Int Tax Public Finance (2014) 21:923–954
DOI 10.1007/s10797-013-9280-1

Cooperation in environmental policy: a spatial approach

Ronald B. Davies · Helen T. Naughton

Published online: 27 April 2013

Abstract Inefficient competition in emissions taxes for foreign direct investment creates benefits from international cooperation. In the presence of cross-border pollution, proximate (neighboring) countries have greater incentives to cooperate than distant ones as illustrated by a model of tax competition for mobile capital. Spatial econometrics is used to estimate participation in 110 international environmental treaties by 139 countries over 20 years. Empirical evidence of increased cooperation among proximate countries is provided. Furthermore, strategic responses in treaty participation vary across country groups between OECD and non-OECD countries and are most evident in regional agreements.

Keywords Environmental agreements · Foreign direct investment · Spatial econometrics

JEL Classification F53 · Q58

1 Introduction

Among the many controversies surrounding globalization, one of the fiercest is the effect of increased international commerce on environmental quality. Central to the

R.B. Davies (✉)
School of Economics, University College Dublin, Newman Building (G215), Belfield, Dublin 4, Ireland
e-mail: ronbdavies@gmail.com

H.T. Naughton
Department of Economics, University of Montana, 32 Campus Drive #5472, Missoula, MT 59812-5472, USA
e-mail: helen.naughton@umontana.edu

public and academic debate is the implications of competition in environmental policy for foreign direct investment (FDI). As discussed by Rauscher (1995, 1997), if firms seek to avoid emissions taxes (the “pollution haven effect”), then this can lead to governments lowering such taxes in order to attract firms (the “race to the bottom”). Thus, as firms become mobile, competition between hosts can then lead to sub-optimal emissions taxes. This inefficiency then provides a role for international environmental treaties that can coordinate standards across countries and lower world-wide pollution levels. While several papers have considered international competition in environmental policy and others have considered the relationship between FDI and the environment, none of the previous papers fully integrate these two ideas.

This paper provides an empirical contribution towards filling this gap. First, we develop a model of pollution tax competition with cross-border spillovers.[1] This simple model yields two key predictions. First, when cross-border spillovers are larger, Nash equilibrium taxes are lower. This is because if a country suffers pollution damages even if the firm locates elsewhere, it is better to host the firm and collect the benefits that hosting provides as this offsets at least some of the pollution damages. Second, when cross-border spillovers increase, the gain from cooperation (i.e. raising emissions taxes and lowering pollution) can increase. This, however, requires joint participation in raising taxes since it is not a unilateral best response to do so. This yields a testable prediction: that a country’s own treaty participation depends on that of others and that it is more responsive to the participation of nearby countries.

The second contribution of the paper uses spatial autoregression to test this idea. Using information on 110 multilateral environmental agreements (treaties) and 139 countries between 1980 and 1999, we find that the higher the treaty ratification by a country’s neighbors, the more treaties the country will itself ratify. Furthermore, this effect is declining in distance between countries just as the theory predicts when cross-border spillovers are declining in distance. This is direct evidence of international strategic interactions in environmental policy. In particular, given the sign of our coefficient, we find that policies are strategic complements, a key requirement for finding an inefficient “race to the bottom” in environmental standards. As such, it supports the contention that international economic agreements should be coupled with clauses related to environmental policy. In addition, we find that the strategic responses vary across country groups between OECD and non-OECD countries. When using participation in all treaties, we find that OECD members often have stronger effects on the treaty participation of other countries than do non-OECD countries. However, when separating out regional agreements that restrict their attention to a geographic area from those with a global focus, we find that both OECD and non-OECD countries have comparable influences in regional agreements while there is no evidence of interactions among global treaties.

The theoretical tax competition literature has demonstrated that the nature of the Nash equilibrium from tax competition for FDI is highly sensitive to the functional forms and parameters of the model. Depending on these choices, as discussed by Wilson’s (1986) seminal model, equilibrium taxes between jurisdictions can be strategic substitutes or strategic complements. As a result, Nash equilibrium taxes can be too

[1] See Mason (2005) for a recent overview of the evidence of cross-border pollution.

high or too low relative to their optimal level.[2] In part, this ambiguity arises due to changes in the elasticity of capital with respect to taxes since a rise in one country's tax can increase or decrease the sensitivity of investment to the other country's tax. As demonstrated by Rauscher (1995), Markusen et al. (1995), and Hoel (1997), including pollution externalities introduces additional ambiguities. In addition to tax sensitivity, ambiguities arise in the desirability of investment (since benefits to hosting must be compared to the environmental costs of hosting). Furthermore, Barrett (1994) finds that whether a race to the top or to the bottom in environmental taxes occurs can be determined by the market structure. Since these issues make it impossible to derive general results on the nature of tax competition equilibria even without cross-border spillovers, any results derived from a general model would be contingent on numerous additional assumptions. This is indeed what is shown by Fredriksson and Millimet (2002) who also consider strategic interaction in pollution abatement costs with cross-border pollution.[3]

This indicates that the nature of the interaction in environmental policies is an empirical question. To frame the empirics, we utilize a very simplified model that yields the commonly held (but not necessarily accurate) result that international competition for multinational enterprises (MNEs) leads to a race to the bottom in environmental policy. In order to motivate the weights used in the empirics, emissions not only cause pollution damages at their point of origin, but also overseas in the other country. The extent of these overseas damages depends on a parameter called the transfer coefficient. When the transfer coefficient is high (as it might be when countries are close to one another) these cross-border damages are higher.

In the Nash equilibrium of the tax setting game, governments set taxes too low for three reasons. First, as is well-known in the tax competition literature, since a government does not internalize the loss of hosting benefits for the other country, it will set sub-optimal taxes in order to attract FDI. Second, with cross-border pollution, a host government does not internalize the international pollution damages caused by FDI within its borders. Therefore it will overly encourage firms to invest in itself by implementing low taxes. Third, if a country does not host a given unit of capital, it will still suffer pollution damages due to cross-border pollution. This gives an additional reason to attract mobile capital. Combining these implies that Nash equilibrium tax rates will be too low compared to those that maximize the sum of the two countries' welfares. Furthermore, this third effect means that as the transfer coefficient rises (i.e. countries become closer to one another), Nash equilibrium taxes fall. At the same time, a rise in the transfer coefficient increases global damages from pollution. As

[2] Note that even the definition of the optimal level is subject to debate since the optimal tax depends on where the mobile firms' profits accrue. If a social planner is maximizing a function of the host countries' welfares, then she will not necessarily include the profits from FDI as a benefit from investment. This would then tend to lead to a tax rate greater than that which would be set if FDI profits accrue to the citizens of one of the host countries. This is why we use the term "optimal" rather than Pareto efficient since our model does not include FDI profits in the social planner's objective function.

[3] Their model differs in two key ways. First, they assume that the pollution is 'perfectly' cross-border implying the same pollution level is faced by the two countries. Second, their model does not involve any competition for capital. Instead, in their model equilibrium pollution abatement is too low because neither country can trust the neighbor to choose the higher, globally more efficient, level of pollution abatement.

such, when the distance between countries falls, the gain from joining an international environmental treaty (that raises emissions taxes) can increase.

This then gives us a testable prediction regarding emissions tax competition: treaty participation of nearby countries should tend to increase treaty participation of the country in question. Spatial econometrics provide a method of testing such interactions because they allow the econometrician to use the dependent variable from one observation (treaty participation by country i) as an explanatory variable in another observation (treaty participation by country j).[4] This method contrasts sharply with the literature on FDI and the environment which ignores the strategic interactions between countries, i.e. whether the environmental policy of one country is affected by the environmental policy of another.[5] Of those papers that do consider strategic interactions in environmental policy (but ignore the effects of FDI), they are limited either in their time series or country information.[6]

Using spatial probit techniques, Beron et al. (2003) and Murdoch et al. (2003) estimate strategic interactions in ratification of the Montreal and the Helsinki Protocols, respectively.[7] Beron et al. use trade-based, emissions-based, and contiguity weighting schemes for construction of the spatial lag to find no significant strategic interactions in ratification of the Montreal Protocol between their sample's cross-section of 89 countries. Murdoch et al. use a cross-section of 25 European countries to estimate the strategic interactions in Helsinki Protocol ratification using emissions-based weights. They model treaty participation in a two-stage setting, where in the first stage countries decide whether or not to ratify the Protocol and in the second stage they choose their level of sulfur emissions reduction. The authors find positive and statistically significant interaction effects in Helsinki Protocol ratification. Our study improves upon these studies in two ways. First, we employ panel data on 139 countries for 1980–1999, allowing us to control for contemporaneous effects of neighboring countries as well as country fixed effects. Second, we employ a more comprehensive measure of international cooperation that involves 110 treaties instead of using a single treaty.[8] This allows for the possibility that nations view treaties as substitutes for one

---

4 For a detailed discussion on the workings of spatial econometrics, see Anselin (1988).

5 Antweiler et al. (2001) find little evidence of an effect of FDI on SO_2 concentrations. Brunnermeier and Levinson (2004) provide a literature review of the studies considering the effect of host country environmental regulations on FDI. More recent studies include Jeppesen et al. (2002), Fredriksson et al. (2003), List et al. (2003), Javorcik and Wei (2004), Henderson and Millimet (2007), and Rose and Spiegel (2009). A recent working paper by Drukker and Millimet (2007) looks at the effects of U.S. states' inbound FDI as a function of home environmental regulation as well as neighboring states regulation. The evidence of the effect of environmental stringency on investment decisions has been mixed. In contrast to the FDI literature, Antweiler et al. (2001), Dean (2002), Harbaugh et al. (2002), Frankel and Rose (2005), Cole and Elliott (2003) and Naughton (2010) find that openness to trade improves the environment.

6 For a review of empirical tax competition studies see Brueckner (2003).

7 Congleton (1992) is one of the early studies looking at international environmental treaty formation. He focuses on one treaty and ignores possible strategic interactions between countries.

8 A related literature on preferential trade agreements finds a significant negative effect of distance on preferential trade agreements (PTAs). See Magee (2003), for example. The reason for strong effects of distance on PTAs would almost certainly be driven by trade costs which increase with distance—if trade costs are high (distance is high) then there would be less reason for trade and, thus, for trade agreements. In another line of literature on cross-border pollution effects, Sigman (2002) reveals evidence of free

another (i.e. if country j ratifies a treaty, country i will ratify an additional treaty although it may not be the same one).[9] In addition, by decomposing our broad number of treaties into regional and global ones, we are able to isolate potential differences as a treaty varies in its scope.

Eliste and Fredriksson (2004) find small positive strategic interactions in stringency of environmental regulations for the agricultural sector across 62 countries in 1992. The spatial lags in this study use weighting schemes based on trade relations, contiguity, and distance. It is not surprising that the estimated spatial lags are small in magnitude because of their focus on an immobile sector. Our study expands on the definition of environmental stringency and controls for country fixed effects.

Of the studies that do use panel data to estimate strategic interactions in environmental policy, all employ US state level data to estimate strategic interactions in environmental stringency. Fredriksson and Millimet (2002), Levinson (2003) and Fredriksson et al. (2004) all find that states compete in environmental stringency, as measured by an index developed by Levinson (2001). Levinson (2003) also finds competition across states in the hazardous waste disposal tax rates. Additionally, Fredriksson et al. (2004) allow for strategic interactions across different policy variables. They find that considering strategic interactions in a single policy setting provides lower bound estimates. This is an additional reason to use multiple treaties in our estimation. Although we use a comparable empirical approach, we work with international data. One of the primary difficulties in extending these state-level studies to international competition is that emissions taxes and other policies are very difficult to compare across countries due to the wide range of regulatory policies surrounding them. This is one of the primary advantages of using international environmental treaties as our variable of interest, since by definition these are comparable across countries.

