.L. (2004). Chasing the smokestack: strategic policymaking with multiple instruments. *Regional Science and Urban Economics*, 34: 387— 410.
- Fredriksson, P.G., and Millimet, D.L. (2002). Strategic interaction and the determination of environmental policy across US states. *Journal of Urban Economics*, 51(1): 101—122.
- Galinato, G.I., and Chouinard, H.H. (2018). Strategic interaction and institutional quality determinants of environmental regulations. *Resource and Energy Economics*, 53: 114—132.
- Gordon R.H. (1983). An optimal taxation approach to fiscal federalism. *The Quarterly Journal of Economics*, 98(4): 567—586.
- Holzinger, K., and Sommerer, T. (2011). 'Race to the bottom' or 'race to Brussels'? environmental competition in Europe. *JCMS: Journal of Common Market Studies*, 49(2): 315—339.
- Kelejian, H.H., and Piras, G. (2014). Estimation of spatial models with endogenous weighting matrices, and an application to a demand model for cigarettes. *Regional Science and Urban Economics*, 46: 140—149.
- Konisky, D.M. (2007). Regulatory competition and environmental enforcement: Is there a race to the bottom? *American Journal of Political Science*, 51(4): 853—872.
- LeSage, J., and Pace, R.K. (2009). *Introduction to Spatial Econometrics*. Chapman and Hall CRC.
- Levinson, A. (2003). Environmental regulatory competition: A status report and some new evidence. *National Tax Journal*, 56(1): 91—106.

- Millimet, D.L. (2003). Assessing the empirical impact of environmental federalism. *Journal of Regional Science*, 43(4): 711—733.
- Millimet, D.L. (2014). Environmental federalism: a survey of the empirical literature. *Case Western Reserve Law Review*, 64(4): 1669—1757.
- Pearce, D., and Palmer, C. (2001). Public and private spending for environmental protection: a cross-country policy analysis. *Fiscal studies*, 22(4):403—456.
- Pesaran, M. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica*, 74: 967—1012.
- Pesaran, M. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, 34(6-10): 1088—1116.
- Shi, W.O. and Lee, L.-F. (2018). A spatial panel data model with time varying endogenous weights matrices and common factors. *Regional Science and Urban Economics*, 72: 6—34.
- Tang, S.X. (2017). Competition or coordination: Strategic environmental policymaking across OECD countries. mimeo.
- Wilson, J.D. (1999). Theories of tax competition. *National Tax Journal*, 52(2): 269—304.
- Woods, N.D. (2006). Interstate competition and environmental regulation: A test of the race-to-the-bottom thesis. *Social Science Quarterly*, 87(1): 174—189.
- You, W.H., Zhu, H.M., Yu, K., and Peng, C. (2015). Democracy, financial openness, and global carbon dioxide emissions: heterogeneity across existing emission levels. *World Development*, 66: 189—207.

