Competition or Cooperation: Strategic Environmental Policymaking Across OECD Countries

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October 24, 2019

Abstract

This paper estimate OECD countries' strategic interaction, which is the effect of other countries' changes in environmental policies on one country's environmental policy strictness. Considering that the strategic interaction can be caused by distinct mechanisms, such as the cooperation, competition for the investment, and pollution spillovers, this paper also disentangles different mechanisms. This paper employs a new index on measuring countries' environmental policy stringency and uses spatial econometrics with Instrumental Variables. The panel dataset includes 26 OECD countries for the period 1990 to 2012. I find that there is a positive and statistically significant strategic interaction on environmental policy. The strategic responses in environmental policymaking are more evident among EU countries than others, which indicates cooperative efforts. Interjurisdictional competition and pollution spillovers appear to play limited roles in causing the interaction.

Keywords: Environmental Policy; Interjurisdictional Competition; Strategic Interaction; International Cooperation

JEL Classification Numbers: H87 H77 Q58

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1 Introduction

Given increasing globalization, the possibility exists that it sparks a "race to the bottom" when governments set policies. A "race to the bottom" implies that governments may choose low corporate tax rates, lax labor standards, and lax environmental standards to compete for investment. Such a possibility raises substantial concerns that public policies may not achieve social welfare maximization. Studies of public policy have found reductions in corporation tax rates and labor standards which are consistent with the "race to the bottom" hypothesis (Devereux et al., 2008; Davies and Vadlamannati, 2013; Olney, 2013). However, regarding environmental policymaking, the causal empirical evidence among countries is still lacking.

In the literature (Millmet, 2014; Carruthers and Lamoreaux, 2016; Genschel and Schwarz, 2011), a common way to study the "race to the bottom" hypothesis is to examine its one prediction, whether jurisdictions engage in strategic policymaking. To be more specific, the strategic policy interaction is the effect on one jurisdiction's environmental policy caused by other jurisdictions' changes in environmental policies. But this effect can be caused by distinct mechanisms. Besides the interjurisdictional competition that would potentially cause "race to the bottom" (Oates and Schwab, 1988; Cerny 1994; Drezner 2001; Murphy 2006)[1], other mechanisms include international coordination, pollution spillovers, and others (Kennedy, 1994; Markusen et al., 1995; Besley and Case, 1995; Brueckner, 2003). If the observed strategic interaction is not mainly caused by interjurisdictional competition, without "race", the "race to the bottom" would not become a serious issue. However, there are very few empirical papers in the environmental policy literature that disentangle the mechanism behind the effect and provide empirical evidence on the potential causes. In addition, most of papers in the literature estimate environmental interaction at the subnational level, such as across U.S. states (see Fredriksson and Millimet 2002; Fredriksson et al. 2004; Levinson 2003). The evidence on countries is limited. This paper aims to fill these gaps in the literature. This paper contributes to the literature by directly estimating the causal effect of other countries' changes in environmental policies on one country's policymaking. Considering that this effect can be caused by distinct mechanisms, this paper also unpacks different underlying mechanisms behind the interaction.

In the estimation of causal effect of other countries' policy changes, I use instrument variables to deal with the endogeneity issue due to the reverse causation. I use other countries' political characteristics as instruments for the environmental policies. Regarding the distinct mechanisms, the first mechanism this paper explores is the possible coordination

[1] There are some excellent surveys on tax competition works (Wilson, 1999; Wilson and Wildasin, 2004; Keen and Konard, 2011; Boadway and Tremblay, 2012).

and cooperation across countries in the European Union (EU). I separate observations based on whether countries have EU membership and estimate the strategic interactions among EU countries and non-EU countries respectively. I also explore the effect of adopting the euro as a common currency on the policy interdependence among EU countries. To differentiate the interactions caused by interjurisdictional competition, I separate observations based on whether countries have tight capital control (Devereux et al., 2008). Tight capital control restrains capital mobility, and thus the incentive to compete by changing policy in response to another country's policy change is greatly diminished. If interjurisdictional competition plays a major role in the strategic interaction, we would expect different interactions among countries without capital control than among countries with capital control. The third potential mechanism of strategic interaction, pollution spillovers across nations, is also explored. When pollution spillovers exist, other jurisdictions' environmental policies which have an impact on their own countries' pollution directly affect the receiving jurisdiction's environmental quality. When the receiving jurisdiction takes this spillover effect into account in the policy making (Kennedy, 1994; Markusen et al., 1995), transboundary spillovers bring about a strategic interaction. To separate the interaction caused by transboundary spillovers, I study the spillovers of oxidized sulphur and control for the pollution transported from other jurisdictions. After controlling for pollution spillovers, the coefficient on others' environmental policies does not estimate the strategic interaction through the spillovers mechanism[2].

I find that a weighted average stringency of environmental policies in other countries has a positive and statistically significant causal impact on the home country's policy stringency. The coefficient is 1.064 when GDP per capita is used as the weight. As with the analysis on EU and non-EU countries, I find that EU countries' environmental policies have a positive impact on both other EU and non-EU countries. Moreover, when the home country is in the EU, it reacts more to other EU countries than to non-EU countries. The strong policy interaction across EU countries may indicate the coordination efforts. Also, this strategic interaction becomes stronger after adopting the euro as a common currency. Regarding differentiating interjurisdictional competition, empirical results show the strategic interaction among countries without tight capital control is not statistically different from the interaction among countries with capital control. This result indicates that interjurisdictional competition plays a limited role behind the environmental policy interdependence. Regarding transboundary spillovers, the results show that pollution from other countries has a

[2]One related paper is Murdoch, Sandler, and Vijverberg (2003), which explores the effect of transboundary pollution spillovers on environmental treaty participation using 25 European countries' cross-section data. My paper combines the method in Murdoch et al. (2003) and spatial econometrics to disentangle the interaction brought about by transboundary spillovers.

positive effect on the receiving country's environmental policy stringency, indicating that cross-border spillovers play a role in the environmental policymaking process. The scale of impact of pollution spillovers on environmental policy interaction is relatively small, though.

It is important to study strategic interactions among countries besides among subnational governments, such as U.S. states. Countries play an important role in combating pollution, reducing emissions and promoting environmental protection. Moreover, the behavior of countries may show different interaction pattern for the following reasons. First, countries have more discretion in deciding environmental policies as compared with subnational governments. There is no powerful central authority for countries as there is when considering state governments. Even though there are some supranational organizations, such as the European Union, the delegation of environmental authority is mainly of member countries (Principle of Subsidiarity). Second, the movement of resources, such as capital, has more friction across countries than within a country because of different cultures, languages, legal environments, and possible trade barriers. The increase in movement resistance may affect the reaction of capital flows with respect to environmental policy, which in turn affects the interjurisdictional competition pattern. Finally, political considerations, such as national images, responsibilities, and pressures from other countries[3] could also play a role in policy decisions at the country level.

One reason for the limited national level analysis of environmental policy is the lack of measure of environmental policy which is appropriate and comparable across countries and has longitudinal data. Studies tend to use proxies to measure environmental policy stringency. For example, Kellenberg (2009) uses survey questions from the Global Competitiveness Report (GCR), which were answered by business executives. Davies and Naughton (2014) use the number of environmental treaties a country has ratified as a measure of environmental policy. Cole et al. (2006) and Cole and Fredriksson (2009) use grams of lead content per gallon of gasoline as a proxy, while Mulatu et al. (2010) employ an Environmental Sustainability Index. These indicators tend to measure policy stringency in one dimension, and also lack consistency[4]. In this paper, I use a new composite index, namely Environmental Policy Stringency (EPS) developed by the OECD (Botta and Kozluk, 2014). This index attempts to capture the multidimensionality of regulations and improve cross-country comparisons. Both market-based and non-market-based policy instruments are considered[5].

[3]One example is that after President Trump declared to withdraw U.S. from the Paris Climate Accord on June, 2017, global debates, criticisms even outrages are provoked.

[4]Brunel and Levinson (2013) provide a review and comparison on different measures.

[5]The OECD EPS database contains information on 15 different environmental policy instruments implemented in OECD countries, which include both Non-Market Based (NMB) and Market Based (MB) instruments. EPS has been used to in other papers, such as Albrizio et al. (2016). In addition, the credibility of EPS has been confirmed by comparisons with other measures of environmental policy stringency, such

Differentiating the underlying mechanisms for the strategic interaction helps us to better understand the stringency of environmental policy that is adopted. My empirical results do not support the position that interjurisdictional competition plays a significant role in setting a country's environmental policies. If interjurisdictional competition is limited, the possibility of a "race to the bottom" would not be a serious concern. Carruthers and Lamoreaux (2016) also support this view after a detailed review of the related literature on the environmental regulation competition. The limited impact of interjurisdictional competition on environmental policy stands in contrast with corporate tax interaction; Devereux et al. (2008) find that reductions in equilibrium tax rates can be explained almost entirely by intense competition across countries. The contrasting impact of interjurisdictional competition on environmental policy or corporate taxation could partly explain the distinct trends in the two policies.

There is a possibility that the estimates in this paper are biased by the presence of unobserved shocks, and the results merely demonstrate a co-movement across countries' environmental policies. This paper utilizes several ways to address this. First, I construct instrumental variables for the main independent variable of interest, other countries' environmental policies. I use other countries' political characteristics to construct instruments, and the results of econometric tests confirm the validity and relevance of my instruments. Second, I control for time fixed effects, country fixed effects and country-specific time trend to absorb time-specific common shocks, country permanent characteristics, as well as policy trend that is specific to each country. Third, to confirm the credibility of my estimates, I present a number of specification tests and robustness checks to further probe the validity of the estimates. I utilize four different weighting schemes to construct the weighted average of other countries' environmental policies, and the results of positive strategic interaction are consistent across different weights. Moreover, to check the robustness of estimates, control variables are one-year, two-year, and three-year lagged, respectively. Considering that environmental policy usually changes progressively, I also control for the one-year lagged dependent variable in one robustness check and find that there is still positive strategic interaction across countries. In another robustness check, I recalculate the measure on the environmental policy (EPS) to exclude the potential correlation across countries in the calculation of EPS and find that the positive interaction still exists.

The rest of the paper proceeds as follows: Section 2 provides a theoretical framework for the empirical approach. Section 3 describes both the empirical specifications and data. Results and robustness checks are presented in sections 4 and 5, respectively. Section 6 presents discussions and conclusions.

as Global Competitiveness Report (GCR) responses.

2 The Model

To frame the empirical analysis, this section presents a simple model of a jurisdiction's choice of environmental policy. Governments strategically interact on environmental policy-making due to the existence of interjurisdictional competition and transboundary pollution spillovers. Besides these two mechanisms of strategic policy interaction, another possible mechanism is coordination and cooperation, which is not considered in the current model. However, the model can be easily generalized to incorporate other mechanisms. The main purposes of the model are to provide intuition on how the two mechanisms affect government's policy strategic interactions and provide theoretical foundations for the econometric models.

This model is based on the canonical model of interjurisdictional competition (Oates and Schwab, 1988) and extends Oates and Schwab by considering transboundary pollution spillovers. In this model, the government in each jurisdiction devises environmental policy to maximize local social welfare.

2.1 Social Welfare and Production

Assume there are n jurisdictions. For each jurisdiction, the social welfare is modeled as the utility of a single representative agent, i, who resides in the jurisdiction. This agent get utility from consuming a composite private good, denoted by c_i, and consuming a local public good g_i. This resident also suffers from local environmental damage e_i. The utility can thus be denoted as:

$$u_i(c_i, g_i, e_i; \tilde{X}_i) \tag{2.1}$$

where $\tilde{X}_i$ is a vector of other characteristics of jurisdiction i. The utility function is increasing and concave in c_i and g_i, and it is decreasing and convex in e_i The marginal utilities of the private good and public good are positive, respectively $u_{ic} > 0$ and $u_{ig} > 0$, while the marginal utility of environmental damage is negative, $u_{ie} < 0$. We make no assumptions about the cross-partial. The utility function may differ across jurisdictions.