The remainder of the paper proceeds as follows. The next section presents a simple theoretical model to frame the empirics. In Sect. 3 we overview the empirical approach and discuss the data. Section 4 discusses the empirical results and Sect. 5 concludes.

2 Theoretical model

As discussed above, any general theory of tax competition for FDI will be plagued by ambiguities that can only be resolved by making restrictive assumptions.[10] Since our goal in this section is to construct a model that motivates our empirical work including our choice of weights, rather than impose such restrictions ex-post we impose them at the beginning by choosing specific functional forms. This is the easiest

riding effects in river pollution emissions. In a later study, Sigman (2004) finds that bilateral trade between upstream and downstream countries reduces free riding, implying the presence of strategic trade effects.

[9] Roberts et al. (2004) and Egger et al. (2011) also estimate models determining treaty participation. However, neither of these studies allow for strategic interactions.

[10] Wilson (1999) and Gresik (2001) provide recent overviews of tax competition for FDI. Their literature reviews highlight the various ambiguities found in the literature both with and without pollution.

method of illustrating our underlying story: that proximity can increase the inefficiencies resulting from tax competition and increase the gain from cooperation.

Consider a multinational firm that invests in two countries, home and foreign. Foreign variables are denoted with *s. The timing of choices is that governments simultaneously choose emissions tax rates and then the MNE maximizes profits through its capital allocation. Using subgame perfection, we begin by describing the firm and work our way backwards. Production in each country uses capital (K) in a constant returns to scale technology. We normalize the production function so that output in home is K and output in foreign is K^*. This output is then sold on world markets according to the inverse demand curve:

$$P = A - \frac{B}{2}\left(K + K^*\right). \tag{1}$$

The firm faces three types of costs. First, it faces a cost of raising capital $\frac{\gamma}{2}(K + K^*)^2$. Second, it faces transportation costs between each country and the world market. Per-unit transportation costs from home are $\frac{\alpha}{2}K$ while those from foreign are $\frac{\delta}{2}K^*$.[11] Third it faces a tax on the emissions it creates in a given country. Emissions are a linear function of output, where units are again normalized so that home (foreign) emissions are $K(K^*)$. The per-unit home emissions tax is t and the per-unit foreign emissions tax is t^*. Combining these yields the firm's profit function:

$$\pi = \left(A - \frac{B}{2}\left(K + K^*\right)\right)\left(K + K^*\right) - \frac{\alpha}{2}K^2 - \frac{\delta}{2}K^{*2}$$
$$- tK - t^*K^* - \frac{\gamma}{2}\left(K + K^*\right)^2. \tag{2}$$

Taking tax rates as given, the first order conditions from this with respect to K and K^* are

$$A - B\left(K + K^*\right) - \alpha K - t - \gamma\left(K + K^*\right) = 0 \tag{3}$$

and

$$A - B\left(K + K^*\right) - \delta K^* - t^* - \gamma\left(K + K^*\right) = 0. \tag{4}$$

From these, we obtain the following effects of taxation:

$$\frac{dK}{dt} = -\frac{B+\gamma+\delta}{\Delta} < 0 \quad \text{and} \quad \frac{dK^*}{dt} = \frac{B+\gamma}{\Delta} > 0$$
$$\frac{dK}{dt^*} = \frac{B+\gamma}{\Delta} > 0 \quad \text{and} \quad \frac{dK^*}{dt^*} = -\frac{B+\gamma+\alpha}{\Delta} < 0$$

where $\Delta = (\alpha + \delta)(B + \gamma) + \alpha\delta > 0$. Thus, an increase in one country's tax drives FDI from that country to the other. It is also worth noting that total investment $K + K^*$

[11] Alternatively, these transportation costs could be increasing costs of hiring local factors such as labor. If the wage is an increasing convex function of labor hired, as would occur if other sectors use labor, then it is possible to derive labor cost functions as they depend on K and K^* that are comparable to these transport cost functions. This approach could also provide a link between these and the benefits of hosting. However, in the interest of simplicity and in order to better link the theory and empirics, we use this trade cost approach.

is decreasing in either tax rate. These results on the impact of taxes on capital (either in a given country or worldwide) are standard in the literature and are robust to generalizations of our functional forms.

Tax rates are chosen simultaneously by the two governments in order to maximize their own national welfares. Given the symmetry in the two country's problems, we focus on the home country.[12] Home welfare consists of three items. The first is a benefit of hosting FDI given by K^{λ} where $\lambda \in (0, 1)$. These benefits can arise, for example, from the firm's hiring of local factors or technological spillovers to the local economy (see Barba Navaretti and Venables 2006, for an overview of the theory and empirics of host country effects). The second is the damage from emissions. These are a function of both local emissions and those overseas. For home, damages are $K^{\theta} + aK^{*\theta}$ where $\theta \geq 1$ and $a \in (0, 1)$. This latter parameter is referred to as the transfer coefficient. Intuitively, this function allows for potentially increasing marginal damages for emissions in a given location and that, for a given level of emissions, overseas damages cause a smaller loss than do local emissions.[13] Third, there are the revenues collected on local emissions tK. Thus, home welfare is

$$Y\big(t, t^*\big) = K^{\lambda} + tK - \big(K^{\theta} + a\big(K^*\big)^{\theta}\big). \tag{5}$$

The best response home tax, $t(t^*)$, is implicitly given by

$$\frac{dY}{dt} = \big(\theta K^{\theta-1} - \lambda K^{\lambda-1} - t\big(t^*\big)\big)\frac{B+\gamma+\delta}{\Delta} + K - a\theta K^{*\theta-1}\frac{B+\gamma}{\Delta} = 0. \tag{6}$$

From this, we find four results. First, treating FDI as a parameter:

$$\frac{dt(t^*)}{dK} = \big(\theta(\theta-1)K^{\theta-2} - \lambda(\lambda-1)K^{\lambda-2}\big) + \frac{\Delta}{B+\gamma+\delta} > 0 \tag{7}$$

i.e. a rise in FDI increases home's best-response tax rate since pollution damages rise and the benefits of hosting decline. This would suggest that countries with greater inbound FDI have stronger environmental policies. Second, holding capital allocations constant,

$$\frac{dt(t^*)}{d\alpha} = \big(\lambda K^{\lambda-1} + t\big(t^*\big) - \theta K^{\theta-1}\big)\frac{B+\gamma+\delta}{\Delta} + a\theta K^{*\theta-1}\frac{B+\gamma}{\Delta} > 0. \tag{8}$$

Thus, for a given level of FDI, a country with higher trade costs will impose higher taxes. Third,

$$\frac{dt(t^*)}{dt^*} = \frac{((\theta(\theta-1)K^{\theta-2}-\lambda(\lambda-1)K^{\lambda-2})\frac{B+\gamma+\delta}{\Delta}+1+a\theta(\theta-1)K^{*\theta-2}\frac{B+\gamma+\alpha}{\Delta})\frac{B+\gamma}{\Delta}}{((\theta(\theta-1)K^{\theta-2}-\lambda(\lambda-1)K^{\lambda-2})(\frac{B+\gamma+\delta}{\Delta})+2)\frac{B+\gamma+\delta}{\Delta}+a\theta(\theta-1)K^{*\theta-2}(\frac{B+\gamma}{\Delta})^2} > 0, \tag{9}$$

[12] For simplicity, we assume that both λ and a are the same across countries. While the first is not necessary for our results, the second is useful in determining properties for the social planner's desired taxes as discussed below.

[13] Note that we could also consider a step function where it is only after emissions in a given location exceed a certain level that the marginal damages become increasing. However, since this complication does not aid us in providing a model to describe the empirical question, we omit it here.

i.e. tax rates are strategic complements. This is consistent with the concern that a cut in one nation's emissions taxes will reduce those elsewhere. Finally, we find that

$$\frac{dt(t^*)}{da} = -\left(\left(\theta(\theta-1)K^{\theta-2} - \lambda(\lambda-1)K^{\lambda-2}\right)\frac{B+\gamma+\delta}{\Delta} + 1\right) - a\frac{(B+\gamma)^2}{\Delta(B+\gamma+\delta)}\theta(\theta-1)K^{*\theta-2} - \frac{B+\gamma}{B+\gamma+\delta}\theta K^{*\theta-1} < 0 \quad (10)$$

indicating that as the transfer coefficient rises, home's best-response tax falls.[14] Graphically, this would be a shift in home's best response from the solid line to the dashed line in Fig. 1 when a rises from a_1 to a_2. The intuition for this change is straightforward. As the transfer coefficient rises, the damage home suffers from foreign emissions rises. As such, home has a greater incentive to "steal" that investment since this allows it to enjoy the benefits of hosting and collect additional emissions taxes, offsetting a portion of the environmental damages. Given the symmetry in the two nation's objectives, a similar set of results holds for the foreign best response $t^*(t)$.

The Nash equilibrium is where best responses coincide. Denote these by t^n and t^{*n}. Graphically, this is point A in Fig. 1. As the transfer coefficient rises, both responses shift, resulting in lower equilibrium tax rates. This is shown in Fig. 1 by a shift from A to B. Note that as tax rates fall, total investment (and total environmental damages) rise.

In order to contrast the non-cooperative equilibrium with cooperation, consider the tax choices of a social planner who maximizes $W(t,t^*) = Y(t,t^*) + Y^*(t,t^*)$, the sum of national welfares. The first order conditions for this problem result in cooperative tax rates t^c and t^{*c}. Note that at the non-cooperative equilibrium levels:

$$\left.\frac{dW}{dt}\right|_{t=t^n, t^*=t^{*n}} = \left(\lambda K^{*\lambda-1} + t^{*n} - \theta K^{*\theta-1}\right)\frac{B+\gamma}{\Delta} + a\theta K^{\theta-1}\frac{B+\gamma+\delta}{\Delta} > 0 \quad (11)$$

as long as foreign welfare is increasing in K^* (i.e. hosting is desirable). A similar condition holds for the foreign tax. This implies that non-cooperative tax rates are lower than their cooperative levels and that emissions taxes are inefficiently low. This difference arises from the fact that, when setting its unilaterally optimal tax, a nation ignores the benefits that investment generated for the other nation. Further, it ignores the cross-border pollution its local production causes. Note that this result does not hold in general as discussed by Markusen et al. (1995) since under different

[14] The unambiguous nature of this result comes from the assumption that damages are additively separable across countries. If this is not the case, as for example when damages are $(K + aK^*)^\theta$, in addition to the effect discussed above, a rise in a implies a rise in the marginal damages from domestic investment as well. As discussed in relation to (7), this tends to lead to an increase in the best response tax. Combining these results in an ambiguous effect that depends, among other things, on θ, which governs the degree of non-linearity.

