How Does Multilevel Climate Governance Work? :

A Nexus of Policy Diffusion and Multilateral Aid

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Abstract

Diffusion holds the key to both the mechanism of carbon emission and a solution to the problem of emission excesses. In essence, diffusion represents spatial dependence through connectivity between states and affects their policies or even regulations entailed in the framework of global governance. Even though it is of critical importance to climate governance in influencing trust and incentives for cooperation, diffusion has received limited attention from international relations analysts of climate change. Using spatial modeling and systemic international relations theories, we uncover that, on average, diffusion adversely affects other states' emission efficiency and that emission by states with competitive trading activity is a major source of the adverse diffusion. This result holds even if international and domestic countervailing factors are taken into account. An in-sample simulation analysis confirms that, for better climate governance, the adverse diffusion can be neutralized by a coalition of numerous trading states, rather than by a limited number of large states (*e.g.*, G20).

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1. RESEARCH QUESTIONS

Diffusion holds the key to both the mechanism of carbon emission and a solution to the problem of emission excesses. In essence, diffusion represents spatial dependence through connectivity between states and affects their policies or even regulations entailed in the framework of global governance. Hence, the nature of diffusion has important implications not only for states' policies, but also for global environmental cooperation.

Suppose that emission in state *i* affects that in state *j*. If *i*'s regulation for emission reduction has a positive effect in reducing *j*'s emission, then diffusion can be regarded as a contributor to global governance. With the positive diffusion, the governance framework does not have to achieve universal membership since member states' regulatory outcomes spread to nonmember states, creating an informal governance network. On the contrary, if *i*'s emission-reducing regulation has an adverse effect in increasing *j*'s emission, then diffusion should be viewed as a disturbance to climate governance, and then a large number of contracting states, or even universal membership, may be a necessary condition for effective governance. What this means is that a correct understanding of diffusion is essential for climate governance and the study of environmental cooperation.

Accordingly, analysts have investigated various diffusion mechanisms, using sophisticated theoretical schemes and methodological tools. For instance, motivated by the trade-environment debate, Cao and Prakash (2010) examined the effect of trade competition on the pollution levels of sulfur dioxide (SO_2) and biochemical oxygen demand (BOD). Likewise, Cao and Prakash (2012) analyzed the effect of trade competition on treaty commitments as well as the pollution levels of SO_2 and BOD within domestic constraints characterized as veto players. Perkins and Neumayer (2008, 2009) assessed the influence of transnational linkage on the pollution efficiency of CO_2 and SO_2 by evaluating how transnational agents—trade, foreign direct investment (FDI), and telecommunication—help disseminate pollution control technologies from one state to another. In addition, they examined trade in specific industrial sectors—manufactured goods and machineries—as major domains of competitive diffusion. Last and not the least, Prakash and Potoski (2007) and Perkins and Neumayer (2010) investigated how trade, FDI, and business travel affect the adoption of global voluntary environmental standards known as the Global Compact and ISO 14001, while assessing intervening effects of states' economic size and democracy.

As reviewed above, the existing international relations studies of climate change analyzed diffusion based primarily on cross-border economic activity and domestic politics, paying limited attention to interstate politics and thus failing to comprehend diffusion in a broader context of global governance within which states are still important actors. However, in the real world, economic activity and domestic politics are not the only driving forces behind diffusion. Diffusion takes various mechanisms and intermediaries with varying strengths and directions. As discussed in the next section, theories of international relations suggest that diffusion may be activated not only by economic interdependence, but also by state power and international organizations. Rightly, analysts of diffusion in other policy realms, such as financial liberalization and taxation, have taken these diffusion intermediaries into consideration in the context of coercion and emulation (Elkins et al. 2006, Cao 2009, 2010). Yet analysts of environmental diffusion have ignored political intermediaries because they were concerned primarily with economic agents and the relationship between economic liberalization and environmental protection by evaluating hypotheses concerning races either to the top or to the bottom (Vogel 1995, Neumayer 2001). Which theory provides a good approximation of the actual diffusion mechanism is a highly empirical question.