The production process in jurisdiction i uses capital K_i and some immobile factor, which are assumed to be labor L_i. Assume that all residents work for simplicity. Thus L_i is also the number of residents. Local environmental policy, Q_i also affects local productive activity. Posit that the production function exhibits constant returns to scale. The production function is:

$$\begin{aligned} Y =& F_i(K_i, L_i, Q_i) \\ =& L_i F_i(K_i/L_i, 1, Q_i/L_i) \\ =& L_i f_i(k_i, q_i) \end{aligned} \tag{2.2}$$

where $y = f_i(k_i, q_i)$ is the output per person. k_i denote the amount of capital per person employed in locality i. In the production function, besides capital, the environmental policy also has effect on the output. Take one type of environmental policy, "cap and trade" as example. Assume that local government uses "cap and trade" to regulate emissions. In this case, government sets a total limit on aggregate allowable emissions. The stringency of environmental policy affects the amount of allowable emissions. Larger amounts of allowable emissions means less abatement and higher optimal output for firms and thus higher output per person in local jurisdiction. To simplify the interpretation, let q_i be the total allowable emissions per person in jurisdiction i. Also, assume that the amount of allowable emissions is equal to the amount of actual emissions because environmental law is perfectly enforced and the allowable emission limit is binding.

Let's assume a well-behaved neoclassical production function exhibiting constant returns to scale in all factors, with f_i increasing and strictly concave in the amount of capital and allowable emissions. This means $f_{ik} > 0 > f_{ikk}$ and $f_{iq} > 0 > f_{iqq}$. An increase in q_i raises the marginal product of capital, $f_{ikq} > 0$. The production functions may differ across jurisdictions; the technologies are not necessarily identical.

2.2 Mechanism 1: Interjurisdictional Competition

The n jurisdictions interact with each other. One mechanism behind the interaction is interjurisdictional competition for mobile capital. Governments set policies to compete for capital which is freely mobile among jurisdictions and fixed at the national level. Let $\overline{k_i}$ denote the stock of capital per person with which residents of jurisdiction i are endowed. The allocation of capital satisfies the following capital market clear condition:

$$\sum_i \overline{k_i} * L_i = \sum_i k_i * L_i \tag{2.3}$$

Jurisdictions have an incentive to compete for capital because it contributes to social welfare in two aspects. First, capital is a production factor, and it increases output and therefore local consumption of the composite private good. We know that the total value of private good production is $f_i(k_i)$, and the gross return per unit of capital is $f_{ik}(k_i)$. Thus the total return to the immobile factor, labor, and permitted emissions of production is $f_i(k_i) - k_i f_{ik}(k_i)$, which is labor income of the representative resident. Residents also receive income from their endowment of capital $r\overline{k_i}$, where r is the net return to capital. The private good consumption of the representative resident in jurisdiction i is:

$$c_i = f_i(k_i) - k_i f_{ik}(k_i) + r\overline{k_i} \tag{2.4}$$

The second way through which capital promotes social welfare is that taxes on capital generate government revenue to finance public goods. Local government levies taxes on capital at tax rate t_i and spend government expenditures on the local public good:

$$g_i = t_i k_i \tag{2.5}$$

Since capital contributes to the private goods consumption and public goods provision, governments has an incentive to compete for the capital. And the movement of capital follows the rule that the net return to capital must be equal across jurisdictions in equilibrium:

$$f_{ik} - t_i = r \quad \forall i \tag{2.6}$$

Given the above capital mobility constraint, government in locality i is able to compete for a larger amount of mobile capital through adjusting two policy instruments. One is to reduce tax rate t_i and the other is to increase the allowable emissions q_i to increase f_{ik}, which means lower environmental standard. Since the net return to capital r is affected by other jurisdictions' policies, in order to attract the amount of capital that maximizes its social welfare, each government would strategically set its own policies in response to other jurisdictions' policies. See section 3.1.4 for the formal derivation.

2.3 Mechanism 2: Transboundary Pollution Spillovers

Another mechanism that drives the strategic interaction across jurisdictions is transboundary pollution spillovers. Environmental damage e_i in jurisdiction i is linked to the pollutant emissions not only of those from its own jurisdiction, but also those spilled over from neighboring jurisdictions. From section 3.1.1, we know that the actual pollutant emissions in jurisdiction i is equal to the permitted emissions q_i. Assume that each unit of emission orginated from jurisdiction i deposits α_i percentage in its own jurisdiction. Each unit of emission originated from jurisdiction j deposits β_{ij} percentage to jurisdiction i. Thus, the pollution depositions in jurisdiction i is the sum of those from its own emissions $\alpha_i q_i$ and those transmitted from all other jurisdictions $\sum_{j \neq i} \beta_{ij} q_j$. The environmental damage can be written as a function of pollution depositions:

$$e_i = e_i(\alpha_i q_i + \sum_{j \neq i} \beta_{ij} q_j) \tag{2.7}$$

where $\alpha_i, \beta_{ij} \in [0, 1]$. Assume the environmental damage function e_i to be increasing and strictly convex in the amount of pollution depositions. This means $e_{iq}, e_{iqq} > 0$.

Note that this equation reflects two types of spillovers. One type is represented by $1 - \alpha_i$, which is the fraction of emissions that are not deposited on own locality, meaning the fraction of emissions that spill out to other jurisdictions or public areas (such as public sea). Let's call this type of spillovers "spill-out" for the rest of this paper. The second type is $\sum_{j \neq i} \beta_{ij} q_j$, which reflects neighbors' pollution which flowed into one's jurisdiction. We use "spill-in" to refer to this type.

When transboundary pollution spillovers exist, the environmental quality in jurisdiction i is directly influenced by other jurisdictions' environmental policies. To achieve the optimal level of environmental quality, jurisdiction i thus adjusts its environmental policy based on other jurisdictions' policies; it forms a policy strategic interdependence.

2.4 Strategic Interaction on Environmental Policy

The government in each jurisdiction has discretion on two policy instruments: capital taxation and environmental policy. Given government policies, other resource allocation decisions are made by private-sector agents operating in competitive markets. Governments choose capital tax rate and environmental policies to maximize the equilibrium level of social welfare, that is, the utility of a representative resident.

$$\max_{t_i, q_i} [u_i(c_i, g_i, e_i; \tilde{X}_i)] \tag{2.8}$$

Substituting c_i, g_i, e_i by using private goods consumption (2.4), public goods provision (2.5) and environmental damage function (2.7), respectively, we get

$$\max_{t_i, q_i} [u_i[f_i(k_i) - k_i f_{ik}(k_i) + r\overline{k_i}, t_i k_i, e_i(\alpha_i q_i + \sum_{j \neq i} \beta_{ij} q_j); \tilde{X}_i]] \tag{2.9}$$

The equilibrium allocation of capital and the equilibrium net rate of return r are determined through a system of capital mobility constraints (equation 2.6 for jurisdiction i and similar equations for other jurisdictions) and capital market clearing condition (2.3). The equilibrium capital in jurisdiction i and net rate of return r are thus functions of the vector of capital tax rates $\mathbf{t} \equiv (t_1, ..., t_n)$ and the vector of environmental policies $\mathbf{q} \equiv (q_1, ..., q_n)$. The private goods consumption c_i and public goods consumption g_i, which are functions of capital and net rate of return, are thus also functions of $\mathbf{t}$ and $\mathbf{q}$. We can simplify the objective function as follows:

$$\max_{t_i, q_i} [u_i[V_i(\mathbf{t}, \mathbf{q}), e_i(\alpha_i q_i + \sum_{j \neq i} \beta_{ij} q_j); \tilde{X}_i]] \tag{2.10}$$

where $V(\mathbf{t}, \mathbf{q})$ is a vector of private goods and public goods consumption. The two first order conditions that describe the solution to this local optimization problem are:

$$\frac{\partial u_i}{\partial t_i} = u_{iV} \frac{\partial V_i}{\partial t_i} = 0 \tag{2.11}$$

$$\frac{\partial u_i}{\partial q_i} = u_{iV} \frac{\partial V_i}{\partial q_i} + u_{ie} e_i' \alpha_i = 0 \tag{2.12}$$

where u_{iV} and u_{ie} are first derivatives of utility u_i with respect to goods consumption function V_i and environmental damage e_i, respectively. e_i' is the first derivative of environmental damage over pollution depositions, $e_i' = \frac{\partial e_i}{\partial(\alpha_i q_i + \sum_{j \neq i} \beta_{ij} q_j)}$. The above first order conditions imply that government jointly sets tax rates and environmental policy to maximize local social welfare. Considering that the focus of this paper is on environmental policy, the determination of tax rates will not be discussed here. To control for the interplay of tax rate and environmental policy, in the econometric equation, the corporate tax rate is included as one of the control variables.

The first order condition (2.12) generates the environmental policy reaction function of jurisdiction i. Treating the environmental policies of other jurisdictions, i.e. q_j, as exogenous, the environmental policy in jurisdiction i, q_i, strategically reacts to q_j. The reaction function can be generated through differentiation of first order condition (2.12)[6].

$$\begin{aligned}\frac{dq_i}{dq_j} &= -\frac{u_{iV}\frac{\partial^2 V_i}{\partial q_j \partial q_i} + \frac{\partial u_{iV}}{\partial q_j}\frac{\partial V_i}{\partial q_i}) + (u_{ie}e_i^{''}\beta_{ij}\alpha_i + \frac{\partial u_{ie}}{\partial e_i}e_i^{'}\beta_{ij}e_i^{'}\alpha_i)}{\partial(u_{iV}\frac{\partial V_i}{\partial q_i} + u_{ie}e_i^{'}\alpha_i)/\partial q_i} \\ &= (-\frac{u_{iV}\frac{\partial^2 V_i}{\partial q_j \partial q_i} + \frac{\partial u_{iV}}{\partial q_j}\frac{\partial V_i}{\partial q_i}}{\partial(u_{iV}\frac{\partial V_i}{\partial q_i} + u_{ie}e_i^{'}\alpha_i)/\partial q_i}) + (-\frac{u_{ie}e_i^{''}\beta_{ij}\alpha_i + \frac{\partial u_{ie}}{\partial e_i}e_i^{'}\beta_{ij}e_i^{'}\alpha_i}{\partial(u_{iV}\frac{\partial V_i}{\partial q_i} + u_{ie}e_i^{'}\alpha_i)/\partial q_i}) \\ &= A + B\end{aligned} \tag{2.13}$$

where $e_i^{''}$ is the second derivative of environmental damage e_i over pollution depositions $(\alpha_i q_i + \sum_{j \neq i} \beta_{ij} q_j)$.

As we can see from equation (2.13), there are two parts in the strategic reaction, denoted as A and B. A and B reflect the two reasons why q_i responds to q_j[7]:

- In A, the response is due to q_j having an effect on the private and public goods consumption in jurisdiction i, $V_i(\cdot)$. q_j's impact on $V_i(\cdot)$ is caused through q_j's impact on the amount of capital in jurisdiction i. So the mechanism behind the strategic reaction, part A, is the effect of others' environmental policies on capital, which is Mechanism 1: interjurisdictional competition. The sign of part A is ambiguous since the sign of $\frac{\partial u_{iV}}{\partial q_j}$ is ambiguous.

- Part B indicates the policy reaction that is caused by q_j's impact on environmental damage in locality i, e_i. Due to transboundary pollution spillovers, other jurisdictions' emissions can spill into locality i and affect local environmental damage. The degree of pollution spillovers is parameter β_{ij}. If there is no transboundary spillovers, which means $\beta_{ij} = 0$, then the strategic interaction of part B is also zero. Thus the mechanism behind part B is transboundary pollution spillovers, denoted as Mechanism 2. The sign of part B is also ambiguous. $u_{ie}e_i^{''}\beta_{ij}\alpha_i$ is negative since $u_{ie} < 0$, $e_i^{''}, \beta_{ij}, \alpha_i > 0$. While $\frac{\partial u_{ie}}{\partial e_i}e_i^{'}\beta_{ij}e_i^{'}\alpha_i$ is positive.

Thus, the slope of the reaction function may take either sign and needs to be estimated in the empirical part. There are various factors that have an impact on the magnitude of

[6] Assume implicit function $G(\mathbf{q}) = G(q_i, ..., q_j, ..., q_n) = u_{iV}\frac{\partial V_i}{\partial q_i} + u_{ie}e_i^{'}\alpha_i = 0$, the implicit partial differentiation describes that $\frac{dq_i}{dq_j} = -\frac{\partial G(q_i,q_j)/\partial q_j}{\partial G(q_i,q_j)/\partial q_i}$. Calculation on $\partial G(q_i, q_j)/\partial q_j$ and $\partial G(q_i, q_j)/\partial q_i$ achieves equation (2.13).