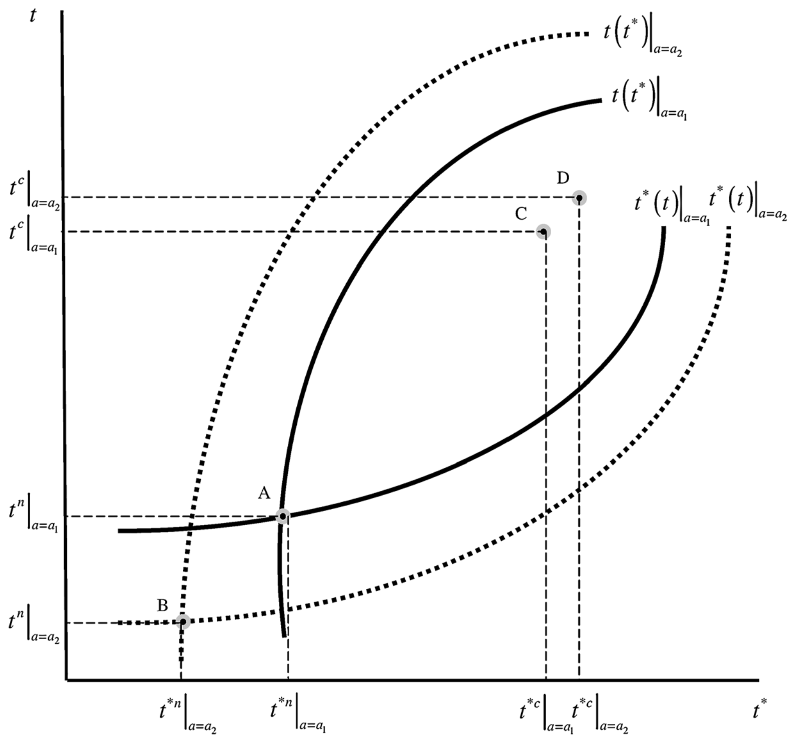


Fig. 1 Change in equilibrium taxes when a rises from a_1 to a_2

assumptions (particularly very large damages from pollution) inefficiently high taxes are possible.[15]

To consider how the cooperative solution varies with the transfer parameter, define

$$\Phi \equiv \frac{d^2W}{dt^2} = \left(\lambda(\lambda-1)K^{\lambda-2} - (1+a)\theta(\theta-1)K^{\theta-2}\right)\left(\frac{B+\gamma+\delta}{\Delta}\right)^2 + \left(\lambda(\lambda-1)K^{*\lambda-2} - (1+a)\theta(\theta-1)K^{*\theta-2}\right)\left(\frac{B+\gamma}{\Delta}\right)^2 - 2\frac{B+\gamma+\delta}{\Delta} < 0$$

$$\Gamma \equiv \frac{d^2W}{dt^{*2}} = \left(\lambda(\lambda-1)K^{*\lambda-2} - (1+a)\theta(\theta-1)K^{*\theta-2}\right)\left(\frac{B+\gamma+\alpha}{\Delta}\right)^2 + \left(\lambda(\lambda-1)K^{\lambda-2} - (1+a)\theta(\theta-1)K^{\theta-2}\right)\left(\frac{B+\gamma}{\Delta}\right)^2 - 2\frac{B+\gamma+\alpha}{\Delta} < 0$$

and

[15] Furthermore, McAusland (2002) and Eerola (2004) find that, due to the exclusion of multinational firm profits from the countries' objective functions that taxes are inefficiently high compared to the global welfare maximum. Similarly, since our combined welfare measure does not include multinational profits optimal taxes are higher than those that would arise from maximizing the sum of Y, Y^*, and the firm's profits.

$$\begin{aligned}\Omega \equiv \frac{d^2W}{dt\,dt^*} &= -\big(\lambda(\lambda-1)K^{\lambda-2} - (1+a)\theta(\theta-1)K^{\theta-2}\big)\frac{B+\gamma}{\Delta}\frac{B+\gamma+\delta}{\Delta} \\ &\quad - \big(\lambda(\lambda-1)K^{*\lambda-2} - (1+a)\theta(\theta-1)K^{*\theta-2}\big)\frac{B+\gamma}{\Delta}\frac{B+\gamma+\alpha}{\Delta} + 2\frac{B+\gamma}{\Delta} \\ &> 0\end{aligned}$$

where $\Psi \equiv \Phi\Gamma - \Omega^2 > 0$ by the social planner's second order conditions. From this, we see that

$$\begin{aligned}\frac{dt^c}{da} = \Psi^{-1}\frac{\theta}{\Delta}\big(&\Gamma\big(K^{*\theta-1}(B+\gamma) - K^{\theta-1}(B+\gamma+\delta)\big) \\ &- \Omega\big(K^{\theta-1}(B+\gamma) - K^{*\theta-1}(B+\gamma+\delta)\big)\big)\end{aligned}$$

and

$$\begin{aligned}\frac{dt^{*c}}{da} = \Psi^{-1}\frac{\theta}{\Delta}\big(&\Phi\big(K^{*\theta-1}(B+\gamma) - K^{\theta-1}(B+\gamma+\alpha)\big) \\ &- \Omega\big(K^{\theta-1}(B+\gamma) - K^{*\theta-1}(B+\gamma+\delta)\big)\big).\end{aligned}$$

When trade costs are sufficiently similar (resulting in similar levels of investment) and/or θ is close to one (i.e. emissions costs are nearly linear), both of these are positive.[16] As the transfer coefficient rises, environmental damages rise from a given amount of capital.[17] This reduces the socially desired level of total capital, leading to higher cooperative tax rates and lower overall investment (a shift from C to D in Fig. 1). This result is comparable to that of Cremer and Gahvari (2004), who study competition in commodity taxes and emissions taxes with cross-border pollution. They too find that harmonization of emissions taxes above the Nash equilibrium level across countries reduces aggregate emissions and increases overall welfare. Thus, when countries are sufficiently similar and/or emissions damages are not too convex, as the transfer coefficient rises, the gap between the Nash and cooperative taxes rises. As a result, the total gains from cooperating and increasing tax rates increases as the transfer coefficient increases.

To extend this result to the sustainability of an agreement, we can embed the above one-shot game into an infinitely repeated game where the common discount rate is $\rho < 1$. When countries are symmetric, home's future gains from cooperation

[16] When emissions damages are strictly convex and investment levels differ due to differing trade costs, in addition to the above tradeoffs, the social planner chooses to set different taxes in order mitigate emissions costs by setting a higher tax in the low cost country (since investment, and thus marginal emission damages, will be higher here). Similar incentives arise when transfer coefficients differ between countries. When the transfer coefficient rises, marginal emissions cost rise, increasing the incentive to use a tax wedge to discourage investment in the low trade cost location. The net impact on taxes is ambiguous. We omit a full treatment of this situation to conserve space for the empirical analysis.

[17] An alternative modeling choice would be to have the transfer coefficient represent the percent of emissions that "land" in the overseas country, leaving only $(1-a)K$ emissions in home. This yields similar results regarding Nash equilibrium taxes compared to the social planner's taxes since as a rises, a country's incentive to attract FDI rises since its pollution costs fall. Under this assumption, however, worldwide pollution damages are invariant to the transfer coefficient, implying that the social planner's desired taxes do not change when a changes. Nevertheless, here too the gains from cooperation rise as the distance between countries falls.

are $\frac{\rho}{1-\rho}(Y(t^c, t^{*c}) - Y(t^n, t^{*n})) > 0$ which are rising with the transfer coefficient. Since cooperation requires that this is greater than the one shot gain from deviation, $(Y(t(t^{*c}), t^{*c}) - Y(t^c, t^{*c})) > 0$ as long as ρ is sufficiently close to one, the gain from cooperation will rise faster than the gain from deviation making cooperation more likely.[18]

If the damages from cross-border pollution are falling in distance, i.e. a is inversely related to the distance between countries, then proximate countries will have a greater incentive to cooperate than distant ones. If participation in international environmental agreements is a sign of such cooperation, the theory predicts that nearby countries may be more likely to jointly sign on to environmental agreements than distant countries. In the next section, we turn to discussing the empirical methods used to test for such patterns.

3 Empirical approach and data

If competition for FDI leads to inefficiently low taxes and conversely higher gains from cooperation, this should be evidenced in the data on environmental treaty participation by the finding that one country's treaty participation depends on that of others. Furthermore, if due to cross-border spillovers these gains are greater for nearby countries, then a country's own treaty participation should depend more on the participation of proximate countries rather than distant ones. In this section we use participation in international multilateral environmental treaties to measure cooperation in environmental policy. The set of multilateral environmental treaties and amendments to these treaties is large and growing.[19] We use treaty participation data provided by Mitchell (2002–2008). By February 2009, the International Environmental Agreements Database Project had coded ratification data by country for 340 multilateral agreements. Of these, 247 multilateral treaties affected our sample countries between 1980–1999.[20] We further reduced our sample of treaties to 110 to include only those that had explicit environmental targets or requirements to be met by participating countries.[21] The dependent variable in our empirical model is a log of treaty participation measured as the count of treaties a country has ratified.[22,23]

[18] For a more complete discussion of the sustainability of environmental agreements, see the contributions of Dellink et al. (2008) or Chander and Tulkens (2006, 1995) among others.

[19] For an overview of international environmental treaties see Mitchell (2003).

[20] The appendices provide participation information for the individual treaties and the countries in the sample.

[21] We found similar results when using all possible treaties. These results are available on request.

[22] Note that countries that initially sign treaties must also ratify the treaty to become a party. We use ratification as this brings policy that much closer to actual implementation with economically meaningful impacts. Further note that some environmental treaties may be negotiated but never actually make it to the ratification stages. Therefore, our dependent variable excludes these treaties. It is likely that some environmental treaties in our sample also faced difficult times during negotiations but were ratified after the end of the sample. With no data on treaties that may have been negotiated but never signed, it is difficult to determine what the effect of these treaties would be on the estimated models.

[23] Because different treaties deal with different environmental problems and some may have a stronger impact on national environmental policy than others, this measure is best considered a proxy for the strict-

Our empirical specification follows Fredriksson and Millimet (2002):

$$E_{it} = \rho \sum_{j \neq i} \omega_{ij} E_{jt} + \varphi FDI_{it} + x_{it}\beta + Country_i + Year_t + \varepsilon_{it} \tag{12}$$

where E_{it} is the log of treaty participation by country i in year t; ω_{ij} is the time invariant weight assigned to country j by country i; E_{jt} is the log of treaty participation by country j in year t; ρ is the spatial lag coefficient that measures strategic interaction in treaty participation; FDI_{it} is log of FDI flow into country i in year t; x_{it} is a vector of country i characteristics in year t; $Country_i$ are country fixed effects; $Year_t$ are year fixed effects; and ε_{it} represents idiosyncratic shocks uncorrelated across countries and over time.[24] Our sample consists of an unbalanced panel of 139 countries between 1980 and 1999. The sample of countries is shown in Fig. 2.

The spatial lag, $\sum_{j \neq i} \omega_{ij} E_{jt}$, is the weighted average of other countries' treaty participation. The coefficient on the spatial lag provides information about the strategic interactions in treaty participation and our theoretical model predicts it to be positive (i.e. environmental policies are strategic complements). That is if a country's neighbors increase treaty participation in a given year, then the country tends to increase its participation as well.[25] It is important to note that the spatial lag introduces an endogeneity problem inherent to spatial autoregression: E_{it} depends on E_{jt} and E_{jt} on E_{it}. This gives us the first endogenous variable that we will need to control for.