Therefore, in analyzing diffusion in climate change, we seek to incorporate state power and international governmental organizations (IGOs) as diffusion intermediaries which have received limited scholarly attention. In doing so, we try to nest our analysis within the scholarship of international relations by employing systemic theories of realism, liberalism and constructivism. Realism, in particular, recognizes that state power is the primary engine of international relations and governance across various policy realms even in the age of heightened transnational movements (Hirst and Thompson 2009). This state-centric approach accords with the fact that states are still significant players as either regulators or facilitators of carbon emission or both. Indeed, almost all states are contracting parties to the United Nations Framework Convention on Climate Change (UNCCC) and have been making regulatory efforts in reducing carbon emission more or less. At the same time, as part of their sovereign roles, states encourage economic activity and stimulate growth through various public policy instruments, including infrastructure construction, public corporations, and industrial subsidies, all of which result in carbon emission.

Likewise, IGOs are mixed blessings. In general, IGOs facilitate certain policy actions by providing member states with forums for learning and emulation of best practices as well as with regulatory, financial and other arrangements conducive to the policy actions. Specifically, regarding climate change, there exist pro-environment organizations, such as the United Nations Environmental Plan (UNEP) as the secretariat for UNCCC and the European Union (EU) for establishing a regional emission trading scheme. In contrast, there are other IGOs that have either opposed the need for reducing fossil fuel consumption (*e.g.*, the Organization of the Petroleum Exporting Countries [OPEC]) or facilitated economic competition with limited environmental concerns (*e.g.*, the World Trade Organization [WTO]).

Thus, diffusion intermediaries may be not just trade, but also state power and IGOs. These intermediaries generate diffusion in either positive or negative directions through their distinct arrangements, resources, and techniques. Given these possibilities, it is appropriate for us to analyze diffusion on climate change comprehensively from the varying theoretical perspectives.

This paper is structured as follows. Section 2 introduces international relations theories in relation to an analysis of diffusion and derives working hypotheses from them. Section 3 presents a statistical model and data to test the hypotheses. Section 4 provides statistical results, discussion, and an in-sample simulation. Given these results, Section 5 concludes the paper, providing hints for analytical refinements and policy implications regarding the future direction of climate governance.

2. THEORY AND HYPOTHESES

Diffusion means the transmission of substances, norms, ideas, or technologies from one unit to another. Strang and Soule (1998, 266) and Eyestone (1977, 441) defined diffusion as the “spread of something within a social system.” When it changes the behavior of units, diffusion becomes a “pattern of successive adoptions of a policy.” This suggests the *dispersion* or *dissemination* of a practice throughout a population: that is, multiple adoptions of basically similar practices. The adoption is due to various mechanisms, including coercion, competition, learning, and emulation (Elkins, et al. 2006). Each of the diffusion mechanisms constitutes important international dynamics. Thus, theorists of international relations have discussed the mechanisms and intermediaries of diffusion in the context of their distinct worldviews. In general, realists focus on coercion and state power, liberalists competition and economic interdependence, and constructivists emulation and communication. Despite these varying theoretical concerns, as mentioned earlier, empirical analysts of environmental diffusion have focused on economic interdependence, paying limited attention to alternative diffusion mechanisms and intermediaries. In what follows, we summarize the diffusion mechanisms outlined by the three major theories and develop working hypotheses for our empirical analysis in the realm of climate change.

2.1 State power

Diffusion may not be horizontal. It may be vertical, dictated by power and centrality (Ballester et al. 2006, Bonacich 1987). Among international relations theories, power and centrality are the major concerns of realism. From the realist perspective, great powers or hegemons have the abilities to impose coercion or inducement that drives diffusion. Such arguments are often invoked to explain international regimes as well as interstate dependence.

Classical realists, such as Carr (1939), Morgenthau (1985), argue that major states employ a variety of strategies, including arms, trade, investment, etc., to expand their political and economic interests in geographical or policy domains. Krasner (1976) has maintained that international regimes almost invariably reflect the interests, power, and intervention of great powers. Waltz (1979) presents a neorealist claim in a general form—powerful states predictably seek to impose their (arbitrary) views on other states. Yet realists are agnostic in specifying the type of policy influence projected by a great power, ascribing it to the political ideology held by the great power (e.g., Morgenthau 1985, pp. 99-110). Thus, realism may hypothesize that *the greater state j's power relative to state i, the greater influence j's climate policy has on i, and the greater the diffusion in either a positive (emission-reducing) or a negative (emission-increasing) direction*.