[7] Note that the yardstick competition is not considered in this model. However this model can be easily generalized to incorporate the yardstick competition by generalize the utility function as: $u_i(c_i, g_i, e_i; q_{-i}; \tilde{X}_i)$, where q_{-i} is a vector of other jurisdictions' environmental policies. In this case, others' policies have direct impact on i's utility, and the strategic interaction have an additional component to reflect this impact.

the reaction function (2.13). For example, in part A, $\frac{\partial V_i}{\partial q_j}$ indicates the effect of jurisdiction j's environmental policy on jurisdiction i's goods consumption. The larger this effect is, the larger the magnitude of the strategic reaction will be. In part B, β_{ij} is the fraction of pollution emissions that originated from jurisdiction j and transported to jurisdiction i. The higher the degree of the spillovers, the larger policy response will be.

Equation (2.13) shows the environmental policy strategic response of jurisdiction i to jurisdiction j's policy. Similar equations can be applied to the response functions of jurisdiction i to other jurisdictions, such as k. Estimating the reaction function (2.13) is currently impossible due to the lack of data. The empirical work in the literature usually estimates the reaction function $\frac{dq_i}{d\sum_{j\neq i} w_{ij}q_j}$, which is the reaction of jurisdiction i's environmental policy to the weighted average of many other jurisdictions' policies; w_{ij} denotes the weight assigned to locality j by i. $\frac{dq_i}{d\sum_{j\neq i} w_{ij}q_j}$ is a function of equation (2.13) and a vector of weights, $\mathbf{w}$, illustrated as follows:

$$\frac{dq_i}{d\sum_{j\neq i} w_{ij}q_j} = R(\frac{dq_i}{dq_1}, ..., \frac{dq_i}{dq_{i-1}}, \frac{dq_i}{dq_{i+1}}, ..., \frac{dq_i}{dq_n}, \mathbf{w}) \tag{2.14}$$

3 Empirical Strategy and Data

This section describes the estimation specifications and data used for estimating government environmental policy strategic interaction. The econometric equations are based on the discussion in Section 2, which includes estimation on strategic interaction and ways to differentiate different mechanisms behind strategic interaction.

3.1 Estimating Strategic Interaction

To examine the effect of other countries' environmental policies on one country's environmental policy, I use the following econometric equation which is based on the equation (2.14) in Section 2:

$$q_{it} = \delta_1 \sum_{j\neq i} w_{ijt}q_{jt} + \theta X_{it-2} + \alpha_i + \eta_t + Trend_i + \varepsilon_{it} \tag{3.1}$$

The dependent variable, q_{it}, is a measure of environmental policy in country i at time t. $\sum_{j\neq i} w_{ijt}q_{jt}$ represents other countries' environmental policies at time t, known as the "spatial lag" in the literature. It is the weighted average of other countries' environmental policies, within which w_{ijt} is a non-negative weight used to average other countries' policies and is assigned to country j by country i at time t. To easily make a distinction between dependent variable and the spatial lag in the following discussion, I use "home country's environmental policy" to refer to the dependent variable and use "other countries' environmental policies" to represent the spatial lag. X_{it-2} is a vector of time lagged control variables including statutory corporate tax rate. ε_{it} represents idiosyncratic shocks that are uncorrelated across states and over time. Country fixed effects, α_i, time fixed effects, η_t, and country-specific trend, $Trend_i$, are also included to absorb country permanent characteristics, time-specific common shocks, and linear trends specific to each country. The above econometric equation is also known as the "spatial autoregressive model".

Control variables (X_{it-2}) are lagged considering that it takes time for environmental policy to react to changes in one country's social and economic conditions[8]. The lagged control variables could also mitigate potential endogeneity problem that is caused by the impact of environmental policy on social and economic conditions. In the main estimation, control variables are lagged by two years. In the robustness checks, one-year and three-year lagged control variables are used. In choosing the vector of control variables, I control for socioeconomic conditions in a country which has potential to impact residents' policy preferences and policy choice. I thus include the log of per capita GDP (expenditure-side real GDP at chained PPPs in constant 2011 US dollars). A country's exposure to world markets could also affect the environmental policy especially when there is international competition on investment. I include a measure of the economy openness, the sum of exports plus imports relative to GDP, to control for it. The statutory corporate tax rate is included to control for government's interplay of setting tax rate and environmental policy discussed in Section 3. I also control for some demographic variables, including the degree of urbanization, population (in log form), the percent of population that is older than 65, the percent of population that is younger than 14. Considering that young and elderly people may be more vulnerable to pollution, the populations structure could also be a factor that affects one country's environmental policy. Following Boockmann and Dreher (2003) and others, I also control for political conditions which have directly impact on the policymaking. Four political variables are included. The first is democracy, which is the average score of Freedom House's indexes on civil right and political liberty and ranges from 1 (severely limited liberties) to 7 (full liberties)[9]. The second and third variables are government fractionalization, and checks and balances, which are variables from Database of Political Institutions (Beck et al., 2001). Government fractionalization is the probability that two deputies picked at random from among the government parties will belong to different parties. The more parties in

[8]Other studies which use lagged control variables include Davies and Vadlamannati (2013), Olney (2013).
[9]https://freedomhouse.org/

the government there are, the more fractionalized the government is, thus the larger this index is. Checks and balances measures the number of decision-makers whose agreement is necessary before policies can be changed. This variable counts the number of veto players, which is an individual or collective actor who has to agree in order for the legislative status quo to change, adjusting for whether these veto players are independent of each other. The last one is the Political Constraint Index from Henisz (2000), which estimates the extent to which a change in the preferences of any one actor may lead to a change in government policy. Table A.1 in Appendix summarizes variables and data sources.

I employ the Generalized Methods of Moments (GMM) continuously updated (CUE) Instrumental Variables (IV) estimator (Hansen, Heaton, and Yaron, 1996). The estimator includes fixed effects and calculates errors that are robust to arbitrary heteroscedasticity and arbitrary autocorrelation. Besides, research suggests that the finite sample performance of CUE may be superior than two-step GMM. In particular, there is evidence suggesting that CUE perform better than IV/GMM in the presence of weak instrument (Hahn, Hausman, and Kuersteiner, 2004). There are several other issues in the estimation need to be properly addressed, including endogeneity problem, choosing proper weights, and the issue of time fixed effects. The discussion on these issues is as follows.

This paper uses Environmental Policy Stringency Index (EPS) as the measure of environmental policy (Botta and Kozluk, 2014). The EPS index contains information on fifteen different environmental policy instruments implemented in OECD countries, which include both non-market-based and market-based instruments. non-market-based policies include limits to pollutants (SO_x, NO_x, particulate matters and Sulfur Content of Diesel) and government energy-related R&D expenditures as a percentage of GDP. Market-based policies contain feed-in-tariffs (solar and wind)[10], taxes (on CO_2, SO_x, NO_x, and diesel), price on CO_2 trading schemes, renewable energy certificates trading scheme, energy certificate emission trading scheme and the presence of deposit and refund schemes.

3.1.1 Endogeneity Problem

There are several issues regarding the estimation. The first issue is the endogeneity problem associated with the "spatial lag" (other countries' environmental policies). Countries choose their environmental policies simultaneously and take the expectations on other countries' policies into their own policy-making consideration. This implies that the environmental policy of jurisdiction i (dependent variable q_{it}) also has an impact on other

[10] Feed-in tariffs (FITs) are a policy mechanism used to encourage deployment of renewable electricity technologies. A FIT program typically guarantees that customers who own a FIT-eligible renewable electricity generation facility, such as a roof-top solar photovoltaic system, will receive a set price from their utility for all of the electricity they generate and provide to the grid.

jurisdictions' environmental policies (the spatial lag $\sum_{j \neq i} w_{ijt} q_{jt}$). Due to this reverse causation issue, the spatial lag is endogenous. I use instrumental variables (IV) for the spatial lag to address it. The instruments are the weighted average of other countries' political characteristics, $\sum_{j \neq i} w_{ijt} Z_{jt}$. The weighting scheme used to construct instruments, w_{ijt}, is the same as for devising the spatial lag. The political variables that are used to construct instruments include: democracy, checks and balances, and governmental fractionalization.

Two conditions are needed to be satisfied for the instruments to be valid. First, the instruments are exogenous, which means they are not correlated with disturbance ε_{it}. Specifically, the home country's environmental policy (dependent variable q_{it}) is not directly affected by other countries' political environments (the instruments). After controlling for country fixed effects, time fixed effects and various covariates of the home country in the econometric equation, I consider our instruments more likely to be exogenous as other countries' political environments have limited direct impact on the home country's environmental policy. In practice, I conduct overidentification tests, and the Hansen's J statistics can not reject the exogeneity of instrument sets in most specifications. One possible concern is the selection issue, namely, firms and individuals may sort themselves based on other jurisdictions' environmental policies. This concern is also the reason why I do not use socioeconomic and demographic variables as instruments. Due to the selection issue, these socioeconomic variables, also instruments, become functions of the dependent variable, i.e., environmental policies, which makes the instruments endogenous. The sorting issue is of less concern regarding political variables as the cross-country mobility of officials is much more constrained than firms and individuals.

The second condition is that the instruments are correlated with the spatial lag. This means that one country's political characteristics are correlated with its environmental policies. This correlation is relatively intuitive. For example, the degree of democracy in one country has an impact on its policies. Leaders in a democratic country are more dependent on election results for their careers and thus are more likely to deliver popular policies to cater for voters. However, this phenomenon is less likely to happen in a more centralized country. This impact of democracy on policies is also found by Davis and Vadlamannati (2013), who discover that more democratic countries have significantly better labor rights. Other political variables, government fractionalization and checks and balances have a direct impact on a country's policymaking process, which are thus correlated with environmental policies. Empirically, I present the results of weak instrument tests that reject the hypothesis that the instruments are weak.

In the literature, instrumental variables (IV) method is commonly used to address this endogeneity issue as in this paper[11]. Fredriksson and Millimet (2002), Davies and Naughton (2014), and others use this method. Fredriksson and Millimet (2002) choose Z_{jt} to be neighboring states' socioeconomic and demographic characteristics including population, population density, and the degree of urbanization. One concern in using socioeconomic and demographic variables is that these variables may not be exogenous and random over subnational governments. This issue can be partly solved by using political variables to construct instruments since government officials can hardly sort themselves across countries[12]. Olney (2013) uses the strength and political ideology of the ruling party and unionization density as instruments to examine strategic interaction of employment protection policies. Like Olney (2013), I use political variables to construct instruments.

3.1.2 Weighting Schemes

Choosing the proper weighting schemes for the spatial lag is another important issue. To estimate the system, we need to specify the weighting matrix as a priori. The weights assigned to country j by the home country should reflect country j's degree of importance when the home country makes policy decisions. The degree of importance varies with the reasons why the home country reacts to country j's policy change. As discussed above, the potential underlying mechanisms of government policy interaction include interjurisdictional competition, transboundary spillovers, yardstick competition and international coordination.

In this paper, I use four different weighting schemes to reflect different mechanisms. In the first weight, I use GDP per capita (GDPPC) to construct it. The weight country i assigned to country j is $w_{ijt} = \frac{GDPPC_{jt}}{\sum\limits_{k \neq i} GDPPC_{kt}}$. When the home country uses environmental policy to compete for mobile resources, the more competitive the two countries are in attracting capital, the more weight that should be assigned. Countries with higher GDP per capita may have a larger influence on the capital movement considering that Foreign Direct Investment (FDI) may be attracted to higher-skilled and/or wealthier markets.

The second weighting scheme is constructed by using the variable, openness. $w_{ijt} = \frac{Openness_{jt}}{\sum\limits_{k \neq i} Openness_{kt}}$. Openness is the sum of exports plus imports relative to GDP, which is a common proxy for the inverse of trade costs in the empirical FDI literature. Openness has an impact on the movement of capital. As discussed by Blonigen (2005), horizontal FDI takes place to avoid trade costs.