While the theory suggests that the weights used in the construction of the spatial lag should be declining in distance (increasing in cross-border pollution), it does not suggest a specific form. Similar to Levinson (2003), the results presented in this paper use the following specification of spatial weights, which we refer to as ω_1:

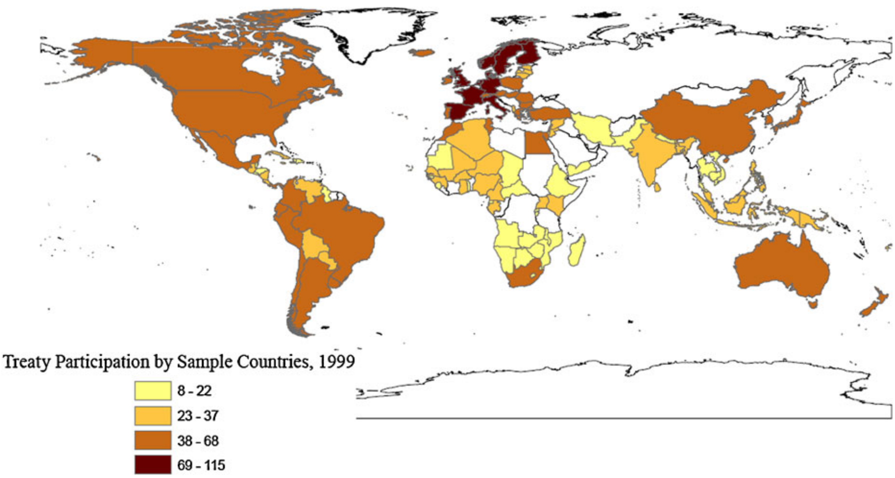
$$\omega_{ij} = 1/d_{ij}^2 \Big/ \sum_{k \neq i} 1/d_{ik}^2 \tag{13}$$

where d_{ij} is the distance between country i and country j. The sum in the denominator ensures that our spatial lag is a weighted average not just a weighted sum of other countries' treaty participation. This so-called "row standardization," where the sum

ness of a country's overall environmental policy. While this underlying latent variable can be thought of as cardinal, the proxy itself is ordinal since it measures the number of treaties in which a given country participates. Assuming that the two are positively correlated, a change in an exogenous parameter that increases treaty participation would tend to increase environmental stringency. An earlier version of the paper using the non-logged number of treaties found comparable results. In addition, the earlier version estimated the regression separately for treaties that applied to water, air, or other types of pollution. The results for the different categories were broadly similar to those reported here.

[24] Our treaty participation variable is the log of 1 + the number of treaties a country has ratified. The reason for adding one is that there are two observations at the start of our sample for which no treaties were ratified. If we exclude these two observations and do not add one to the number of ratified treaties, comparable results are found.

[25] A negative spatial lag suggests that an increase in proximate countries' treaty participation would reduce treaty participation. This type of dynamic could arise if the emissions tax response functions are strategic substitutes (i.e. best responses have a negative slope). As discussed above, generalized versions of emissions tax competition show that this is indeed a theoretical possibility although one contradicted by most of our estimates.



Included countries: Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Barbados, Belarus, Belize, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Republic, Chad, Chile, China, Colombia, Congo, Dem. Rep., Congo, Republic of, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Czech Republic, Denmark, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia, The, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea, Republic of, Latvia, Lebanon, Lesotho, Lithuania, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Rwanda, Senegal, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, St. Kitts & Nevis, St. Lucia, St.Vincent & Grenadines, Swaziland, Sweden, Switzerland, Syria, Taiwan, Tanzania, Thailand, Togo, Trinidad & Tobago, Tunisia, Turkey, USA, Uganda, Ukraine, United Kingdom, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

Fig. 2 Treaty participation by sample countries, 1999

of weights for each country equals one, is standard in spatial autoregression analysis. We also consider the following two alternative weighting schemes, ω_2:

$$\omega_{ij} = \frac{\min}{d_{ij}} \Big/ \sum_{k \neq i} \frac{\min}{d_{ik}} \tag{14}$$

where min stands for the minimum of distances between all country pairs, and ω_3:

$$\omega_{ij} = \exp\left(-\frac{d_{ij}}{1000}\right) \Big/ \sum_{k \neq i} \exp\left(-\frac{d_{ik}}{1000}\right). \tag{15}$$

These weights are a function of the distance between countries, d_{ij}, but also the remoteness of country i. Consider a thought experiment where we are keeping all but one country j's location relative to i fixed and we move j further away. Under ω_1, the weight of j falls by $\frac{d\omega_{ij}}{dd_{ij}} = \frac{-2}{d_{ij}}\omega_{ij}(1 - \omega_{ij})$. Under ω_2, it falls by $\frac{d\omega_{ij}}{dd_{ij}} = -\frac{1}{d_{ij}}\omega_{ij}(1 - \omega_{ij})$. Under ω_3, it falls by $\frac{d\omega_{ij}}{dd_{ij}} = \frac{-1}{1000}\omega_{ij}(1 - \omega_{ij})$. The comparison across schemes, however, depends on both the initial weight within that scheme as well as on the distance. If the initial weight of j was the same across schemes, then for countries with distance less than 2000 km, ω_1 penalizes distance the most whereas ω_3 penalizes it the least. For countries past this distance, however, ω_3 would result in the greatest decline in the weight. Further, as an alternative thought experiment, consider moving a given country i to a more remote location that increases its distance to all other countries. This can then reverse the ordering of the different weighting schemes. Therefore although all three schemes result in weights decreasing with distance, the rate at which they do so varies in complex ways and there is no straightforward ordering of the degree to which they penalize distance.

Similar to Cole et al. (2006) FDI is our other endogenous variable.[26] Our theoretical model includes FDI in the government's problem of choosing emissions taxes and emissions taxes influence the capital owner's allocation of FDI across countries. Therefore, we include FDI as a determinant of treaty participation and instrument for it as described below to control for the endogeneity. Consistent with the theoretic results in Eq. (12), we anticipate a positive coefficient on FDI. Note that although it may not necessarily be the case that a given treaty directly affects a multinational firm, to the extent that treaty participation is correlated with policies that do have a direct impact, our estimates are informative regarding the nature of competition for FDI.

In addition to the endogenous spatial lag and FDI variables, the model includes a set of exogenous variables. Table 1 provides the definitions and sources for each variable. GDP and population together control for the size of the economy and its average income. Following other studies, we expect to find that large economies are likely to participate in more international agreements. On the other hand, holding GDP constant, increasing population decreases GDP per capita. If environmental quality (provided by increased standards and treaty participation) is a normal good then the income effect captured by population would lead to a negative coefficient. To control for country i's trade costs, we utilize the logged inverse of openness, that is, GDP over the sum of exports and imports.[27] Although a rough measure of trade costs, the advantage is its availability and indeed it is arguably the most commonly used proxy for trade costs in the literature.[28] The model suggests that higher trade costs should increase treaty participation. A country's political climate is captured through the political freedom variable. Political freedom comes with improved information about environmental issues and ability of citizens to impact government policy. Hence, presuming that citizens prefer strong environmental standards, political freedom should increase treaty participation.

Finally, we include country fixed effects to control for time-invariant and slow changing characteristics of each country such as education, population growth rates, the presence of forested land (which act as carbon sinks, lowering environmental

[26] Ederington and Minier (2003), Fredriksson et al. (2003), and List et al. (2003) also argue that environmental regulation can be impacted by FDI.

[27] This measure was used by Neumayer (2002) in his study of environmental treaty participation. When it was found significant, the estimates suggest that more open countries participate in more agreements.

[28] Managi et al. (2009) also include this measure of trade openness in estimating the determinants of treaty participation.

Table 1 Variable definitions and data sources

Variable	Description	Source
Ln(Treaty participation)	Ln(1 + number of treaties ratified)	Mitchell (2002–2008) (IEAD).
Ln(FDI)*	Ln(FDI flow − minimum FDI flow + 1), where FDI flow is in constant $millions.	UNCTAD (2012) (FDI Database)
Ln(Trade Costs)	ln(GDP/(Exports + Imports))	Heston et al. (2002) (PWT 6.1)
Ln(GDP)	Ln of GDP ($, constant)	Heston et al. (2002) (PWT 6.1)
Ln(Population)	Ln of population (in 1,000s)	Heston et al. (2002) (PWT 6.1)
Freedom Index	14 − (CL + PR), where CL is the civil liberties index and PR is the political rights index. CL and PR vary between 1 and 7 and higher numbers indicate lower freedom.	Freedom House (2005)
Ln(Market Potential)	Distance weighted average of other countries' GDP, matrix of weights is the non-row-standardized version of the one used in construction of the spatial lag.	GDP from Heston et al. (2002), distances from CEPII (2009)
Urban Percentage	Urban population (% of total population)	World Bank, World Development Indicators 2004

*FDI flow is negative for some observations, thus to avoid dropping these in the log specification we scale up the variable

damages), and so on.[29] Thus, our results are driven by changes in treaty participation between 1980–1999 and not by pre-1980 participation. Year fixed effects filter out the impact of country-invariant factors including global macroeconomic conditions, the number of treaties available in a given year, and so forth. This also controls for the possibility that the spatial lag, which generally increases over time, is simply capturing some trend in overall treaty participation. In addition, these year effects filter global averages and totals within a given year, one example of which would be overseas investment (K^*), which affects the home tax rate by changing the marginal damages from overseas production, or average foreign trade costs, which affect the sensitivity of capital decisions to the home tax rate.

[29] A previous version of the paper included additional control variables including export diversification and unemployment. This was achieved at the cost of reducing the number of countries. Qualitatively similar results were found however. In addition, that version of the paper excluded country fixed effects from some estimates but included time-invariant variables such as the area of a country. Here, these are captured by the country fixed effects which are used in all regressions. These alternative results are available on request.

Estimating Eq. (12) using OLS would provide biased estimates because of the endogeneity problems. We use instrumental variable (IV) estimation instead of spatial maximum likelihood (ML) estimation for two reasons. First, IV estimation provides consistent estimates even in the presence of spatially correlated errors (Kelejian and Prucha 1998). Second, this approach facilitates the endogeneity of FDI and inclusion of more than one spatial lag discussed in Sect. 4 below. Brueckner (2003) describes both IV and ML methodologies used in estimation of strategic interactions. Furthermore, we typically use the generalized method of moments (GMM-IV) instead of the two-stage least squares (2SLS) because, with heteroskedastic errors GMM-IV is more efficient (Baum et al. 2003).

As we have two endogenous variables, we require at least two excluded instruments. The first of these is the distance weighted average of population, using the same weights as those used to calculate the spatial lag. As will be seen in the results, a country's own population is an important determinant of treaty participation. This makes the weighted average of population a strong instrument for the weighted average of other countries treaty participation. Further, since there is no obvious reason to expect that a country behaves differently when its neighbors have large populations instead of small ones, this variable should be excludable (particularly in light of the country effects which capture invariant factors such as geography).[30] In unreported results we included the weighted average of population and utilized various other weighted averages as excluded instruments. In these estimates, which are available on request, the weighted average of population was never significant for the ω_1 and ω_2 weighting schemes and was significant at the 10 % level for ω_3 only when using the Fuller(4) estimator (which is described below). This supports the excludability of this instrument. The second excluded instrument is market potential, defined as the weighted sum of other countries' GDPs using $1/d_{ij}$ as the weight.[31] The rationale here is twofold. First, as will be seen, GDP is also significantly correlated with treaty participation. In the literature estimating the degree of competition for FDI via taxes or labor policies, both the weighted average of population and GDP are common excluded instruments.[32] Second, proximity to other markets is often significantly correlated with FDI which tends to come from large economies but is deterred by distance (see Blonigen et al. 2007 for more discussion). As with the weighted average population, it is not clear why one should expect the GDP elsewhere to directly impact a country's own treaty participation, particularly when controlling for country and time

[30] One possible concern is that this measure is capturing proximity to large markets that may present future economic opportunities. As such, a country may choose to use environmental policy today in an attempt to attract and lock-in FDI for the future. A similar issue could arise for market potential. Although this is potentially controlled for by the country and year effects, in unreported results we also included the distance-weighted population or GDP growth rates of other countries as an additional control variable. These were never significant and did not alter the main findings.