2.2 Economic interdependence

A second hypothesis posits that diffusion is a horizontal process associated with economic interdependence. The magnitude and direction of diffusion are determined by a process between units, often characterized as competition or learning. In general, strategic interdependence is said to arise whenever the actions of some unit(s) affect the marginal utility of alternative actions for some other unit(s). (We follow Brueckner 2003; see also Braun and Gilardi 2006.)

Consider two states, *i* and *j*, with (indirect) utilities from their alternative actions or policies. The two states have (homogenous) population preferences regarding the economy and environment. When state *i* chooses its policy to maximize its own welfare, this alters the optimal policy in *j*, and *vice versa*. Due to environmental externalities (e.g., carbon spillovers), welfare (i.e., a combination of climate stability and economic growth) in each state will depend on both states' actions. Due to externalities, *i*'s utility depends on its policy and that of *j*. This implies that actions by *i* induce *j* either to move in the same direction, making *i* and *j* *strategic complements*, or to move in opposite directions as *strategic substitutes*.

In this paper, we focus strategic complements for the following reason. In the short run, strategic substitutes may appear when states are unable to adjust their behavior quickly to those of related states due to transaction costs or other policy stickiness. In the long run, however, states implement gradual adjustments and make interstate relations strategically complementary, with state policies moving in the same direction.

A case of strategic complement ensues in concert with technological diffusion via learning. Such learning takes place when state *i* imports energy-efficient products (*e.g.,* electronic automobiles) from state *j*. In turn, this incentivizes state *i* to learn environmentally-sound technologies from state *j* (Tews, et al. 2003, Vogel 1997). However, such learning processes might not occur in trading irrelevant products (*e.g.,* agricultural products and foods). Learning might occur in the opposite direction from transacting energy-inefficient products (*e.g*., fuel-inefficient automobiles). Without good qualitative import restrictions, these products are imported into state *i*, worsening its emission efficiency. In sum, we assume that diffusion via learning is driven by state i's importation of specific products. *The greater the energy-efficient (-inefficient) exports, the greater the positive (negative) diffusion.*

A second case of strategic complement is that state *i* follows the climate performance of its competitors who compete in the same export markets. For instance, if firms in state *i* are energy-efficient and are faced with diluted environmental regulations in state *k*'s markets, they will lose their market shares with their costly energy-efficient products insofar as firms in state *j* can send their cheap energy-inefficient products to *k*'s markets. This compels firms in *i* to shift their costly energy-efficient products to cheaper energy-inefficient ones (Borgatti and Everett 1992). The opposite is true for enhanced environmental regulations in export markets that encourage firms in both states to manufacture energy-efficient products in order to expand their market shares. Thus, it can be hypothesized that *the more intensely state i's firms compete for export markets with state j's firms, the greater the diffusion in either a positive or a negative direction.*

2.3 Communication

A third hypothesis, consistent with the theory of social constructivism, posits that the magnitude and direction of spatial dependence are determined by the density of social communication between states. Repeated interstate communication promotes socialization and assimilation, which in turn facilitate behavioral convergence between them (Johnston 2001, Granovetter 1985, Uzzi 1996). In this vein, IGOs play an important communicative function as well as monitoring, regulatory and secretariat functions for contracting states of international treaties. Risse (2000) argues that IGOs perform a focal-point role by sponsoring regular policy forums where member states' policy-makers, regulators, IGO officials and NGO representatives exchange experiences, ideas and "best" practices, while nurturing trust and comraderies among them at professional levels. In doing so, IGOs generate multilateral pressure in ameliorating the hierarchical, coercive characteristics of interstate relations, turning them into cooperative ones (Ruggie 1993).

More specifically, if two states, *i* and *j*, share a number of IGO memberships, then they gain opportunities to communicate, deliberate and share "best" practices. The process is identical to what is called learning or emulation in the diffusion literature (Elkins et el. 2006). As noted earlier, constructivists are silent about specific policy directions associated with interstate cooperation mediated by IGOs, given their policy heterogeneity (either pro- or anti-environment). Thus, it is conjectured that *the more joint IGO memberships states have, the* *greater the diffusion in either a positive or a negative direction.*

3. METHODS AND DATA

3.1 Model

To evaluate the three hypotheses empirically, we use a spatial autoregressive model (SAR model or spatial lag model) that has been employed to analyze diffusion or spatial dependence.[1] The SAR model helps us investigate how unit i's policy choice (dependent variable) is affected by the nearby unit j's policy choice (lagged dependent variable as function).