[11]Another method is the maximum likelihood methods (Anselin, 1988). Case, Rosen, and Hines (1993), Murdoch, Rahmatian, and Thayer (1993), Besley and Case (1995), Murdoch, Sandler, and Sargent (1997) and others use this method. Anselin (1988) provides detailed discussion on this method.

[12]Dahlberg and Edmark (2008) solve this issue by employing a policy intervention in Sweden as IV to estimate the strategic interaction on the welfare benefit levels.

I also use similarity of income per capita to capture the similarity among countries and construct weights (following Case, Rosen and Hines, 1993). Similarity of income per capita is measured as the inverse of income per capita difference $1/(|inc_{jt} - inc_{it}|)$, where inc_{jt} is the income per capita of country j. The weights are constructed as $w_{ijt} = \frac{1/(|inc_{jt}-inc_{it}|)}{\sum\limits_{k\neq i} 1/(|inc_{kt}-inc_{it}|)}$. This weights take the mechanism of yardstick competition into consideration. When the home country makes environmental policy mainly due to voters' pressure caused by yardstick competition, countries that have more similar conditions would have larger impact on voter's preferences, and thus should be assigned with higher weights.

Besides the above weighting schemes, I also use the simple average weighting scheme $w_{ijt} = \frac{1}{n-1}$, where $n-1$ is the number of countries besides the home country. In sum, this paper uses four alternative weighting schemes to construct the spatial lag, which are GDP per capita, openness, similarity of income per capita, and simple average. These weighting schemes intend to capture other countries' degree of importance when the home country makes environmental policies in terms of different aspects. While since we are unable to measure the degree of importance precisely and comprehensively, I construct different weighting schemes. And the results of using different weighting schemes can serve as a comparison and robustness checks to each other.

3.1.3 Time Fixed Effects

Another issue is the time fixed effects. It is not feasible to include every year dummies to absorb the year-specific shocks that are common to all countries. This is because of the construction of spatial lag. Take the uniform weights case as an example; the spatial lag is other countries' simple average of environmental policies $\sum\limits_{j\neq i} w_{ijt}E_{jt} = \frac{\sum\limits_{j\neq i} E_{jt}}{n-1}$, which can be rewritten as $\frac{\sum\limits_{j\neq i} E_{jt}}{n-1} = \frac{\sum\limits_{j} E_{jt}-E_{it}}{n-1} = \frac{\sum\limits_{j} E_{jt}}{n-1} - \frac{E_{it}}{n-1}$. In a certain year, $\frac{\sum\limits_{j} E_{jt}}{n-1}$ is fixed across countries; if we include every year dummies in the regression to average out the common part across countries, $\frac{\sum\limits_{j} E_{jt}}{n-1}$ would be averaged out, and only $-\frac{E_{it}}{n-1}$ is used for estimating the coefficient of spatial lag. And the coefficient of spatial lag on the home country's environmental policy E_{it} is thus $-\frac{1}{(n-1)}$ by construction. It is not a proper estimate of the strategic interaction. This issue has also been recognized by Devereux et al. (2008), Davies and Vadlamannatid (2013) and others. To control for the time fixed effects without bringing about the above issue, this paper includes both a country-specific time trend and a set of three-year period dummies in the regression.

3.2 Disentangling Different Mechanisms

Besides estimating an overall degree of strategic interaction across countries, I also differentiate the distinct underlying reasons of strategic interaction. The specifications that differentiate the coordination among EU countries, interjurisdictional competition, and transboundary pollution spillovers are presented.

3.2.1 To Differentiate the Coordination

To disentangle the strategic interaction that is brought about by the coordination among countries, particularly among EU countries, I explore the different interaction patterns between EU and non-EU countries. There are noticeable differences between countries holding EU membership and countries that do not. Countries in the EU enjoy a single market with almost free movement of capital, goods, services, and people. This mobility is further enhanced with the establishment of the Euro area (Eurozone) in 1999. Moreover, there have been substantial efforts on environmental policy coordination across countries in EU, especially since the adoption of the First Environmental Action Programme in 1973.

I use the following econometric equation to estimate the different strategic interaction patterns:

$$\begin{aligned} q_{it} = \delta_1^1(EU_{it})q_{-it}^{EU} + \delta_1^2(EU_{it})q_{-it}^{NEU} + \delta_1^3(1-EU_{it})q_{-it}^{EU} + \delta_1^4(1-EU_{it})q_{-it}^{NEU} \\ + \theta X_{it-2} + \alpha_i + \eta_t + Trend_i + \varepsilon_{it} \end{aligned} \tag{3.2}$$

This specification is similar to the specification (3.1) which estimates the strategic interaction. The covariates included in X_{it-2}, the country fixed effects, time fixed effects and country-specific trend are the same with specification (3.1). The difference between these two specifications lies in the spatial lags.

I separate the countries other than the home country i by EU membership and calculate two spatial lags within each group, one for EU countries and one for non-EU countries. The variable EU_{it} is a dummy variable and equals to 1 if country i holds the EU membership at year t. q_{-it}^{EU} is a spatial lag that is constructed within countries holding EU membership. q_{-it}^{NEU} is the spatial lag for countries without EU membership. Then the two spatial lags are interacted with whether the home country is an EU member state, which gives us four variables. The instruments are also recalculated this way. Table A.2 in the Appendix lists the names of EU countries and non-EU countries.

This specification allows home country to respond differently to other countries depending on whether other countries hold EU membership. The coefficient δ_1^1 is the effect of policies of other EU countries on the policy of a EU country. The coefficient δ_1^4 reflects the effect of policies of other non-EU countries on the policy of a non-EU country. We expect to see larger effect among EU countries.

3.2.2 To Differentiate Interjurisdictional Competition

To differentiate the strategic interaction brought by interjurisdictional competition, the strength of capital control is used. Theoretically speaking, interjurisdictional competition requires free mobility of capital among jurisdictions, which leads to equal net return to capital across jurisdictions. It means that if there is no control on capital movement, then the equation (2.6) $f_{ik} - t_i = r \quad \forall i$ is satisfied for all jurisdictions. While if some jurisdictions have tight capital control that restrains capital mobility, say jurisdiction j^c, equation (2.6) does not have to hold. And the net return to capital does not necessarily equal the net return to capital in other jurisdictions, $f_{j^c k} - t_{j^c} \gtreqless r$. In the case of an extreme capital control, the amount of capital in jurisdiction j_c is fixed given its own tax rate t_{j^c} and environmental policy q_{j^c}. A fixed amount of capital implies that the private and public goods consumptions V_{j^c} are also fixed. Thus, part A in equation (2.13) is zero and the strategic interaction is not caused by interjurisdictional competition.

I use the following econometric equation to differentiate the strategic interaction that is brought about by interjurisdictional competition.

$$q_{it} = \delta_1^1(cc_{it})q_{-it}^C + \delta_1^2(cc_{it})q_{-it}^N + \delta_1^3(1-cc_{it})q_{-it}^C + \delta_1^4(1-cc_{it})q_{-it}^N + \theta X_{it-2} + \alpha_i + \eta_t + Trend_i + \varepsilon_{it} \tag{3.3}$$

Following Devereux et al. (2008), and similar to the specification (3.2), four spatial lags are constructed based on whether other countries and the home country have tight capital control in this equation . cc_{it} indicates whether country i has tight capital control in year t; it is equal to 1 if there is tight capital control and equal to 0 otherwise. Based on whether one country has tight capital control, I separate countries besides the home country into two groups and construct spatial lags within each group, respectively. Within countries that have tight capital control, $q_{-it}^C = \sum_{j \neq i} w_{ijt} cc_j q_{jt}$ is constructed; within countries that do not have tight capital control, $q_{-it}^N = \sum_{j \neq i} w_{ijt}(1-cc_j)q_{jt}$ is constructed. The two spatial lags are then interacted with cc_{it}, whether home country has tight capital control, which generates four variables in the econometric equation. The coefficient δ_1^4 is the effect of policies of other countries where capital is freely mobile on the policy of a home country which also does not have capital controls. Other coefficients can be interpreted similarly.

The difference in the four coefficients, δ_1^1, δ_1^2, δ_1^3, δ_1^4, manifest the strategic interaction caused by interjurisdictional competition and other mechanisms. The reason is that when a country has tight capital control, the capital mobility in this country is restrained; so, its incentive to compete for capital through strategically adjusting environmental policy is relatively weakened. The weaker incentive on interjurisdictional competition would be reflected in the difference in the values of the coefficients, especially between δ_1^1 and δ_1^4. δ_1^4 reflects the strategic interaction between the home country and other countries when neither has capital control, in which the interjurisdictional competition is relatively stronger. While δ_1^1 reflects the strategic interaction between the home country and other countries that both sides have capital control, and the interjurisdictional competition plays a limited role in policymaking. It thus reflects the interaction mainly caused by other mechanisms. The difference between the two coefficients reflect the strategic interaction that is brought about by interjurisdictional competition. If we do not find significant difference between them, we could claim that the interaction is not mainly due to interjurisdictional competition.

This paper uses the Chinn-Ito index, 2014 version, (Chinn and Ito, 2006) to measure capital control. The Chinn-Ito index is an index measuring a country's degree of capital account openness and is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)*. The indexes on the "most financially open" countries and "least financially open" countries are 2.39 and -1.89 respectively. To distinguish between countries which are principally open to capital flows and which are not, I divided the observations based on the value of the index. For countries in time t that has a value of the index above 1, they are regarded as "has no tight capital control" and $cc_{it} = 0$. Otherwise, the country is regarded as "has tight capital control" and $cc_{it} = 1$. Besides using 1 as the number to divide whether there is tight capital control, I also use alternative number, 0, to check the robustness.

3.2.3 To Differentiate Transboundary Pollution Spillovers

The strategic interaction can also be caused by transboundary pollution spillovers; other jurisdictions environmental policies determine the amount of local pollution emissions which can transport to the home country and affect its environmental quality. To differentiate the strategic interaction brought by transboundary spillovers, I control for the pollution depositions from other countries. I use the following specification to estimate.

$$q_{it}^{OSP} = \delta_1^{OSP} \sum_{j \neq i} w_{ijt} q_{jt}^{OSP} + \delta_2 D_{-it} + \delta_3 (1 - \alpha_{it}) + \theta X_{it-2} + \alpha_i + \eta_t + Trend_i + \varepsilon_{it} \quad (3.4)$$

Similarly, the covariates in the X_{it-2}, the country fixed effect, time fixed effect and country-specific trend in the above specification are the same as for specification (3.1). Besides the similarities, there are two differences. The first is this equation explores the strategic interaction specifically on countries' oxidized sulphur policies instead of general environmental policies as in specification (3.1). Considering that the degree of transboundary spillovers varies greatly across different types of pollutants, I choose one type of pollutant, oxidized sulphur, as the example to study the transboundary pollution spillovers. Thus, the environmental policies used in the equation are chosen to be most related to oxidized sulphur. I employ an Oxidized Sulphur Policy index (OSP) instead of EPS to construct the dependent variable and the spatial lag. OSP is an index that is created by the author by employing the same information on SO_x taxes and SO_x emission limit when constructing EPS. The second distinction from specification (3.1) is that this specification adds two transboundary spillover variables, which are called "spill-in" and "spill-out". Spill-in, denoted as D_{-it} in the equation, reflects that neighbors' pollution flowed into the home country, and this paper uses oxidized sulphur pollution depositions which are from all other countries to measure it. Spill-out reflects that one own jurisdiction's pollution spills out to neighboring jurisdictions, which is quantified as the fraction of total sulfur emissions that are deposited on other countries $(1 - \alpha_{it})$. The level of emissions is not used due to its high correlation with the dependent variable, environmental policies.

Regarding strategic interaction, when we control for the spill-ins, D_{-it}, in the regression, δ_1^{OSP} does not reflect the impact caused by transboundary pollution spillovers. This is because that when the pollution depositions from other countries, D_{-it}, are controlled for, the environmental quality in the home country is not influenced by other countries' environmental policies through transboundary pollution spillovers. Thus, under this specification, the home country would not strategically react to other countries' environmental policies due to the transboundary spillovers. The strategic interaction that is caused by the transboundary spillovers can be reflected by the difference between coefficients of the spatial lag in the case of controlling or not controlling for the spill-ins.