[31] In unreported results, we instead used the distance-weighted average of political freedom rather than one of these two weighted averages and obtained qualitatively similar results. Inclusion of all three weighted averages resulted in rejection of valid overidentification restrictions; hence we do not include it in the reported results even though comparable estimates are found. These regression results are available upon request.

[32] Examples include Devereux et al. (2008), Klemm and van Parys (2012), and Davies and Vadlammanti (2013).

Table 2 Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Treaty Participation*	2178	10.74	8.85	0	50
Ln(Treaty Participation)	2178	2.21	0.72	0	3.93
Spatial Lag, ω_1	2178	2.20	0.51	0.72	3.62
Spatial Lag, ω_2	2178	2.21	0.34	1.28	3.16
Spatial Lag, ω_3	2178	2.21	0.53	0.81	3.41
Ln(FDI flow)	2178	8.70	0.42	7.85	12.58
Ln(Trade Costs)	2178	−4.07	0.60	−6.09	−2.21
Ln(GDP)	2178	17.28	2.06	11.94	22.94
Ln(Population)	2178	9.06	1.82	3.71	14.04
Freedom Index	2178	7.08	3.86	0	12
Ln(Market Potential)	2178	7.51	1.26	4.44	12.16
Urban Percentage	2178	0.51	0.23	0.04	1

*Regression equations use Ln(Treaty Participation)

dummies.[33] The third excluded instrument is urbanization. As discussed by Blonigen and Piger (2011), this is often a significant predictor of FDI.[34] In unreported results, we moved market potential and urbanization from excluded instruments to included instruments one at a time. When doing so, this additional included variable was never significant.

Summary statistics for each of the variables are reported in Table 2. We also provide treaty participation information by year and treaty type in Table 3 and Table 4, respectively. Before continuing to the results, it is important to note that our data form an unbalanced panel, primarily due to missing data for the earlier years in the sample. This has two implications. First, as with any estimation attempt, there is a concern that the sample may be non-random, introducing sample selection bias. In truth, this is a potential concern in our data as the missing observations are most common in poorer countries and in transition economies (which, prior to the dissolution of the USSR, did not exist). Second, and of particular concern in spatial estimation, is that when a country is missing from a given year of data it does not factor into the construction of the spatial lag. This does two things. First, whenever a country that should be included cannot be, there is mis-measurement of the spatial lag. Second, when a country enters or leaves the construction of the lag, it changes the weights

[33] The model predicts that trade costs matter when setting environmental policy because of how they influence investment behavior and output. Thus, the realized outcome is what is important, i.e. the exports factoring into trade openness, not merely the potential for exporting (excepting the issue raised in Footnote 30). Thus, after controlling for actual trade, market potential should be excludable.

[34] Note that since we are estimating a country's total inbound FDI flows, we do not control for parent country variables as bilateral FDI flow regressions do (e.g. Eaton and Tamura 1994, or Blonigen and Davies 2004).

Table 3 Number of observations, mean participation and max participation by year

Year	Obs.	Mean participation	Max participation
1980	92	6.7	21
1981	92	7.2	22
1982	95	7.3	24
1983	95	7.8	27
1984	99	7.8	28
1985	99	8.2	29
1986	101	8.6	30
1987	103	8.9	30
1988	104	9.1	32
1989	100	9.8	33
1990	107	9.9	33
1991	110	10.5	34
1992	117	11.1	37
1993	119	11.4	39
1994	124	12.3	41
1995	124	13.2	44
1996	128	13.7	47
1997	125	14.3	50
1998	125	14.9	50
1999	119	16.3	50
Total	2,178		

for all countries due to the row standardization of the weights. This introduces variation into the spatial lag not due to changes in treaty participation, but by construction of the weighted average. In an attempt to examine how these might affect our results, in unreported results we split the sample into two, one from 1980–1990 and one from 1990–1999. In particular, as can be seen in Table 3, the latter sample had relatively few missing observations. In both subsamples, we found results similar to those obtained from the full sample although significance was weaker. Finally, our treaty measure only includes treaties that were ratified, not those which failed. It is possible that failed treaties influence the decision of participating in successful ones introducing measurement error into our participation variables. It is important to keep these limitations in mind when interpreting the results.[35]

[35] Wang and Lee (2013a, 2013b) compare different spatial autoregressive estimators (including some using imputed values for missing dependent variables). In our case, however, we also have missing data for explanatory variables (for example, as is the case with former members of the USSR prior to independence). As such, this approach is not feasible in our data.

Table 4 Types of treaties with average participation in 1980, 1990 and 1999

Type of treaty	Number of treaties	Average participation in 1980	Average participation in 1990	Average participation in 1999
Marine	27	7.8	12.4	16.6
Nature	24	6.7	12.5	18.5
Fish	17	2.8	4.4	7.1
Nuclear	12	7.8	13.9	24.3
Air	11	0	3.9	28.7
Hazardous Materials	7	0	0	6.7
Freshwater	6	0.7	2.2	4.2
Military	3	22.7	31.7	56.3
Lead	1	32	35	41
Energy	1	4	5	8
Transboundary	1	0	0	22
Total	110			
Regional	66	3.2	5.5	8.7
Global	34	7.1	13.4	30.5
Global-Marine	10	17	24.9	31.8
Total	110			

4 Results

We begin our analysis by using the baseline weighting matrix ω_1 and illustrate how the results compare across different methods of dealing with endogeneity. We then explore the robustness of the results to different weighting schemes, how countries respond differently to wealthier and poorer nations, and how the results compare between treaties with a regional focus and those with a global focus.

4.1 Baseline results

Table 5 begins with an initial specification without a spatial lag and an exogenous treatment of FDI. In column (2) we instrument for FDI but still exclude the spatial lag. In columns (3)–(6) we include both FDI and the spatial lag as endogenous variables. Column (1) is estimated using OLS. Columns (2) and (3) use GMM-IV. Columns (4), (5), and (6) undertake different IV estimation approaches: two-stage least squares (2SLS), jackknife two-stage least squares (JN2SLS), and the Fuller (1977) estimator. The advantage of these latter two is that although more computationally burdensome, unlike GMM-IV or 2SLS, the results are more robust to weak instruments and do not suffer from small sample biases. In Monte Carlo experiments, Hahn et al. (2004) find that, particularly in the presence of weak instruments, these estimators outperform other options. This sequence of specifications allows us to determine if any biases

Table 5 Log of treaty participation

Variables	(1) OLS	(2) GMM-IV	(3) GMM-IV	(4) 2SLS	(5) JN2SLS	(6) Fuller(4)
Spatial Lag			0.142**	0.150**	0.150**	0.149**
			(0.066)	(0.067)	(0.072)	(0.065)
Ln(FDI)	0.002	0.397*	0.395*	0.345	0.345	0.280
	(0.015)	(0.228)	(0.231)	(0.236)	(0.258)	(0.189)
Ln(Trade Costs)	−0.044***	0.054	0.051	0.039	0.039	0.023
	(0.016)	(0.060)	(0.060)	(0.061)	(0.067)	(0.050)
Ln(GDP)	0.109***	0.072**	0.072**	0.071**	0.071**	0.078**
	(0.022)	(0.034)	(0.033)	(0.033)	(0.036)	(0.030)
Ln(Population)	−0.709***	−0.288	−0.309	−0.358	−0.358	−0.427**
	(0.054)	(0.253)	(0.253)	(0.258)	(0.281)	(0.211)
Freedom Index	0.001	0.008*	0.008*	0.007	0.007	0.006
	(0.002)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
Constant	5.452***	−0.327	−0.501	0.244	0.244	1.198
	(0.564)	(3.440)	(3.508)	(3.587)	(3.917)	(2.926)
Observations	2178	2178	2178	2178	2,178	2178
R-squared	0.968	0.956	0.957	0.960	0.960	0.963
H_0: *equation underidentified*						
Kleibergen-Paap rk LM		18.679***	18.382***	18.382***	18.382***	18.382***
(P-value)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
H_0: *instruments are weak*						
Kleibergen-Paap rk Wald F		9.879	6.464	6.464	6.464	6.464
Range of critical values for Stock-Yogo weak ID test		7.25–19.93	5.45–13.43	5.45–13.43	5.45–13.43	5.45–13.43
H_0: *instruments are valid*						
Hansen J Statistic χ^2		0.001	0.993	0.993	0.993	1.017
(P-value)		(0.973)	(0.319)	(0.319)	(0.319)	(0.313)
H_0: *FDI exog* χ^2		3.086*	2.773*	2.773*	2.773*	2.773*
(P-value)		(0.079)	(0.096)	(0.096)	(0.096)	(0.096)

All specifications include year and country fixed effects. Robust standard errors in parentheses unless otherwise specified. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

are present in the initial econometric specification. All specifications in subsequent tables are estimated using GMM-IV and Fuller.[36]

Beginning with FDI, across specifications the point estimate is positive as anticipated. However, this coefficient is only significant when dealing with its endogeneity and utilizing the GMM-IV estimator.[37] Allowing for the endogeneity of FDI also noticeably increases the point estimates. Turning to the exogenous controls, as antici-

[36] We opted for Fuller rather than JN2SLS as the Fuller estimator was less computationally demanding.

[37] As reported at the bottom of the table, we reject the null that FDI should be considered exogenous.

pated, GDP is positive and significant while population is negative and significant for most specifications. These results are suggestive of larger, wealthier countries ratifying more treaties. When it is significant, the freedom index is positive. Trade costs, meanwhile, are significantly negative when not dealing with the endogeneity of FDI. However, after controlling for this source of endogeneity bias, the point estimate becomes positive as predicted by theory (albeit insignificant). Although the controls are sometimes insignificant, it must be remembered that all specifications include both country and year fixed effects and that this may be due to relatively little variation within a year or for a given country.

Turning to the spatial lag, across estimation methods, we find positive and significant coefficients of approximately 0.15. Thus, if there was a standard deviation increase in the weighted (logged) treaty participation by all other countries, a given nation would increase its treaty participation by about 8 %.[38] This positive coefficient is consistent with the theory-predicted strategic complementarity of environmental policy, a condition that is crucial to the possibility of an inefficient race to the bottom in environmental policy.

Finally, different test statistics are reported at the bottom of Table 5. Our equations are never underidentified (using the Kleibergen-Paap test). There is some evidence that our instruments may be weak (using the Stock-Yogo weak ID test) and hence we provide the Fuller(4) results that perform well even with weak instruments (Hahn et al. 2004). Finally, Hansen J overidentification test provides evidence that our instruments are valid, i.e. exogenous and thus excludable.

4.2 Alternative weighting schemes

In the theory, we assume the existence of a transfer coefficient that describes the extent of cross-border environmental effects. Although it is reasonable to posit that this is inversely related to distance, theory does not suggest a specific functional form. Therefore the first two columns of Table 6 repeats the results of columns (3) and (6) of Table 5 using the weighting scheme described in equations and the last four columns provide comparable estimates using the weighting schemes of and. We present both the GMM-IV and Fuller(4) estimates.