The SAR model is specified as follows:

$$y_{i,t} = \beta_0 + \varphi y_{i,t-1} + x_{i,t}\beta + \rho w_{i,j,t-1} y_{j,t-1} + C_i + \varepsilon_{i,t}$$

In our analysis, we seek to explain climate performance measured as the amount of CO_2 emissions per GDP $y_{i,t}$ as a function of variables of the diffusion mechanism suggested by an international relations theory as well as other control variables. Most importantly, the spatial component, $\rho W_{i,j,t-1} y_{j,t-1}$, represents the temporarily lagged spatial lag term to account for a diffusion effect as the weighted average of country *j*'s climate performance. The connectivity matrix or spatial-weighting matrix, *W*, is an *N* by *N* matrix where *N* is the number of states, with elements $w_{i,j,t-1}$ capturing relative connectivity or influence from state j to *i*. We row-standardize a spatial matrix in the model, which generates $w_{i,j,t-1} y_{j,t-1}$, a weighted average of other observations.

According to Neumayer and Plumper (2012) and Franzese and Hayes (2008a, pp. 8-9), the relative and absolute accuracy and power with which the spatial lag weights, $W_{i,j}$, reflect and can gain leverage upon the interdependence mechanisms actually operating empirically and with which the domestic, exogenous-external, and/or context-conditional parts of the model can reflect and gain leverage upon the *common-shocks* alternatives critically affect the empirical attempt to distinguish and evaluate their relative strength because the two mechanisms produce similar effects. Furthermore, in order to mitigate a simultaneity bias in estimation of the SAR model, the spatial component, $\rho W_{i,j,t-1} y_{j,t-1}$, is lagged by one year, assuming that an outcome in state *i* is affected by those in other connected states after a time lag.

The spatial coefficient denoted by ρ varies between -1 and 1 and measures the strength of spatial dependence between states, but restricts the directions of spatial dependence globally. This is due to the two constraints – (1) the weight matrix is row-standardized and (2) the direction of dependence is captured solely by the ρ coefficient. Thus, the ρ coefficient indicates the globally uniform direction of spatial dependence between states. A positive coefficient indicates strategic complement, while a negative coefficient strategic substitute. Locally heterogeneous directions may be indicated by a non-standardized weight matrix that finely captures the heterogeneous directions as well as the strengths of spatial dependence between states. Nonetheless, methodologically, the global restriction is justified by our analytical objective of uncovering the generalized direction of diffusion due to a particular intermediary, while, theoretically, it is justified by the systemic international relations theories used to guide our analysis.

As for other explanatory variables in the model, $\varphi y_{i,t-1}$ represents the effects of lagged dependent variable, $y_{i,t-1}$, and $x_{i,t}\beta$ captures the effects of state-specific characteristics and international arrangements. In addition, state-specific fixed effects C_i are added to the model to allow for cross-sectional heterogeneity.

3.2 Dependent variable

In our analysis, we employ the amount of CO_2 emissions (gram per gross domestic product [GDP] using purchasing power parity based on US dollars) as the dependent variable. The variable indicates the "efficiency" of CO_2 emission in state *i* by measuring how much CO_2 state *i* emits to obtain per GDP.[2] This GDP-adjusted emission variable is a good proxy of climate performance for a cross-national analysis where states vary considerably in economic size. The data cover 132 states for the period 1991-2008 and are drawn from the website of the International Energy Agency (IEA).

3.3 Independent variables

Among the explanatory variables of the model, the key is a spatial weight, a connectivity matrix *W*. There exists no scholarly consensus on the correct specification of connectivity for diffusion. As discussed in the preceding section, theorists have discussed coercion, competition and emulation as plausible diffusion mechanisms in conjunction with the related international relations theories, realism, liberalism and constructivism, respectively. In our analysis, we have attempted to find the best analytical model among the alternatives. To do so, we have created several spatial weight matrices that represent the essence of the diffusion mechanism informed by the theories: Each matrix indicates how a pair of states are related or connected with each other, based on a particular theory. These matrices are specified as follows.