Regarding the coefficients on the two spillover variables, δ_2 directly measures the impact of spill-ins on environmental policy stringency. A positive coefficient indicates that when there are more pollution spilled over from other countries, government may increase standard to mitigate the damage of more pollution. δ_3 reflects how government responds to the spill-outs, and a negative coefficient shows that governments relax environmental standard when they can spill a higher fraction of pollution to other countries. In this case, a negative δ_3 reveals free-riding behavior.

The spillover variables are constructed using transport matrix from European Monitoring and Evaluation Programme (EMEP) (Eliassen and Saltbones, 1983; EMEP/MSC-W calculated SR country tables and data[13]). This matrix measures the amount of sulfur emitted by country j (column entries) that falls on country i (row entry). The sulfur depositions imported from other countries and the fraction of one country's emission deposited on its own are constructed, respectively. I use only European countries in this estimation since other countries are sparsely located on different continents, and the cross-continent spillovers are quite limited. Some countries, like Australia, barely have spillovers with other countries.

3.3 Summary Statistics

The data used in the estimation covers 26 OECD countries from 1990 to 2012. In the specification (3.1) and (3.3), OECD Environmental Policy Stringency Index (EPS) is used to measure each country's environmental policy stringency. In the specification (3.4), Oxidized Sulphur Policy (OSP) index is used to measure environmental policy on oxidized sulphur. OSP is created by the author by employing the same data on the SO_x taxes and SO_x emission limit when constructing EPS. Table A.1 in Appendix shows variables and data sources.

Figure 1 shows the trend of Environmental Policy Stringency (EPS) over time. Overall, from 1990 to 2012, the average environmental policy became more and more stringent. On average, EU countries have higher policy stringency than non-EU countries. For EU countries, there are two times that EPS falls, 2007 and 2012. These are mainly due to the swings in the carbon price of EU Emissions Trading System (ETS). The trend of increasingly stringent environmental policies across OECD countries is not consistent with the prediction of the "race to the bottom."

Figure 2 and Figure 3 plot the OECD countries' EPS for 1995 and 2010 on a world map, respectively. The categories are the same across maps. We can see that every country has increased the environmental policy stringency since 1995. The country with strictest environmental policy in 2010 is Netherland. Table 1 shows the evolution of different categories EPS. And the Oxidized Sulphur Policy which is used in the specification (3.4) is calculated as the average of index of SO_x taxes and SO_x emission limit. We can see a tightening of EPS in almost all categories over time. Table 2 reports the summary statistics for variables used in the estimation.

4 Empirical Results

This section presents the empirical results from the main specifications. The results from estimating strategic interaction are presented first. Then results of differentiating underlying

[13] See http://emep.int/mscw/ for details

reasons follow.

Figure 4 shows a series of bin scatter-plots of the home country's environmental policy against the spatial lag across continents. The spatial lag is other countries' environmental policies, which is constructed using similarity of income per capita as the weighting scheme. We observe a positive relationship between the home country's environmental policy and the spatial lag in all the continents studied in this paper.

4.1 Results on Estimating the Strategic Interaction

The regression results of estimating strategic interaction across countries, specification (3.1), are shown in Table 3 and Table 4. One country's environmental policy stringency (EPS) is the dependent variable. Spatial lag, other countries' environmental stringency, is the key explanatory variable of interest. Control variables are two-year lagged.

Table 3 shows the results of using similarity of income per capital as the weighting matrix. All regressions contain spatial lag and country fixed effects. From column (1) to (4), control variables, country-specific trend and time fixed effects are added correspondingly. In all the columns, we can see that there is a positive and statistically significant effect of other countries' environmental policy stringency on one country's environmental policy. And the coefficients are larger than one. Our preferred specification is that of column (4), which controls for covariates and absorbs country permanent characteristics, time-varying year-specific common shocks as well as a linear trend that are specific to each country. The coefficient of the spatial lag is 1.25, which is significant at the 1 percent level. A rough interpretation of it is that if the average of other countries' environmental policy stringency increase by 1 point, the home country would increase its environmental policy stringency by 1.25 point. Other variables also have an impact on the stringency of environmental policy. Countries that hold membership of European Union have higher GDP per capita, are more democratic and have higher corporate tax rate tend to have more stringent environmental policies. The degree of urbanization tends to lower the policy stringency. With respect to the instruments, results of the various test are also reported. I test for underidentification using Kleibergen-Paap rk LM statistic (Kleibergen and Paap, 2006). The probability value indicates that we can reject the null-hypothesis of underidentification at the 1% level. I also test for the validity of instruments (overidentification test) using Hansen's J-test (Hansen, 1982), and we are unable to reject the null-hypothesis of exogeneity at the conventional level of significance indicating the validity of instruments. Weak instrument issue is tested using Kleibergen-Paap rk Wald F statistic, which shows that we can reject that the instruments are weak.

Table 4 shows the results of repeating the specification in column (4) of Table 3 using other three weights, including simple average, GDP per capita and openness. Control variables, country-specific trend and time fixed effects are all included. Compared with Table 3, we still find positive strategic interaction on setting environmental policies. The scales of the coefficients are smaller, and the statistical significance of the coefficients are lower compared with the results of using similarity of income per capita as the weighting scheme. The test statistics also show that the estimation models are not underidentified and instruments are exogenous and not weak.

Although the positive strategic interaction across countries is consistent with the prediction of interjurisdictional competition on capital, it's possible that other underlying reasons drive the policy interdependence. The positive coefficient could reflect the policy imitation across countries due to yardstick competition, in which case voters use other countries' environmental policies as yardstick to evaluate the home country officials' performances. It could also be possible that countries increase the stringency to positively reciprocate the lower transboundary pollution spillovers due to other countries' more stringent policies. The positive coefficient could also be capturing the international coordination of combating environmental issues. The various international treaties and agreements reflect the coordination efforts. Further analysis is needed to differentiate the underlying mechanism of the strategic interaction, to which we turn.

4.2 Results of Differentiating the Coordination

From 3 and Table 4, we find positive strategic interaction across countries. We do not know what mechanism and reasons that this relationship can be attributed to. I estimate the specification (3.2) to disentangle the international coordination efforts. Results are shown in table 7. Note that in column (4), there is potential weak identification (low Kleibergen-Paap rk Wald F statistic) and underidentification issue (high underidentification test p Value) when using similarity of income per capita as weighting schemes. Thus the results from the column (1) to (3) are preferred. The coefficients on the first variable, which indicate the reaction of an EU country to other EU countries' policy changes, are positive and statistically significant at 1% level in most specifications. This results indicate that there are strong strategic interactions across EU countries. The coefficients on the third variable, which indicate the response of a non-EU country to other EU countries' policy changes, are also positive and statistically significant at the conventional level. It means that when EU countries increase the environmental standard, other countries also increase their environmental standards. While this positive reaction is not found when the spatial lag is non-EU countries, as shown in the coefficients of the second and fourth variable in the column (1) to (3). I also check the difference across coefficients and find that there is statistically significant difference between the coefficients of the first variable and second variable in most specifications. This means that when the home country is an EU member, it reacts significantly more to other EU countries than to other non-EU countries. Differences across other variables are not found.

I also consider the effect of euro area on the strategic interaction. Results are presented in Table 8. The variable "Eurozone" is a dummy and equals to one if this country is in euro area that year. In our dataset, most EU countries, twelve out of eighteen, adopt the euro as their common currency, mostly in 1999. The coefficients of the first variable, Eurozone * Home country in EU * Spatial lag of EU, are positive and statistically significant in most specifications. This results indicates that the strategic interaction on environmental policymaking is stronger after adopting the euro as their common currency.

In summary, there is a positive impact of environmental policies in EU countries on other countries. The strategic interaction across EU countries is positive and statistically stronger than the interaction across other countries. This interaction is enhanced with the adoption of the euro as a common currency among EU countries.

4.3 Results of Differentiating the Interjurisdictional Competition

I estimate the specification (3.3) to differentiate interjurisdictional competition, results are reported in Table 5. As in Table 4, control variables, country-specific trend and time fixed effects are all included in this set of estimates. The four variables displayed in the table are the interaction of two set of variables; one is whether the home country has tight capital control; the other is whether other countries have tight capital control. For example, the coefficient of the first variable, Home country with capital control * Spatial lag with capital control, captures whether the environmental policy in the home country that have capital control strategically react to policies in other countries that also have capital control. The coefficient of the fourth variable, Home country without capital control * Spatial lag without capital control, captures the effect of policies in other countries where capital is freely mobile on policies in the home country where capital is freely mobile too. The coefficient of the fourth variable is expected to be larger if interjurisdictional competition mainly drives the interaction.

From the results, we can see that the coefficients of the first variable, Home country with capital control * Spatial lag with capital control, are statistically significant at conventional level in all the specifications, which indicates that the other reasons besides interjurisdictional competition contribute to the strategic interaction. When both countries in spatial lag and the home country have no tight capital control (the fourth variable), we expect that the interjurisdictional competition has a larger effect on the strategic interaction. If interjurisdictional competition plays an important role in the strategic interaction, we expect that this impact would be reflected in the difference between the coefficient of the fourth variable and other variables. I test the difference between the coefficient of the first variable and the coefficient of the fourth variable and find that we are unable to reject that these two coefficients are the same for column (1) to (3). The p values are 0.683, 0.202 and 0.843 respectively for the similarity tests of column (1) to (3). In column (4), the coefficient of the fourth variable is negative and statistically insignificant, and the strategic interaction across countries with capital control is stronger than that of countries without capital control.

In sum, I find a lack of difference between the coefficient of the first and fourth variable, which shows that the strategic interactions on environmental policy are similar across countries with or without capital control. This finding indicates that the interaction on environmental policies are not mainly driven by capital movement across countries. The implication is that interjurisdictional competition plays a quite limited role in the strategic interaction on environmental policies.

4.4 Results of Differentiating the Transboundary Spillovers

The regression results of differentiating the transboundary spillovers is shown in table 6, which is estimated based on specification (3.4). Considering the degree of transboundary spillovers varies greatly across pollutants, I use oxidized sulphur as an example to explore the effect of transboundary spillovers on policy stringency. The dependent variable is Oxidized Sulphur Policy (OSP) in one country, which mainly includes taxes and emission limit on SO_x. The spatial lag is other countries' Oxidized Sulphur Policies. Two types of transboundary spillovers are included, "spill-out" which is the fraction of emissions deposited on other countries, and "spill-ins" which is the pollution depositions transported from other countries[14].

Regarding two spillover variables, spill-ins have statistically significant and positive impact on OSP. The results mean that when pollution depositions from other countries increase, the home country tends to increase its environmental policy, presumably to mitigate the harmful effect of pollution. On the other hand, when pollution depositions decrease, the

[14]The sample used for the specifications includes only 21 European countries. Other countries that are sparsely located in different continents have very limited pollution spillovers between them, which are thus not considered in the estimation. The results of using the same sample but without controlling the spill-ins, depositions from other countries, are reported in Appendix Table A.9

home country tend to relax environmental policy stringency. The coefficient is 0.429 when using similarity of income per capita for the weighting matrix. A rough interpretation is that if oxidized sulphur pollution transported from other countries increases by 10%, the home country will increase the stringency of OSP by 0.0429 point. Considering that the mean of the stringency of OSP is 1.69, the scale of the impact is relatively small. When controlling for the spill-ins, the coefficients on the spatial lag of OSP are still positive and statistically significant in most specifications, which means the strategic interaction still exists. These results indicate that other mechanisms besides transboundary spillovers also play a role in generating countries' interaction. I repeat this regression but without controlling for the spill-ins; results are shown in Appendix Table A.9. The coefficients of spatial lag are quite similar with or without controlling for spill-ins. Considering that the strategic interaction of controlling for spill-ins does not include the interaction caused by transboundary spillovers, similar coefficients mean that the transboundary spillovers play a limited role in the strategic interaction.