For all three weighting schemes, we find a statistically significant positive strategic interaction between countries' decisions to ratify treaties. If anything, the two alternative weighting schemes ω_2 and ω_3 predict slightly more responsiveness to the treaty participation of others. Thus, despite the lack of a precise relationship between the transfer coefficient and distance, the robustness of our results across different weighting schemes is reassuring. Across schemes we also find a positive coefficient for FDI that is significant for GMM-IV estimation (as well as for the Fuller estimator when using ω_3). The estimates for the other control variables are also comparable across weighting schemes and in all cases the instruments pass the standard battery of tests.

[38] The standard deviation of the spatial lag with weight ω_1 is 0.51 and $0.51 * 0.15 = 0.0765$.

Table 6 Log of treaty participation, different weighting schemes

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	GMM-IV	Fuller(4)	GMM-IV	Fuller(4)	GMM-IV	Fuller(4)
	ω_1	ω_1	ω_2	ω_2	ω_3	ω_3
Spatial Lag	0.142**	0.149**	0.546***	0.558***	0.461***	0.446***
	(0.066)	(0.065)	(0.168)	(0.162)	(0.102)	(0.096)
Ln(FDI)	0.395*	0.280	0.416*	0.289	0.479**	0.339*
	(0.231)	(0.189)	(0.231)	(0.193)	(0.242)	(0.197)
Ln(Trade Costs)	0.051	0.023	0.050	0.019	0.067	0.033
	(0.060)	(0.050)	(0.060)	(0.051)	(0.063)	(0.052)
Ln(GDP)	0.072**	0.078**	0.071**	0.077**	0.055	0.062**
	(0.033)	(0.030)	(0.033)	(0.030)	(0.035)	(0.031)
Ln(Population)	−0.309	−0.427**	−0.294	−0.422**	−0.248	−0.387*
	(0.253)	(0.211)	(0.253)	(0.213)	(0.260)	(0.216)
Freedom Index	0.008*	0.006	0.008*	0.006	0.009**	0.006*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	−0.501	1.198	−1.628	0.225	−2.139	−0.052
	(3.508)	(2.926)	(3.575)	(3.010)	(3.686)	(3.054)
Observations	2178	2178	2178	2178	2178	2178
R-squared	0.957	0.963	0.956	0.962	0.953	0.961
H_0: *equation underidentified*						
Kleibergen-Paap rk LM	18.382***	18.382***	18.300***	18.300***	17.769***	17.769***
(P-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 6 (*Continued*)

Variables	(1) GMM-IV ω_1	(2) Fuller(4) ω_1	(3) GMM-IV ω_2	(4) Fuller(4) ω_2	(5) GMM-IV ω_3	(6) Fuller(4) ω_3
H_0: *instruments are weak*						
Kleibergen-Paap rk Wald F	6.464	6.464	6.425	6.425	6.223	6.223
Range of critical values for Stock-Yogo weak ID test	5.45–13.43	5.45–13.43	5.45–13.43	5.88–10.83	5.45–13.43	5.88–10.83
H_0: *instruments are valid*						
Hansen J Statistic χ^2	0.993	1.017	1.277	1.307	1.356	1.405
(P-value)	(0.319)	(0.313)	(0.258)	(0.253)	(0.244)	(0.236)
H_0: *FDI exog* χ^2	2.773*	2.773*	2.967*	2.966*	3.534*	3.531*
(P-value)	(0.096)	(0.096)	(0.085)	(0.085)	(0.060)	(0.060)

All specifications include year and country fixed effects. Robust standard errors in parentheses unless otherwise specified. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

4.3 Multiple spatial lags

The above theory and regressions make an implicit assumption regarding the nature of policy interdependence since it assumes that countries respond equally to others after accounting for distance. However, it may well be the case that a nation may respond differently to a poor neighbor than it does to a rich neighbor. This could result from differences in the responsiveness of FDI to changes in the policies of rich countries than poor ones. For example, FDI in developing nations may be geared towards resource extraction, an activity that is location specific and therefore fairly unresponsive to differences in emission taxes across countries. If FDI is relatively more responsive to a drop in the emissions tax of a rich country, then a cut in a rich country's tax would result in a greater capital reallocation than would result from an equal reduction in a poor country's tax. This in turn could result in a greater response in neighboring countries to the rich country tax cut as they seek to mitigate this greater capital outflow. In addition, this assumption requires two countries equidistant from a third both respond identically to the treaty participation of the third. If, however, poor countries are at a disadvantage when it comes to attracting FDI, then they may need to respond more to the tax cuts of others in order to reduce capital outflows. In addition to these issues, one might expect that wealthier nations may have greater political influence on the world stage. Furthermore, developing countries may be particularly cognizant of the desires of the rich due to a desire to curry favor and the foreign aid this comes with.

With these issues in mind, our goal next is to investigate how the strategic responses to treaty participation by rich OECD countries differs from the effect of participation by the poorer non-OECD countries. We do this in Table 7 by including two spatial lags—one for OECD countries and one for non-OECD countries.[39] The weighting matrix used in the construction of these lags and their instruments are the same as that used above with the exception that the non-OECD countries get a zero value for treaty participation in the calculation of the OECD lag and vice versa. Across weighting schemes and estimation methods, the OECD spatial lag's coefficient is significantly positive and of comparable magnitude to what was found above. The non-OECD coefficient, meanwhile, is consistently positive but significant only for ω_3. Thus, the impact of non-OECD countries is sensitive to the weighting scheme.

Table 8 extends the analysis of Table 7 by utilizing four spatial lags to allow for different within-group and across-group effects for OECD and non-OECD countries. Four spatial lags are defined to capture the effects of OECD countries on other OECD countries (OECD → OECD), OECD countries on non-OECD countries (OECD → non-OECD), non-OECD countries on OECD countries (non-OECD → OECD), and non-OECD on other non-OECD countries (non-OECD → non-OECD). Thus, the first two rows in Table 8 are how OECD countries affect the two groups and the next two rows are how non-OECD countries affect the two groups. To construct these four spatial lags, the weighted average of treaty participation variables for OECD and non-OECD (used in Table 7) are interacted with an OECD dummy.

[39]Note that Stock and Yogo (2005) only provide critical values for up to two endogenous variables. Thus in this and subsequent tables, we do not report these test statistics.

Table 7 OECD and non-OECD spatial lags

Variables	(1) GMM-IV ω_1	(2) Fuller(4) ω_1	(3) GMM-IV ω_2	(4) Fuller(4) ω_2	(5) GMM-IV ω_3	(6) Fuller(4) ω_3
OECD Spatial Lag	0.148*	0.156**	0.521***	0.541***	0.442***	0.432***
	(0.077)	(0.075)	(0.176)	(0.169)	(0.094)	(0.089)
Non-OECD Spatial Lag	0.167	0.172	0.248	0.339	0.508***	0.490***
	(0.119)	(0.114)	(0.279)	(0.268)	(0.131)	(0.123)
Ln(FDI)	0.373*	0.275	0.465*	0.308	0.458*	0.330*
	(0.209)	(0.178)	(0.245)	(0.201)	(0.237)	(0.195)
Ln(Trade Costs)	0.045	0.021	0.067	0.027	0.061	0.029
	(0.055)	(0.048)	(0.065)	(0.054)	(0.061)	(0.052)
Ln(GDP)	0.075**	0.079***	0.064*	0.072**	0.060*	0.066**
	(0.031)	(0.030)	(0.035)	(0.031)	(0.033)	(0.031)
Ln(Population)	−0.327	−0.429**	−0.271	−0.422*	−0.264	−0.391*
	(0.237)	(0.205)	(0.260)	(0.216)	(0.257)	(0.215)
Freedom Index	0.007*	0.006	0.010**	0.007*	0.008*	0.006
	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.004)
Constant	−0.286	1.190	−1.701	0.425	−1.961	−0.046
	(3.323)	(2.868)	(3.602)	(3.004)	(3.652)	(3.059)
Observations	2178	2178	2178	2178	2178	2178
R-squared	0.958	0.963	0.953	0.961	0.954	0.961
H_0: *equation underidentified*						
Kleibergen-Paap rk LM	23.282***	23.282***	16.486***	16.486***	19.177***	19.177***
(P-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
H_0: *instruments are valid*						
Hansen J Statistic χ^2	0.974	0.994	1.844	1.897	1.389	1.432
(P-value)	(0.324)	(0.3187)	(0.175)	(0.168)	(0.239)	(0.231)
H_0: *FDI exog* χ^2	3.049*	3.050*	3.275*	3.273*	3.314*	3.309*
(P-value)	(0.081)	(0.081)	(0.070)	(0.070)	(0.069)	(0.069)
H_0: *spatial lags equal* χ^2	0.140	0.120	3.33*	2.15	1.67	1.61
(P-value)	(0.704)	(0.735)	(0.068)	(0.143)	(0.197)	(0.205)

All specifications include year and country fixed effects. Robust standard errors in parentheses unless otherwise specified. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

We continue to find positive statistically significant coefficients for the two OECD spatial lags, indicating that treaty participation by OECD countries impacts that of both OECD and non-OECD countries. Further, OECD participation has a greater effect on non-OECD countries than on other OECD members.[40] The exception to this is again ω_3 where these coefficients are statistically equal. However, comparable to the OECD spatial lags, using scheme ω_3 results in not only significantly positive

[40] The test statistics for this comparison are found at the bottom of the table.

Table 8 Cross-sample spatial lags

Variables	(1) GMM-IV ω_1	(2) Fuller(4) ω_1	(3) GMM-IV ω_2	(4) Fuller(4) ω_2	(5) GMM-IV ω_3	(6) Fuller(4) ω_3
OECD → OECD Spatial Lag **(OO)**	0.163**	0.179**	0.463***	0.504***	0.439***	0.442***
	(0.075)	(0.073)	(0.178)	(0.173)	(0.089)	(0.086)
OECD → Non-OECD Spatial Lag **(ON)**	0.224***	0.243***	0.628***	0.660***	0.478***	0.486***
	(0.082)	(0.079)	(0.179)	(0.173)	(0.092)	(0.089)
Non-OECD → OECD Spatial Lag **(NO)**	0.223*	0.242**	0.263	0.358	0.533***	0.540***
	(0.114)	(0.111)	(0.287)	(0.277)	(0.124)	(0.119)
Non-OECD → Non-OECD Spatial Lag **(NN)**	0.166	0.170	0.147	0.226	0.494***	0.477***
	(0.121)	(0.116)	(0.284)	(0.275)	(0.134)	(0.126)
Ln(FDI)	0.346*	0.267	0.447*	0.303	0.444*	0.330*
	(0.207)	(0.176)	(0.242)	(0.200)	(0.233)	(0.194)
Ln(Trade Costs)	0.043	0.026	0.068	0.035	0.060	0.036
	(0.049)	(0.043)	(0.058)	(0.049)	(0.054)	(0.046)
Ln(GDP)	0.076**	0.080***	0.067*	0.076**	0.061*	0.067**
	(0.031)	(0.030)	(0.036)	(0.033)	(0.034)	(0.031)
Ln(Population)	−0.324	−0.394**	−0.233	−0.355*	−0.252	−0.344*
	(0.205)	(0.178)	(0.232)	(0.196)	(0.213)	(0.182)
Freedom Index	0.008**	0.007**	0.011**	0.008**	0.008**	0.007**
	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.003)
Constant	−0.188	0.888	−1.880	−0.063	−1.980	−0.457
	(3.031)	(2.626)	(3.364)	(2.839)	(3.246)	(2.754)
Observations	2178	2178	2178	2178	2178	2178
R-squared	0.960	0.963	0.954	0.962	0.955	0.961
H_0: *equation underidentified*						
Kleibergen-Paap rk LM	23.142***	23.142***	17.701***	17.701***	20.069***	20.069***
(P-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
H_0: *instruments are valid*						
Hansen J Statistic χ^2	0.739	0.753	1.607	1.661	1.372	1.421
(P-value)	(0.390)	(0.386)	(0.205)	(0.198)	(0.242)	(0.233)
H_0: *FDI exog* χ^2	2.911*	2.912*	3.415*	3.415*	3.529*	3.525*
(P-value)	(0.088)	(0.088)	(0.065)	(0.065)	(0.060)	(0.060)
H_0: OO = ON χ^2	5.95***	7.44***	13.83***	14.02***	1.52	2.63
H_0: OO = NO χ^2	1.60	1.99	1.87	1.15	3.29*	4.23**
H_0: OO = NN χ^2	0.00	0.02	5.34**	4.63**	0.63	0.34
H_0: ON = NO χ^2	0.00	0.00	6.42**	4.98**	1.22	1.37
H_0: ON = NN χ^2	0.58	1.13	12.06***	10.79***	0.04	0.02
H_0: NO = NN χ^2	1.41	3.12*	7.12***	12.75***	0.44	1.70