## 7 Appendices

Figure 3: Gabriel contiguity weight matrix

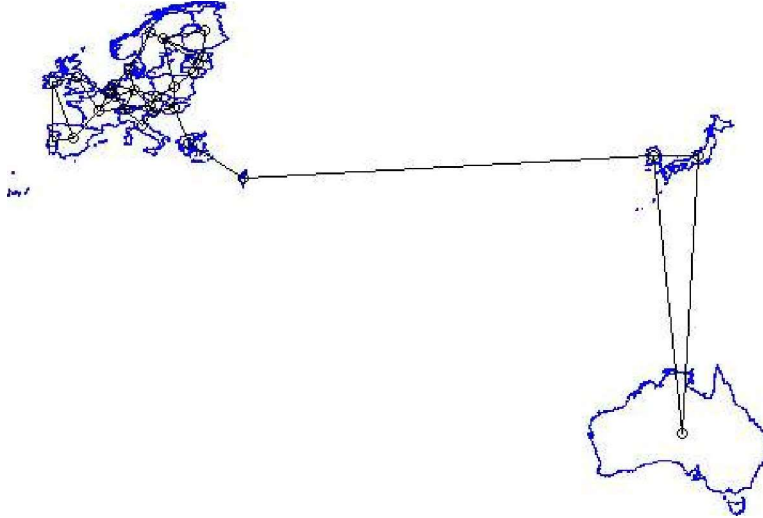


Figure 4: 3 nearest neighbors weight matrix

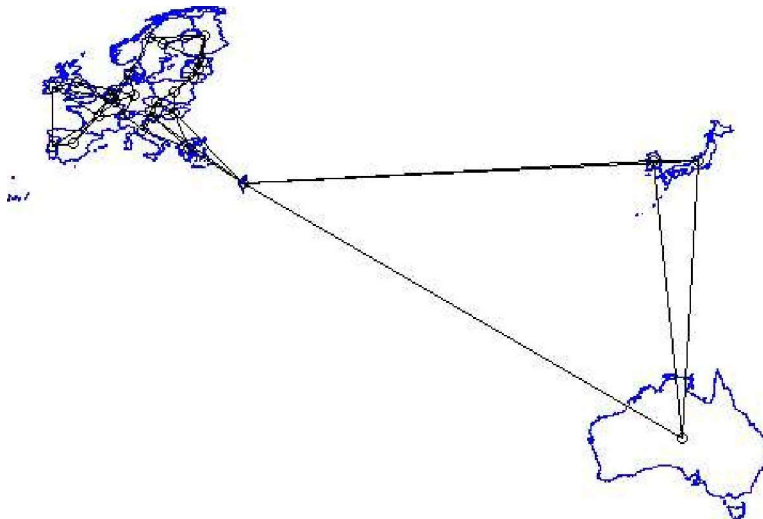


Table 7: Standardised Moran's I statistics; restricted sample

Year	W_cont	W_nn3	W_dinverse	W_GDPpc	W_open	W_simi
1995	18.11***	18.90***	10.940**	19.18***	22.61***	8.90*
1996	13.60**	13.73**	8.78*	15.37***	18.70***	5.38
1997	16.65***	16.11**	10.80**	17.72***	20.80***	8.80*
1998	15.83***	15.65**	9.77**	16.69***	19.64***	8.57*
1999	14.25**	13.89**	10.12**	14.95**	17.67***	8.84*
2000	19.09***	21.73***	15.70***	19.42***	22.69***	12.05**
2001	15.77**	15.46**	14.92***	17.78***	18.52***	10.38**
2002	15.76**	15.44**	14.52***	17.27***	18.20***	10.75**
2003	13.90**	13.28**	12.64**	15.08**	16.94***	7.99*
2004	12.40**	12.51*	10.35**	13.25**	15.23**	6.23
2005	4.03	11.53*	4.53	5.43	5.91	1.25
2006	7.05	13.66**	7.05	7.51	8.4	3.68
2007	2.09	12.20*	4.4	2.37	2.97	1.15
2008	3.1	13.12**	5.59	2.93	3.56	2.38
2009	-1.07	3.67	-3.33	2.47	-0.15	-4.28
2010	0.36	7	-1	1.94	1.21	-3.64
2011	13.78**	19.33***	12.31**	12.48**	15.62***	8.25*
2012	16.73***	24.77***	14.40***	14.97**	18.47***	10.78**
2013	13.03**	24.83***	11.16**	11.90**	14.67**	11.51**
2014	7.48	16.21**	5.35	6.54	8.55*	8.369034*
2015	5.86	14.68**	3.75	4.98	6.62	8.26*
2016	12.26**	24.00***	8.24*	10.42*	13.55**	9.06*
2017	15.94***	27.38***	11.70**	14.50**	18.04***	11.08**

Note:

Table 8: Descriptive statistics for the dependent and the explanatory variables; restricted sample

Variable	Description	N	Mean	St. Dev.	Min	Max
Envprot	Environmental protection (% GDP)	552	0.723	0.307	0.091	1.698
pop	Population	552	19,577,708	23,516,068	408,625	82,657,002
pop0014_pop	Share of pop below 14 (%)	552	0.168	0.021	0.132	0.243
popsup65_pop	Share of pop above 65 (%)	552	0.163	0.023	0.105	0.225
pop_active_pop	Share of active pop (%)	552	0.489	0.039	0.39	0.584
pop_urb_pop	Share of urban pop (%)	552	0.734	0.108	0.506	0.98
trade_costs	Trade costs	552	1.25	0.53	0.26	2.996
gdppc_constant	Constant GDP per capita (\$)	552	38,072.68	23,262.41	5,139.302	111,968.4
unemp_rate	Unemployment rate (%)	552	8.42	4.413	1.805	27.466

Table 9: Estimation results for the benchmark spatial autoregressive model; restricted sample

<i>Dependent variable: log(ENVPROT)</i>						
	<b>W_cont</b>	<b>W_nn3</b>	<b>W_dinverse</b>	<b>W_GDPpc</b>	<b>W_open</b>	<b>W_simi</b>
$\rho$	0.3741*** (0.0692)	0.4416*** (0.0550)	0.3213*** (0.0660)	0.2061* (0.0810)	0.3288*** (0.0642)	0.4033*** (0.0513)
$\lambda$	-0.6582*** (0.0742)	-0.7431*** (0.0769)	-0.5023*** (0.0658)	-0.4196*** (0.0890)	-0.5669*** (0.0724)	-0.6172*** (0.0471)

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01

Table 10: Estimation results for the spatial autoregressive model with common shocks; restricted sample

<i>Dependent variable: log(ENVPROT)</i>						
	<b>W_cont</b>	<b>W_nn3</b>	<b>W_dinverse</b>	<b>W_GDPpc</b>	<b>W_open</b>	<b>W_simi</b>
$\rho$	0.3870*** (0.0751)	0.4394*** (0.0555)	0.3223*** (0.0656)	0.2496* (0.0864)	0.3606*** (0.0640)	0.4043*** (0.0522)
$\lambda$	-0.6768*** (0.0730)	-0.7411*** (0.0773)	-0.5059*** (0.0653)	-0.4657* (0.0908)	-0.5966*** (0.0710)	-0.6173*** (0.0475)

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01