Spill-outs, fraction of emissions deposited on other countries, have a positive effect on environmental stringency; none of the coefficients of spill-outs are negative. The results show that when the home country exports a larger fraction of emissions on other countries, it tends to increase policy stringency rather than loosening policy in order to free ride. These results indicate limited free-riding behaviors on setting oxidized sulphur policies among European countries. To the opposite, there is even a certain degree of cooperation. This finding is consistent with results of Sigman (2002) who finds cooperative behaviors, not free-riding, on water pollution among European countries.

To summarize, transboundary pollution spillovers have impact on countries' environmental policies. Countries increase policy stringency to mitigate larger pollution spill-ins, but the scale of impact is relatively small. The strategic interaction that is caused by spillovers is also limited. Also, I find certain degree of cooperation instead of free-riding behavior on setting environmental policy among European countries.

5 Robustness Checks

A battery of additional robustness checks is also carried out. The first set of estimates replaces the two-year lagged control variables with one-year lagged and three-year lagged control variables. Results are shown in Table A.3 and Table A.4, respectively. Using one-year and three-year lagged control variables, there is still a statistically significant and positive effect of other countries' environmental policy stringency on the home country policy, but only under the weighting scheme of similarity of income per capita. Under other weighting schemes, the coefficients on spatial lag are also positive but not statistically significant at the conventional level. Comparing with the results of using two-year lagged control variables, the magnitude of coefficients is relatively smaller in the specifications using one-year and three-year lagged control variables.

In the second set of estimates, I include a one-year lag of the dependent variable to control for potential dynamic effects. As shown in Table A.5, the lagged dependent variable is positive and statistically significant. After controlling for the lag of the dependent variable, the spatial lag, other countries' environmental policies, still shows a positive and statistically significant effect, although the coefficients are smaller.

Third, I recalculate the measure on the environmental policy (EPS) to exclude the potential correlation across countries in the calculation of EPS. In calculating one country's environmental policy stringency, one piece of information that is used is the carbon price in the "cap and trade" carbon market. To be more specific, in 2005, EU countries introduce emissions trading system (ETS) which links the greenhouse gas emissions in 31 European countries into one market. Since the carbon price in ETS is the same across participating countries, if we use the carbon price to calculate environmental policy stringency, the calculated policy stringency is correlated across countries by construction. This correlation may overestimate the strategic interaction on environmental policy that we intend to measure. Besides, the carbon price may be correlated with economic outcomes and brings a certain degree of endogeneity. So I recalculate the environmental policy stringency (EPS) by excluding the price in carbon market and rerun the regressions using new EPS. The results are shown in Table A.6. There is still positive and statistically significant effect of other countries' environmental policy when using similarity of income per capita as the weighting matrix. The coefficients of using other weighting schemes are not statistically significant, but have a positive sign in first two columns, simple average and GDP per capita as weights, and negative sign of using openness as weights.

Fourth, I use the spatial lag variable that is two years in the future to run the regression. A county should not react to a policy change that has not been made yet, and thus we expect the coefficient should be statistically insignificant. The results are shown in Table A.7. The spatial lag is not statistically significant in all specifications as expected. Also, we can not reject that the coefficients are equal to zero in all specifications.

Fifth, I also check how sensitive the results of differentiating interjurisdictional competition to the way of specifying countries with tight capital control. Instead of using one as the number to divide countries with or without tight capital control, I use zero as the number. Under this setting, when the capital control index of one country, Chinn-Ito index, is larger than zero, then this country is specified as "has no tight capital control". Otherwise, it is specified as “has tight capital control”. The results of estimating specification (3.3) are presented in Table A.8. Under this group scheme, there is no country that is classified as “has tight capital control” since 2008. Thus, the sample size is smaller than before. But we still can not find statistically significant difference between the coefficients of the four variables.

6 Discussion and Conclusion

This paper explores the question of whether OECD countries engage in strategic environmental policymaking and disentangles distinct mechanisms behind the policy interaction. My analysis suggests that there is a positive interaction between countries' environmental policies. Through differentiating the potential mechanisms behind the interaction, I find that the interaction mainly manifests the international coordination on environmental policies, especially among EU countries. Also, EU countries' policies are increasingly coordinated with each others' since the adoption of the euro as a common currency. The interjurisdictional competition and pollution spillovers play limited roles behind the interaction.

My finding can partly explain the trend of increasingly stringent environmental policy since if there is limited race across countries, we do not expect to see the “race to the bottom” on environmental policy. The reasons of limited regulatory races on environmental policy are multilayered. On the one hand, environmental regulations are seldom definitive for firms' locational decisions at the international level. Studies on this topic include Kirkpatrick and Shimamoto (2008), Mulatu et al. (2010) and a review paper, Carruthers and Lamoreaux (2016). Given the limited impact of environmental regulation on capital, countries may not choose environmental policy to compete for capital, but use other policy instruments that have a larger influence on capital movement, such as the corporate tax rate. On the other hand, there has been considerable international cooperation on combating environmental issues. The participation on international environmental treaties is one example. Note that the lack of interjurisdictional competition in setting environmental policies does not imply that there is no competition regarding other government policies. Governments may use other instruments, such as corporate and personal tax rates, to compete for the capital.

It is also important to further explore the incentives and reasons behind the international coordination on environmental policies. Here I discuss some potential reasons. First, some environmental problems and pollution produce externalities across countries. The spillover effects provide an incentive on international coordination. In the empirical results, I also find limited free-riding behaviors on setting oxidized sulphur policies among European countries, which is consistent with the coordination behavior. Second, the environmental standard coordination could reflect the harmonization of product standards among trade partners. To avoid market segmentation, industries in both low-regulating and high-regulating countries have a common interest in harmonizing product standards (Holzinger and Sommerer, 2011). The third potential mechanism is reciprocity. Countries may increase the environmental standards to reciprocate other countries' efforts on combating environmental issues.

The results in this paper have policy implications. The first implication is that decentralized environmental policymaking does not necessarily bring about a "race to the bottom." And the responsibility for providing environmental quality need not rest entirely on a central authority. Second, when a country adopts a more stringent environmental policy, it has a positive external effect on other countries' environmental policymaking. This externality needs to be noticed both from the academic and the public policy perspective. I also recommend to devise certain mechanisms to reward and compensate the positive externality so that our environmental policies achieve more desired outcomes. Third, further coordination and cooperation to reinforce the policymaking interaction are suggested.

These conclusions should be interpreted cautiously because they are based on the analysis of developed OECD countries. In the future, expanding the dataset to include developing countries and embedding different mechanisms in a more complete model are logic next steps for research. Another research direction is to examine what motivates countries' policy coordination and cooperation.

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Figure 1: Environmental Policy Stringency (EPS) Over Time