All specifications include year and country fixed effects. Robust standard errors in parentheses unless otherwise specified. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9 Regional treaties

Variables	(1) GMM-IV ω_1	(2) Fuller(4) ω_1	(3) GMM-IV ω_2	(4) Fuller(4) ω_2	(5) GMM-IV ω_3	(6) Fuller(4) ω_3
OECD → OECD Spatial Lag **(OO)**	0.191***	0.186***	0.745***	0.727***	0.366***	0.354***
	(0.067)	(0.066)	(0.166)	(0.165)	(0.071)	(0.071)
OECD → Non-OECD Spatial Lag **(ON)**	0.195**	0.199**	0.727***	0.711***	0.367***	0.365***
	(0.080)	(0.078)	(0.172)	(0.172)	(0.083)	(0.082)
Non-OECD → OECD Spatial Lag **(NO)**	0.330**	0.308**	0.996**	0.954**	0.505***	0.490***
	(0.134)	(0.133)	(0.403)	(0.399)	(0.138)	(0.137)
Non-OECD → Non-OECD Spatial Lag **(NN)**	0.389**	0.324**	1.033**	0.983**	0.516***	0.472***
	(0.161)	(0.161)	(0.410)	(0.407)	(0.149)	(0.146)
Ln(FDI)	0.169	0.083	0.077	0.052	0.123	0.058
	(0.236)	(0.216)	(0.273)	(0.250)	(0.254)	(0.227)
Ln(Trade Costs)	−0.007	−0.024	−0.031	−0.035	−0.012	−0.025
	(0.055)	(0.051)	(0.063)	(0.059)	(0.059)	(0.054)
Ln(GDP)	0.076**	0.079**	0.082**	0.080**	0.071*	0.073**
	(0.038)	(0.037)	(0.040)	(0.039)	(0.039)	(0.037)
Ln(Population)	−0.615***	−0.689***	−0.701***	−0.723***	−0.616***	−0.669***
	(0.228)	(0.210)	(0.250)	(0.231)	(0.235)	(0.211)
Freedom Index	−0.002	−0.003	−0.003	−0.004	−0.002	−0.003
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
Constant	2.900	4.180	3.520	3.956	3.186	4.111
	(3.374)	(3.121)	(3.760)	(3.477)	(3.513)	(3.162)
Observations	2178	2178	2178	2178	2178	2178
R-squared	0.963	0.964	0.963	0.963	0.965	0.966
H_0: *equation underidentified*						
Kleibergen-Paap rk LM	24.867***	24.867***	17.768***	17.768***	20.910***	20.910***
(P-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
H_0: *instruments are valid*						
Hansen J Statistic χ^2	2.716*	2.712*	3.542*	3.547*	2.664	2.663
(P-value)	(0.099)	(0.100)	(0.060)	(0.060)	(0.103)	(0.103)
H_0: *FDI exog* χ^2	0.272	0.272	0.010	0.010	0.061	0.061
(P-value)	(0.602)	(0.602)	(0.920)	(0.921)	(0.805)	(0.805)
H_0: OO = ON χ^2	0.01	0.06	0.04	0.03	0.00	0.05
H_0: OO = NO χ^2	2.99*	2.29	0.75	0.63	2.76*	2.72*
H_0: OO = NN χ^2	2.05	1.05	0.99	0.79	1.74	1.18
H_0: ON = NO χ^2	2.34	1.53	0.82	0.70	3.24*	2.62
H_0: ON = NN χ^2	1.54	0.69	1.00	0.80	1.22	0.70
H_0: NO = NN χ^2	0.26	0.02	0.13	0.08	0.01	0.03

All specifications include year and country fixed effects. Robust standard errors in parentheses unless otherwise specified. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10 Global treaties

Variables	(1) GMM-IV ω_1	(2) Fuller(4) ω_1	(3) GMM-IV ω_2	(4) Fuller(4) ω_2	(5) GMM-IV ω_3	(6) Fuller(4) ω_3
OECD → OECD Spatial Lag **(OO)**	−0.090	−0.041	−0.412	−0.171	0.120	0.190
	(0.192)	(0.186)	(0.551)	(0.526)	(0.384)	(0.367)
OECD → Non-OECD Spatial Lag **(ON)**	0.020	0.069	−0.015	0.207	0.193	0.263
	(0.217)	(0.209)	(0.566)	(0.539)	(0.394)	(0.377)
Non-OECD → OECD Spatial Lag **(NO)**	0.108	0.172	−0.090	0.211	0.358	0.434
	(0.270)	(0.260)	(0.679)	(0.630)	(0.434)	(0.415)
Non-OECD → Non-OECD Spatial Lag **(NN)**	0.107	0.157	−0.229	0.044	0.405	0.461
	(0.262)	(0.253)	(0.662)	(0.618)	(0.444)	(0.420)
Ln(FDI)	0.729^{***}	0.651^{***}	0.917^{***}	0.715^{***}	0.846^{***}	0.759^{***}
	(0.219)	(0.195)	(0.281)	(0.220)	(0.270)	(0.241)
Ln(Trade Costs)	0.101^{**}	0.085^{*}	0.145^{**}	0.102^{*}	0.126^{**}	0.111^{*}
	(0.051)	(0.046)	(0.066)	(0.052)	(0.063)	(0.057)
Ln(GDP)	0.032	0.040	0.004	0.027	0.010	0.021
	(0.039)	(0.037)	(0.049)	(0.042)	(0.044)	(0.041)
Ln(Population)	−0.242	−0.292	−0.086	−0.220	−0.109	−0.154
	(0.211)	(0.194)	(0.265)	(0.221)	(0.309)	(0.283)
Freedom Index	0.016^{***}	0.015^{***}	0.022^{***}	0.019^{***}	0.017^{***}	0.016^{***}
	(0.004)	(0.004)	(0.006)	(0.005)	(0.004)	(0.004)
Constant	−3.635	−2.849	−5.603	−3.690	−5.629	−4.849
	(3.109)	(2.836)	(3.876)	(3.222)	(4.397)	(3.993)
Observations	2178	2178	2178	2178	2178	2178
R-squared	0.888	0.899	0.853	0.889	0.867	0.881
H_0: *equation underidentified*						
Kleibergen-Paap rk LM	21.603^{***}	21.603^{***}	16.147^{***}	16.147^{***}	16.241^{***}	16.241^{***}
(P-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
H_0: *instruments are valid*						
Hansen J Statistic χ^2	2.484	2.548	1.983	2.040	3.835^{*}	4.018^{**}
(P-value)	(0.115)	(0.110)	(0.159)	(0.153)	(0.050)	(0.110)
H_0: *FDI exog* χ^2	10.678^{***}	10.681^{***}	10.862^{***}	10.820^{***}	10.458^{***}	10.432^{***}
(P-value)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

All specifications include year and country fixed effects. Robust standard errors in parentheses unless otherwise specified. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

non-OECD spatial lags, but in coefficients with magnitudes comparable to those for OECD members. Separating out the cross-sample spatial lags leaves the other coefficients almost the same and we continue to pass the standard tests of the instruments.

These estimates indicate that the results, at least for non-OECD members, are sensitive to the treatment of distance in the construction of the spatial lag. Tables 9 and 10 present a final set of results that builds on this idea by separating our set of treaties into those with a regional or continental focus and global treaties that do not geographically constrain their application. Table 4 provides a breakdown of the relative number of treaties. One might well expect that when distance is a key factor in determining treaty interactions, then the evidence for such interactions is stronger in regional agreements than in global treaties. To explore this, Table 9 presents the estimates for our three weighting schemes when the treaty participation variable and spatial lag only includes regional agreements. As can be seen, unlike the combined treaty participation measure in Table 8, we find positive and significant lags for both the OECD and non-OECD countries across all three weighting schemes. Further, for the most part, we fail to reject the hypothesis that there is no difference in the responsiveness by or to OECD and non-OECD treaty participation. In contrast to the significant regional results, we find no significant spatial lags at all when using the global treaties as shown in Table 10. This indicates that interactions are primarily on a regional level, again supporting the conjecture that the extent of interactions are declining with distance. In addition, it shows the need to be aware of the implications of the weighting scheme when performing spatial estimations not only in construction of the spatial lag, but in the construction of other key variables (such as treaty participation) to reflect the assumptions of the weighting methodology. However, it should be noted that in the regional agreements we weakly reject the null of valid instruments for weights ω_1 and ω_2 while for the global treaties we do so for ω_3. Thus these estimates must be interpreted with caution.

5 Conclusion

The potential inefficiencies caused by competition for mobile firms have become a contentious source of debate in policy, public, and academic circles. In this paper, we present a theoretic model that suggests that such inefficiencies might be greatest among nearby countries due to the presence of cross-border pollution. Therefore, the gains from cooperating through international environmental treaties are greatest among such countries. A useful feature of international treaty participation is that these data are readily available for all countries and the participation measure is comparable across countries. The panel feature of our dataset allows us to control for year as well as country fixed effects. Using information on participation in 110 environmental treaties by 139 countries for 1980–1999, we find evidence that strategic interactions in environmental policies do indeed exist. In particular, the estimates suggest that treaty participation rates are strategic complements and this seems to be driven by treaties with a regional focus. It is important to note, however, that this in and of itself does not necessarily imply a "race to the bottom" since even models with strategic complementarity can result in inefficiently high environmental standards (see for example, the "not in my backyard" model of Markusen et al. 1995). Nevertheless, recognition of this may well be important for the development of future agreements, particularly regional ones involving developing nations where pollution levels are rising rapidly (World Bank 2009).

Acknowledgements We acknowledge Erica Birk for her excellent research assistance. We thank two anonymous referees, Glen Waddell, Bruce Blonigen, Trudy Cameron, Dan McMillen, Arik Levinson, Ronald Mitchell, seminar participants at Miami University, University College Dublin, Trinity College Dublin, National University of Ireland at Maynooth, University of Iceland, Mannheim University, Tilburg University, the University of Strathclyde, Georg-August Universität, University of Alberta, Lawrence University, Deakin University, Monash University, University of Montana, University of Colorado at Denver, Public Policy Institute of California, University of Maryland, Colorado State University, Oklahoma State University, State University of New York at Plattsburgh, and conference participants at the 2005 Association of the Pacific Rim Universities, the 2005 European Trade Study Group, and the 2006 Asia Pacific Economic Association conferences, 2007 Oregon Ad hoc Workshop in Environmental and Resource Economics, and 2008 10th Occasional Workshop on Environmental and Resource Economics. Any errors or omissions are the responsibilities of the authors.