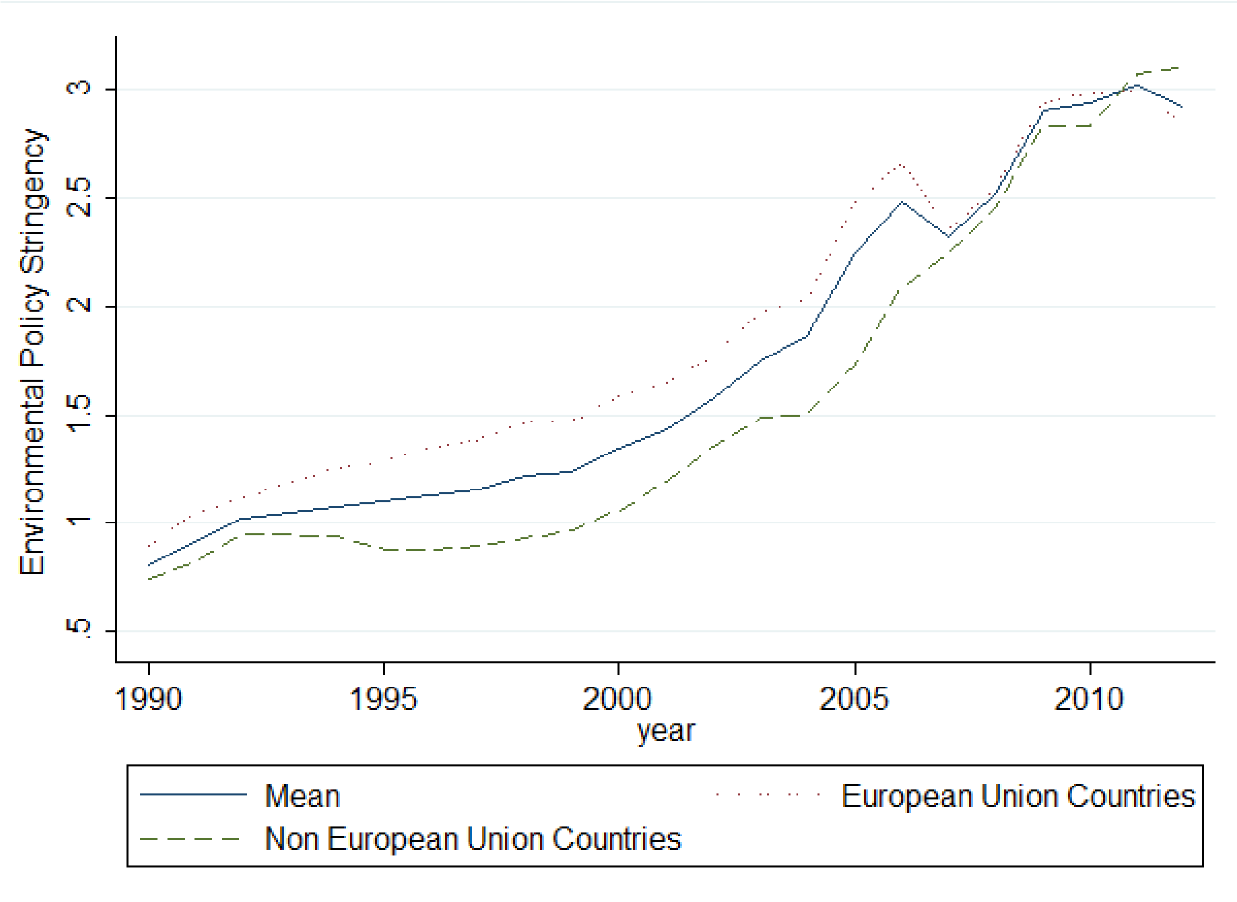


Figure 2: OECD countries' EPS Plotted on a World Map, 1995

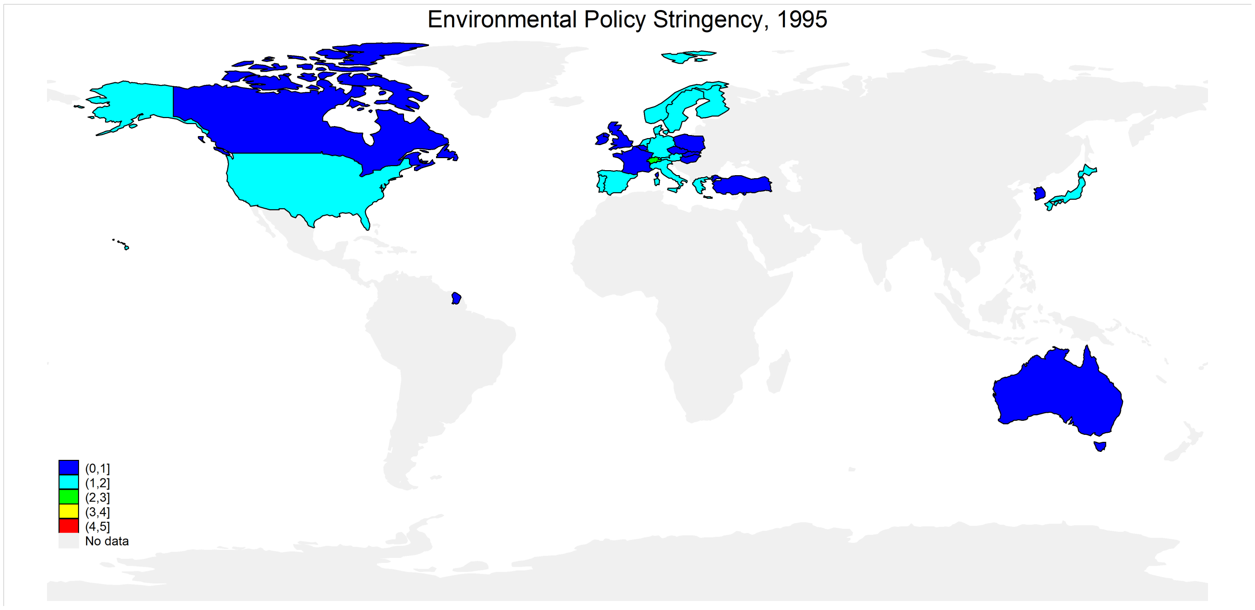


Figure 3: OECD countries' EPS Plotted on a World Map, 2010

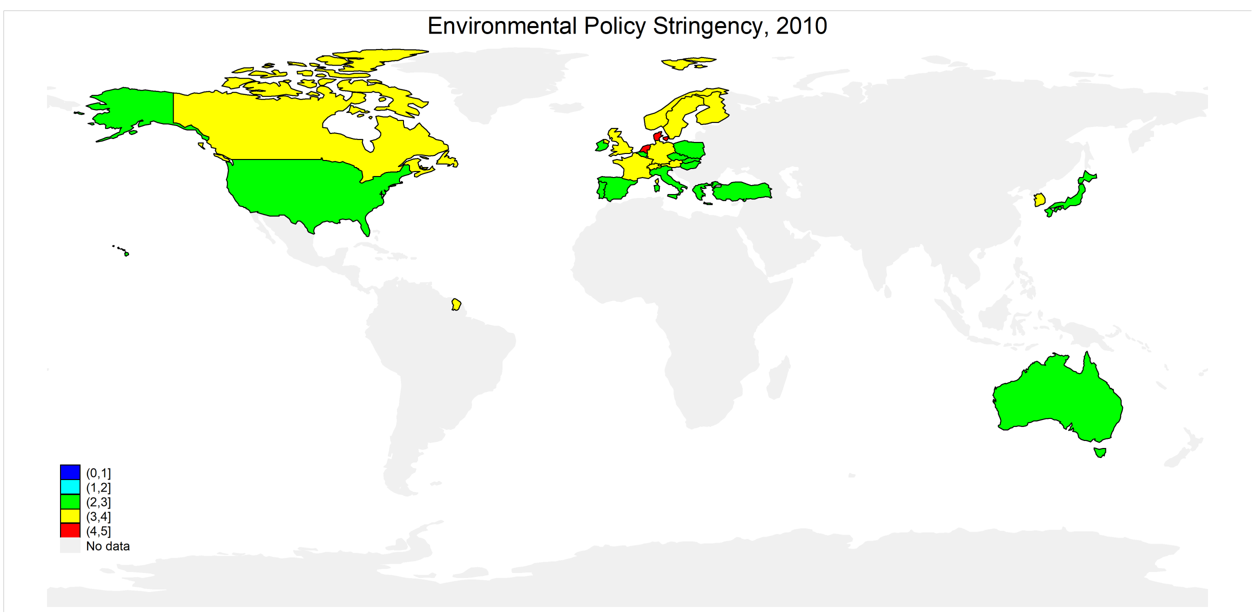
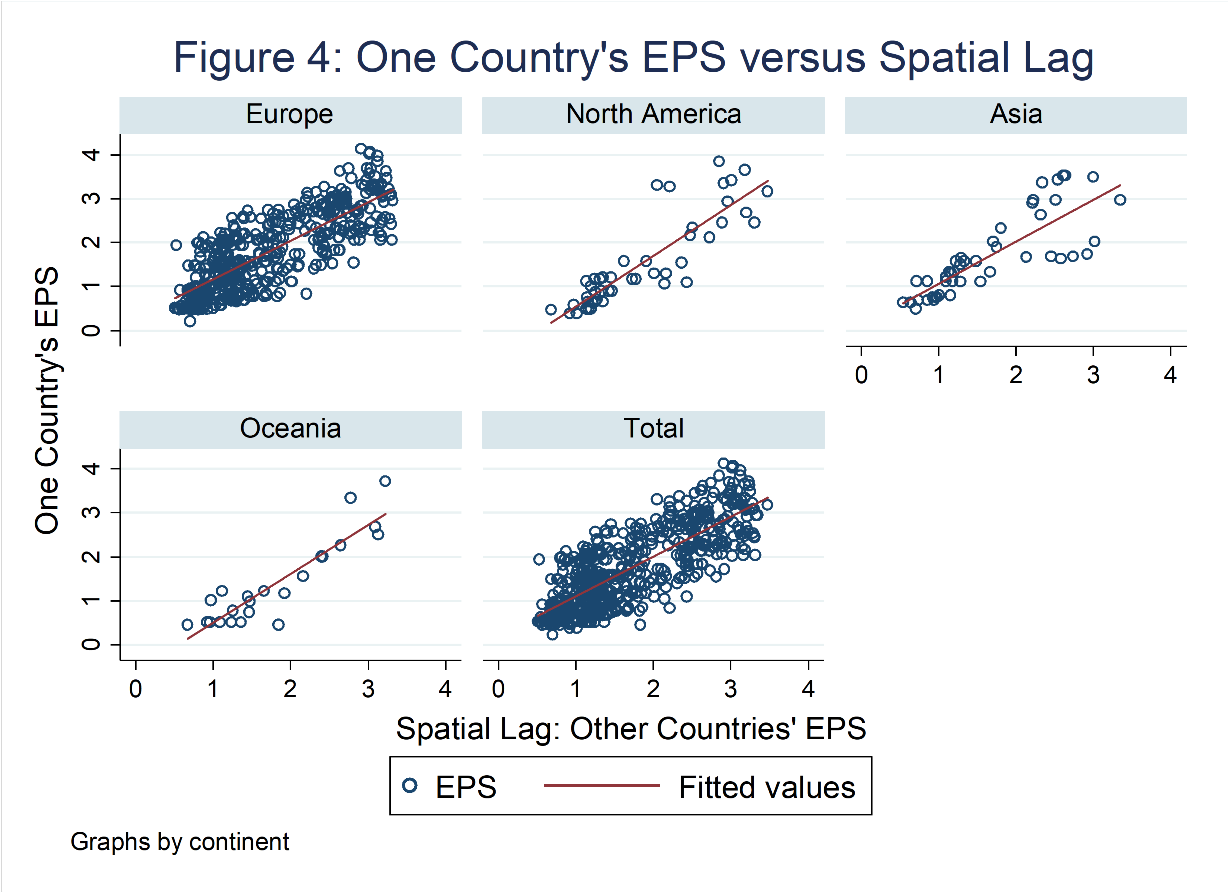


Figure 4: One Country's EPS versus Spatial Lag



Notes: The weighting matrix for constructing the spatial lag is similarity of income per capita.

Table 1: Evolution of EPS, Different Categories

year period	1990-1995	1996-2000	2001-2005	2006-2010	2011-2012	Total
EPS	0.994	1.218	1.775	2.634	2.968	1.74
EPS, Market Based Policy	0.565	0.834	1.221	1.918	2.008	1.186
EPS, Non Market Based Policy	1.423	1.605	2.332	3.352	3.929	2.297
EPS, Oxidized Sulphur Policy	0.583	0.846	2.035	2.985	3.038	1.691
EPS, SOx tax	0.385	0.715	1.4	1.485	1.404	1.005
EPS, SOx limit	0.782	0.977	2.669	4.485	4.673	2.378

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EPS	598	1.74	0.9	0.21	4.13
OSP	598	1.69	1.44	0	5.5
Democracy	598	1.32	0.62	1	5
Gov Fractionalization	598	0.3	0.27	0	0.83
Checks and Balances	598	4.22	1.26	1	11
Spill-ins: Depositions from Others	483	911.54	844.34	59.74	7067
Spill-outs: Fraction of Emissions on Others (%)	483	76.86	8.41	56.12	92
EU Membership	598	0.57	0.49	0	1
GDP Per Capita (Log)	598	10.26	0.39	8.96	11.06
Openness (%)	598	79.31	46.93	12.05	286.3
Corporate Tax Rate (%)	598	32.8	8.53	12.5	58.15
Urbanization	598	74.4	10.14	47.92	97.73
Population (Log)	598	16.8	1.15	15.07	19.57
Population $>$ 65 (%)	598	14.47	3.24	4.54	24.29
Population $<$ 14 (%)	598	18.38	3.58	13.13	36.25
Political Constraint Index	598	0.78	0.09	0.34	0.89

Table 3: Results of Estimating Overall Effect of Strategic Interaction, Similarity of Income per Capita as Weights

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighing Matrix	Similarity of income per capital			
Spatial Lag	1.042***	1.436***	1.201***	1.250***
	(0.0345)	(0.357)	(0.219)	(0.283)
EU membership		-0.0111	0.272**	0.254**
		(0.111)	(0.107)	(0.111)
GDP per capita (log)		-0.146	0.476	0.617*
		(0.38)	(0.347)	(0.35)
Openness		-0.00251	-0.00303	-0.00178
		(0.00413)	(0.0028)	(0.00242)
Corporate tax rate		0.0284***	0.00907**	0.00989***
		(0.00588)	(0.00366)	(0.00373)
Urbanization		0.0117	-0.137***	-0.147***
		(0.0149)	(0.043)	(0.0393)
Population		-3.534	1.333	0.682
		(2.517)	(1.88)	(1.772)
Age structure (> 65 %)		-0.164***	-0.00599	-0.0187
		(0.0631)	(0.0701)	(0.0703)
Age structure (< 14 %)		-0.106***	-0.0850**	-0.0758
		(0.0318)	(0.043)	(0.0546)
Democracy		0.152*	0.194**	0.186***
		(0.0878)	(0.083)	(0.0719)
Political constraint		0.469	0.234	0.244
		(0.339)	(0.261)	(0.257)
Government fractionalization		0.061	-0.0172	0.00668
		(0.155)	(0.12)	(0.119)
Government checks and balance		-0.033	-0.015	-0.0196
		(0.0288)	(0.0179)	(0.0176)
Observations	543	543	543	543
R-squared	0.746	0.713	0.845	0.841
Country-specific Trend	NO	NO	YES	YES
Year FE	NO	NO	NO	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0.00402	0.00137	0.000316
Hansen's J p Value	0.206	0.521	0.253	0.211
Kleibergen-Paap rk Wald F statistic	27.23	6.179	13.1	14.14

Notes: Each column is from a separate regression. Coefficients are estimates from equation (4.1). All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Except for spatial lag, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table 4: Results of Estimating Overall Effect of Strategic Interaction, Other Weights

	(1)	(2)	(3)
	Environmental Policy Stringency (EPS)		
Weighing Matrix	Simple Average	GDP per capita	Openness
Spatial Lag	0.79	1.064*	0.351
	(0.542)	(0.639)	(0.375)
Observations	546	546	546
R-squared	0.895	0.893	0.895
Country-specific Trend	YES	YES	YES
Year FE	YES	YES	YES
Country FE	YES	YES	YES
Underidentification Test p Value	0	0	0
Hansen's J p Value	0.768	0.732	0.43
Kleibergen-Paap rk Wald F statistic	17.22	15	17.05

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. Coefficients are estimates of δ_1 from equation (4.1).