References

Anselin, L. (1988). *Spatial econometrics: methods and models*. Boston: Kluwer Academic.

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment? *The American Economic Review*, *91*, 877–908.

Barba Navaretti, G., & Venables, A. J. (2006). *Multinational firms in the world economy*. Princeton: Princeton University Press.

Barrett, S. (1994). Strategic environmental policy and international trade. *Journal of Public Economics*, *54*, 325–338.

Baum, C. F., Schaffer, M. E., & Stillman, S. (2003). Instrumental variables and GMM: estimation and testing. *Stata Journal*, *3*, 1–31.

Beron, K. J., Murdoch, J. C., & Vijverberg, W. P. M. (2003). Why cooperate? Public goods, economic power, and the Montreal Protocol. *Review of Economics and Statistics*, *85*, 286–297.

Blonigen, B. A., & Davies, R. B. (2004). The effects of bilateral tax treaties on US FDI activity. *International Tax and Public Finance*, *11*, 601–622.

Blonigen, B. A., Davies, R. B., Waddell, G. R., & Naughton, H. (2007). FDI in space: spatial autoregressive relationships in foreign direct investment. *European Economic Review*, *51*, 1303–1325.

Blonigen, B. A., & Piger, J. M. (2011). *Determinants of foreign direct investment*. (National Bureau of Economic Research working paper series, working paper 16704). Cambridge, MA.

Brunnermeier, S. B., & Levinson, A. (2004). Examining the evidence on environmental regulations and industry location. *The Journal of Environment & Development*, *13*, 6–41.

Brueckner, J. K. (2003). Strategic interaction among governments: an overview of empirical studies. *International Regional Science Review*, *26*, 175–188.

CEPII (2009). Distance database online. http://www.cepii.fr/. Accessed October 2009.

Chander, P., & Tulkens, H. (1995). A core-theoretic solution for the design of cooperative agreements on transfrontier pollution. *International Tax and Public Finance*, *2*, 279–293.

Chander, P., & Tulkens, H. (2006). The core of an economy with multilateral environmental externalities. In P. Chander, J. Drèze, C. K. Lovell, & J. Mintz (Eds.), *Public goods, environmental externalities and fiscal competition* (pp. 153–175). New York: Springer.

Cole, M. A., & Elliott, R. J. (2003). Determining the trade-environment composition effect: the role of capital, labor and environmental regulations. *Journal of Environmental Economics and Management*, *46*, 363–383.

Cole, M. A., Elliot, R. J., & Fredriksson, P. G. (2006). Endogenous pollution havens: does FDI influence environmental regulations? *Scandinavian Journal of Economics*, *108*, 157–178.

Congleton, R. D. (1992). Political institutions and pollution control. *Review of Economics and Statistics*, *74*, 412–421.

Cremer, H., & Gahvari, F. (2004). Environmental taxation, tax competition, and harmonization. *Journal of Urban Economics*, *55*, 21–45.

Davies, R. B., & Vadlammanti, K. C. (2013). A race to the bottom in labor standards? An empirical investigation. *Journal of Development Economics*, *103*, 1–14.

Dean, J. M. (2002). Does trade liberalization harm the environment? A new test. *Canadian Journal of Economics*, *35*, 819–842.

Dellink, R. B., Finus, M., & Olieman, N. J. (2008). The stability likelihood of an international climate agreement. *Environmental & Resource Economics*, *39*, 357–377.

Devereux, M., Lockwood, B., & Redoano, M. (2008). Do countries compete over corporate tax rates. *Journal of Public Economics*, *92*, 1210–1235.

Drukker, D. M., & Millimet, D. L. (2007). *Assessing the pollution haven hypothesis in an interdependent world*. Southern Methodist University working paper, working paper number 0703. Faculty of Economics, Southern Methodist University.

Eaton, J., & Tamura, A. (1994). Bilateralism and regionalism in Japanese and US trade and direct foreign investment patterns. *Journal of the Japanese and International Economies*, *8*, 478–510.

Ederington, J., & Minier, J. (2003). Is environmental policy a secondary trade barrier? An empirical analysis. *Canadian Journal of Economics*, *36*, 137–154.

Eerola, E. (2004). Environmental tax competition in the presence of multinational firms. *International Tax and Public Finance*, *11*, 283–298.

Egger, P., Jessberger, C., & Larch, M. (2011). Trade and investment liberalization as determinants of multilateral environmental agreement membership. *International Tax and Public Finance*, *18*, 605–633.

Eliste, P., & Fredriksson, P. G. (2004). Environmental regulations, transfers, and trade: theory and evidence. *Journal of Environmental Economics and Management*, *43*, 234–250.

Frankel, J. A., & Rose, A. K. (2005). Is trade good or bad for the environment? Sorting out the causality. *Review of Economics and Statistics*, *87*, 85–91.

Fredriksson, P. G., & Millimet, D. L. (2002). Strategic interaction and the determination of environmental policy across US states. *Journal of Urban Economics*, *51*, 101–122.

Fredriksson, P. G., List, J. A., & Millimet, D. L. (2003). Bureaucratic corruption, environmental policy and inbound US FDI: theory and evidence. *Journal of Public Economics*, *87*, 1407–1430.

Fredriksson, P. G., List, J. A., & Millimet, D. L. (2004). Chasing the smokestack: strategic policymaking with multiple instruments. *Regional Science and Urban Economics*, *34*, 387–410.

Freedom House (2005). Freedom in the world country rankings: 1972–2005 dataset online. http://www.freedomhouse.org. Accessed October 2002.

Fuller, W. A. (1977). Some properties of a modification of the limited information estimator. *Econometrica*, *45*, 939–954.

Gresik, T. A. (2001). The taxing task of taxing transnationals. *Journal of Economic Literature*, *39*, 800–838.

Hahn, J., Hausman, J., & Kuersteiner, G. (2004). Estimation with weak instruments: accuracy of higher-order bias and MSE approximations. *Econometrics Journal*, *7*, 272–306.

Harbaugh, W. T., Levinson, A., & Wilson, D. M. (2002). Reexamining the empirical evidence for an environmental Kuznets curve. *Review of Economics and Statistics*, *84*, 541–551.

Henderson, D. J., & Millimet, D. L. (2007). Pollution abatement costs and foreign direct investment inflows to US states: a nonparametric reassessment. *Review of Economics and Statistics*, *89*, 178–183.

Heston, A., Summers, R., & Aten, B. (2002). Penn world table version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP). https://pwt.sas.upenn.edu. Accessed October 2002.

Hoel, M. (1997). Environmental policy with endogenous plant locations. *Scandinavian Journal of Economics*, *99*, 241–259.

Javorcik, B. S., & Wei, S. (2004). Pollution havens and foreign direct investment: dirty secret or popular myth? *Contributions to Economic Analysis & Policy*, *3*, 8.

Jeppesen, T., List, J. A., & Folmer, H. (2002). Environmental regulations and new plant locations: evidence from a meta-analysis. *Journal of Regional Science*, *42*, 19–49.

Kelejian, H. H., & Prucha, I. R. (1998). A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive model with autoregressive disturbances. *Journal of Real Estate Finance and Economics*, *17*, 99–121.

Klemm, A., & van Parys, S. (2012). Empirical evidence on the effects of tax incentives. *International Tax and Public Finance*, *19*, 393–423.

Levinson, A. (2001). An industry adjusted index of state environmental compliance costs. In C. Carraro & G. E. Metcalf (Eds.), *Behavioral and distributional effects of environmental policy* (pp. 131–158). Chicago: University of Chicago Press.

Levinson, A. (2003). Environmental regulatory competition: a status report and some new evidence. *National Tax Journal*, *56*, 91–106.

List, J. A., Millimet, D. L., Fredriksson, P. G., & McHone, W. W. (2003). Effects of environmental regulations on manufacturing plant births: evidence from a propensity score matching estimator. *Review of Economics and Statistics*, *85*, 944–952.

Magee, C. S. (2003). Endogenous preferential trade agreements: an empirical analysis. *Contributions to Economic Analysis & Policy*, *2*, 15.
Managi, S., Hibiki, A., & Tsurumi, T. (2009). Does trade openness improve environmental quality. *Journal of Environmental Economics and Management*, *58*, 346–363.
Markusen, J. R., Morey, E. R., & Olewiler, N. (1995). Competition in regional environmental policies when plant locations are endogenous. *Journal of Public Economics*, *56*, 55–77.
Mason, M. (2005). *The new accountability: environmental responsibility across borders*. London: Earthscan.
McAusland, C. (2002). Cross-hauling of polluting factors. *Journal of Environmental Economics and Management*, *44*, 448–470.
Mitchell, R. B. (2002–2008). International environmental agreements database project (version 2007.1). http://iea.uoregon.edu/. Date accessed: February 2009.
Mitchell, R. B. (2003). International environmental agreements: a survey of their features, formation, and effects. *Annual Review of Environmental Resources*, *28*, 429–461.
Murdoch, J. C., Sandler, T., & Vijverber, W. P. M. (2003). The participation decisions versus the level of participation in an environmental treaty: a spatial probit analysis. *Journal of Public Economics*, *87*, 337–362.
Naughton, H. T. (2010). Globalization and emissions in Europe. *European Journal of Comparative Economics*, *7*, 503–519.
Neumayer, E. (2002). Does trade openness promote multilateral environmental cooperation? *The World Economy*, *25*, 815–832.
Rauscher, M. (1995). Environmental regulation and the location of polluting industries. *International Tax and Public Finance*, *2*, 229–244.
Rauscher, M. (1997). *International trade, factor movements, and the environment*. Oxford: Clarendon.
Roberts, J. T., Parks, B. C., & Vasquez, A. A. (2004). Who ratifies environmental treaties? Institutionalism, structuralism and participation by 192 nations in 22 treaties. *Global Environmental Politics*, *4*, 22–64.
Rose, A. K., & Spiegel, M. M. (2009). Noneconomic engagement and international exchange: the case of environmental treaties. *Journal of Money, Credit, and Banking*, *41*, 337–363.
Sigman, H. (2002). International spillovers and water quality in rivers: do countries free ride? *The American Economic Review*, *92*, 1152–1159.
Sigman, H. (2004). Does trade promote environmental coordination? Pollution in international rivers. *Contributions to Economic Analysis & Policy*, *3*, 2.
Stock, J. H., & Yogo, M. (2005). Testing for weak instruments in linear IV regression. In J. H. Stock & D. W. K. Andrews (Eds.), *Identification and inference for econometric models: essays in honor of Thomas J. Rothenberg* (pp. 80–108). Cambridge: Cambridge University Press.
UNCTAD (2012). Foreign direct investment database online. http://www.unctad.org. Accessed February 2009.
Wang, W., & Lee, L. (2013a). Estimation of spatial autoregressive models with randomly missing data in the dependent variable. *Econometrics Journal*, *16*, 73–102.
Wang, W., & Lee, L. (2013b). Estimation of spatial panel data models with randomly missing data in the dependent variable. *Regional Science and Urban Economics*, *43*, 521–538.
Wilson, J. D. (1986). A theory of interregional tax competition. *Journal of Urban Economics*, *19*, 296–315.
Wilson, J. D. (1999). Theories of tax competition. *National Tax Journal*, *52*, 269–304.
World Bank (2009). *The little green data book 2009*. Washington: World Bank.