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Except for spatial lag, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table 5: Results of Differentiating Interjurisdictional Competition, All Weights

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Home country with capital control * Spatial lag with capital control	0.485**	0.300*	0.402**	2.875***
	(0.211)	(0.163)	(0.200)	(0.501)
Home country with capital control * Spatial lag without capital control	0.373	0.532	0.193	-1.619***
	(0.423)	(0.377)	(0.519)	(0.421)
Home country without capital control * Spatial lag with capital control	0.0651	0.0184	0.0166	0.599***
	(0.187)	(0.144)	(0.161)	(0.173)
Home country without capital control * Spatial lag without capital control	0.712*	0.896**	0.526	-0.115
	(0.414)	(0.366)	(0.476)	(0.326)
Observations	546	546	546	543
R-squared	0.893	0.888	0.894	0.832
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0
Hansen's J p Value	0.803	0.782	0.473	0.568
Kleibergen-Paap rk Wald F statistic	8.820	10.94	6.697	2.944

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. There are four spatial lags in each specification. Coefficients of the four spatial lags are estimates of $\delta_1^1, \delta_1^2, \delta_1^3, \delta_1^4$ from equation (4.2). The coefficient on variable "Home country with capital control * Spatial lag with capital control" captures whether environmental policy in home country that have capital control strategically react to policies in other countries that also have capital control. The coefficients on other spatial lags can be interpreted similarly.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lags include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lags. Except for spatial lags, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table 6: Results of Differentiating Transboundary Spillovers, All Weights

	(1)	(2)	(3)	(4)
	Oxidized Sulphur Policy			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Spatial Lag of Oxidized Sulphur Policy	1.029**	0.613	0.804*	0.612***
	(0.438)	(0.392)	(0.487)	(0.194)
Spill-outs: fraction of emissions deposited on other countries	0.0116	0.0154*	0.0103	0.0192**
	(0.00881)	(0.00918)	(0.0101)	(0.00907)
Spill-ins: pollution depositions transported from other countries (log)	0.504***	0.498***	0.510***	0.429**
	(0.183)	(0.176)	(0.183)	(0.211)
Observations	441	441	441	438
R-squared	0.886	0.889	0.887	0.857
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0
Hansen's J p Value	0.857	0.665	0.299	0.327
Kleibergen-Paap rk Wald F statistic	23.24	25.37	10.03	12.59

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. The dependent variable is Oxidized Sulphur Policy which is an index on environmental policies of oxidized sulphur. Coefficients of the three variables are estimates of $\delta_1^{'}, \delta_2, \delta_3$ from equation (4.3). Two variables on the oxidized sulphur spillovers are included in the specifications. Spill-outs captures the oxidized sulphur pollution depositions emitted from home country and transported to other countries, which are measured by the fraction of total emissions that are deposited on other countries. Spill-ins captures the oxidized sulphur pollution depositions that are originated from other countries and spilled inside home country. The sample used for the specifications includes only 21 European countries. Other countries that are sparsely located in different continents have very limited pollution spillovers between them, which are thus not considered in the estimation.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Except for spatial lag, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table 7: Results of EU and non-EU Countries, All Weights

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Home country in EU * Spatial lag of EU	0.899***	0.858***	0.736***	0.363
	(0.261)	(0.232)	(0.217)	(0.425)
Home country in EU * Spatial lag of non-EU	0.048	-0.136	0.109	1.216***
	(0.256)	(0.243)	(0.251)	(0.33)
Home country not in EU * Spatial lag of EU	0.669**	0.473*	0.561**	0.49
	(0.294)	(0.266)	(0.245)	(0.478)
Home country not in EU * Spatial lag of non-EU	0.224	0.227	0.178	0.648*
	(0.299)	(0.301)	(0.248)	(0.335)
Observations	546	546	546	543
R-squared	0.887	0.891	0.876	0.821
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0.126
Hansen's J p Value	0.369	0.229	0.185	0.114
Kleibergen-Paap rk Wald F statistic	11.06	11.76	14.71	1.43

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. There are four spatial lags in each specification which are constructed based on whether other countries or home country are in EU. The coefficient on variable "Spatial lag of EU * home country in EU" captures whether environmental policy in home country that is in EU strategically react to policy changes in other EU countries. The coefficients on other spatial lags can be interpreted similarly.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lags include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lags. Except for spatial lags, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table 8: Results of the Effect of Eurozone on EU Countries, All Weights

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Eurozone * Home country in EU * Spatial lag of EU	0.683***	0.600***	0.570***	3.749
	(0.155)	(0.142)	(0.152)	(3.992)
Home country in EU * Spatial lag of EU	0.442*	0.529**	0.553***	-27.39***
	(0.240)	(0.216)	(0.206)	(7.829)
Home country in EU * Spatial lag of non-EU	-0.285	-0.252	-0.220	4.745
	(0.251)	(0.235)	(0.241)	(3.921)
Home country not in EU * Spatial lag of EU	-0.242	-0.209	-0.0336	-34.20***
	(0.328)	(0.286)	(0.267)	(9.844)
Home country not in EU * Spatial lag of non-EU	0.475	0.534*	0.325	14.42***
	(0.294)	(0.283)	(0.230)	(5.104)
Observations	546	546	546	543
R-squared	0.896	0.897	0.890	-36.705
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0.0844
Hansen's J p Value	0.608	0.564	0.334	0.197
Kleibergen-Paap rk Wald F statistic	10.97	10.44	12.21	1.514

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. There are five spatial lags in each specification which are constructed based on whether other countries or home country are in EU. The variable "Eurozone" is a dummy and equals to 1 if this country is in euro area that year.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lags include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lags. Except for spatial lags, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

A Appendix

Table A.1: Variables and Data Source

Variables	Source
Stringency of environmental policy	OECD Environmental Policy Stringency Index (EPS)
Democracy (simple average of Political Right and Civil Liberty)	Freedom House
Government fractionalization, Checks and balances	Database of Political Institutions (DPI)
Sulphur transport matrix	European Monitoring and Evaluation Programme (EMEP)
GDP per capita (log), Openness	Penn World Table 9.0 (Feenstra, et al. 2015)
Corporate income tax rate	OECD
Urbanization, Population related variables	World Bank's World Development Indicators database
Political Constraint Index	Political Constraint Index (POLCON) Dataset (Henisz, 2000)

Table A.2: List of Countries and EU Membership

EU Countries	non-EU Countries
Austria (1995), Belgium	Australia, Canada
Czech Republic (2004), Denmark, Finland (1995)	Japan, Republic of Korea
France, Germany, Greece, Hungary (2004)	Norway, Switzerland
Ireland, Italy, Netherlands	Turkey, United States
Poland (2004), Portugal, Slovakia (2004)	
Spain, Sweden (1995), United Kingdom	

Notes: For countries with brackets, the regarding number inside the brackets is the year of becoming a European Union member. For countries without brackets in the column of EU Countries, they are EU members for the whole period of our dataset.

Table A.3: Robustness, Control Variables are One-Year Lagged

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Spatial Lag	0.284	0.28	0.26	1.221***
	(0.553)	(0.74)	(0.444)	(0.283)
Observations	572	572	572	568
R-squared	0.895	0.895	0.896	0.845
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0
Hansen's J p Value	0.283	0.365	0.55	0.44
Kleibergen-Paap rk Wald F statistic	16.77	10.4	16.22	14.62

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. Coefficients are estimates of δ_1 from equation (4.1) except that control variables are one-year lagged instead of two-year lagged.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table A.4: Robustness, Control Variables are Three-Year Lagged

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Spatial Lag	0.547	0.399	0.533	1.475***
	(0.53)	(0.568)	(0.359)	(0.34)
Observations	520	520	520	518
R-squared	0.895	0.894	0.895	0.82
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0
Hansen's J p Value	0.541	0.307	0.682	0.24
Kleibergen-Paap rk Wald F statistic	15.17	14.7	18.11	11.74

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. Coefficients are estimates of δ_1 from equation (4.1) except that control variables are three-year lagged instead of two-year lagged.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table A.5: Robustness, Include Lagged Dependent Variable

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of Income per capita
Spatial Lag	0.851*	0.953*	0.45	0.827***
	(0.469)	(0.559)	(0.325)	(0.208)
Lagged EPS	0.515***	0.507***	0.539***	0.536***
	(0.0557)	(0.0597)	(0.0521)	(0.055)
Observations	546	546	546	543
R-squared	0.921	0.92	0.924	0.901
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0
Hansen's J p Value	0.683	0.231	0.186	0.186
Kleibergen-Paap rk Wald F statistic	17.64	14.38	17.56	17.56

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. Coefficients are estimates of δ_1 from equation (4.1) except that one-year lagged dependent variable is also included.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table A.6: Robustness, Recalculated EPS, not Consider CO_2 Trading Scheme

	(1)	(2)	(3)	(4)
	Recalculated Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Spatial Lag	1.368	0.353	-0.767	1.372***
	(1.573)	(1.521)	(0.976)	(0.353)
Observations	546	546	546	543
R-squared	0.874	0.879	0.863	0.802
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0.0978	0.0387	0.0012	0.00123
Hansen's J p Value	0.807	0.811	0.532	0.737
Kleibergen-Paap rk Wald F statistic	2.154	2.556	4.701	11.55

Notes: The dependent variable and spatial lag are constructed using recalculated EPS. In the constructed of index on environmental policy, recalculated EPS doesn't consider the carbon price in CO_2 trading system to avoid the correlation across countries in the calculation. All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. Coefficients are estimates of δ_1 from equation (4.1).

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Except for spatial lag, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table A.7: Robustness, Use Spatial Lag that are Two Years in the Future

	(1)	(2)	(3)	(4)
	Recalculated Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Spatial Lag	0.218	0.450	0.207	0.376
	(0.240)	(0.290)	(0.199)	(0.257)
Observations	494	494	494	493
R-squared	0.895	0.890	0.893	0.893
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0.0291
Hansen's J p Value	0.00138	0.000441	0.000349	0.210
Kleibergen-Paap rk Wald F statistic	45.81	31.96	48.39	5.454

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. The spatial lag is two years in the future.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table A.8: Robustness: Use Alternative Way to Specify Whether a Country Has Capital Control

	(1)	(2)	(3)	(4)
	Environmental Policy Stringency (EPS)			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Home country with capital control * Spatial lag with capital control	0.0274	0.954***	0.0870	0.852**
	(0.446)	(0.350)	(0.304)	(0.418)
Home country with capital control * Spatial lag without capital control	0.456	-0.495	0.894	-0.114
	(1.388)	(0.723)	(0.756)	(0.234)
Home country without capital control * Spatial lag with capital control	0.388	0.329*	-0.0718	0.381**
	(0.524)	(0.171)	(0.283)	(0.162)
Home country without capital control * Spatial lag without capital control	0.470	-0.0549	1.137	0.306
	(1.432)	(0.687)	(0.782)	(0.194)
Observations	416	416	416	413
R-squared	-0.238	0.799	0.895	0.824
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0.00178
Hansen's J p Value	0.416	0.304	0.0298	0.237
Kleibergen-Paap rk Wald F statistic	8.170	9.682	4.727	3.126

Notes: All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. There are four spatial lags in each specification. Coefficients of the four spatial lags are estimates of $\delta_1^1, \delta_1^2, \delta_1^3, \delta_1^4$ from equation (4.2). Countries are divided into two groups based on whether the capital control index is larger than zero.

All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lags include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lags. Except for spatial lags, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.

Table A.9: Results of Using Same Sample with Table 6 without Controlling for Spill-ins

	(1)	(2)	(3)	(4)
	Oxidized Sulphur Policy			
Weighting Matrix	Simple Average	GDP per capita	Openness	Similarity of income per capita
Spatial Lag of Oxidized Sulphur Policy	1.079**	0.757*	0.836*	0.652***
	(0.449)	(0.401)	(0.498)	(0.196)
Spill-outs: fraction of emissions deposited on other countries	0.0059	0.00866	0.0053	0.0145
	(0.00896)	(0.00928)	(0.0103)	(0.00924)
Observations	441	441	441	438
R-squared	0.886	0.889	0.887	0.857
Country-specific Trend	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Underidentification Test p Value	0	0	0	0
Hansen's J p Value	0.857	0.665	0.299	0.327
Kleibergen-Paap rk Wald F statistic	23.24	25.37	10.03	12.59

Notes: This set of specifications use the same sample and similar econometric equation with table 6. The difference is that the spill-ins are not controlled for in this set of specifications. Without controlling for the spill-ins, the coefficient of the spatial lag reflects the strategic interaction brought by transboundary spillovers.

The dependent variable is Oxidized Sulphur Policy which is an index on environmental policies of oxidized sulphur. Coefficients of the two variables are estimates of δ_1^{OSP}, δ_3 from equation (4.3). All specifications include a full set of control variables, country-specific trend, year fixed effect and country fixed effect. Each column is from a separate regression. All specifications are estimated by GMM CUE IV estimation. Instrument sets for the spatial lag include democracy, government fractionalization, checks and balances from other countries, using the same weighting scheme as the spatial lag. Except for spatial lag, other control variables are two-year lagged. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Underidentification test uses Kleibergen-Paap rk LM statistic. Hansen's J statistic is used to determine the validity of the overidentifying restrictions in a GMM model, and high p value indicates valid instruments. Kleibergen-Paap rk Wald F statistic is used for weak instruments test.