(1) *GDP* According to realism, the size of a state's economy indicates its state power for coercion as the primary diffusion intermediary. Since power is relative, we calculate a ratio of state *i*'s real GDP to state *j*'s real GDP. It is conjectured that the greater i's GDP is relative to j's,

the stronger the former's diffusion effect on the latter, irrespective of distance, the extent of interdependence, or the strength of social association. Thus, a first spatial weight matrix is composed of row-standardized elements (i.e. the weights in each row sum to unity) that each indicate the ratio of state *i*'s real GDP (row) to state *j*'s real GDP (column). In this GDP-based matrix, the upper-triangular elements are just the inverses of the lower-triangular elements. We have obtained GDP data from the World Bank open database.

(2) *Trade* A second set of spatial weight matrices presuppose that diffusion accrues from processes of economic interdependence characterized as *competition* and *learning*. To evaluate these hypotheses, we created two connectivity matrices from bilateral trade data (Feenstra et al. 1997). The first connectivity matrix accounts for *learning* and indicates the strength of trade connection as the value of *i*'s import of various pollution-intensive products from *j*. We considered products, including chemical products (section 5 in the United Nations' Standard International Trade Classification [SITC]), manufactured goods (section 6), and machineries and transport equipment (section 7).

The second connectivity matrix indicates the extent of *competition* between states *i* and *j* in the exportation of the abovementioned industrial products. Following Cao and Prakash (2010, 2012), we generated the matrix by calculating the structural equivalence of export profiles, or the extent of trade competition between *i* and *j* in the export markets specified below (Snyder and Kick 1979).[3] Compared with the existing studies examining trade as a main diffusion intermediary, our specification of trade-based spatial weight matrices is unique in that we attempt to analyze the combined effects of trade-related *learning* and *competition* on diffusion. Our specification differs from those in the existing studies as follows. In constructing a spatial matrix for learning through trade, Perkins and Neumayer (2009, 2010) measured bilateral trade connectivity in specific sectors. Although they included manufactured goods and machineries, they excluded chemical products, another powerful emission-intensive sector, and thus effectively removed competition effects through these sectors from their analysis. In this vein, Cao and Prakash (2010, 2012) incorporated competition into their spatial weight by calculating structural equivalence. While their specification covered competition in all traded products, our specification focuses on competition *only* in emission-intensive sectors. Having employed the two spatial weight matrices, we compared their performance statistically and selected the best-fit matrix for the data (learning based on section 5), as explained in the next section.[4]

(3) *IGOs* Consistent with social constructivism, a third spatial weight measures the thickness of social communication as the frequency of joint memberships of IGOs between state *i* and state *j*. More specifically, the IGO-based spatial weight matrix is composed of row-standardized elements of the frequency of joint IGO memberships and is symmetric in that the influence of *i* on *j* is assumed to be equivalent to that of *j* on *i*. The data on IGO memberships is drawn from

the Correlates of War project (Pevehouse et al. 2004).

The elements in the matrices are "row-standardized": they indicate weights in each row sum to unity, thus measuring the relative strength of connectivity between states that determines the magnitude of climate performance diffusion from one state to another. Assuming that the system structure does not drastically change in the short run (seventeen years in our data), we constructed all *W* matrices from the data of year 2000, the mean year of the observations.

3.4 Control variables

The model includes several control variables at the international and domestic levels that are expected to counteract with diffusion captured by the spatial component. At the international level, we highlight two international governing schemes, environmental aid and the Kyoto Protocol, that are likely to have reducing effects on CO_2 emission in the recipient states and the ratifying states, respectively.

The first variable, ***Envaid***, represents the natural logarithm of the amount of environmental aid (US dollar) that state *i* receives in a given year. ***Envaid*** is created based on PLAID 1.9 aid data.[5] The natural logarithm is taken to account for a decreasing effectiveness of aid as the amount of aid increases. We expect that aid is positively associated with CO2 emission efficiency (the coefficient is expected to be negatively signed). The second variable, ***Kyotoc***, is a binary variable that indicates whether or not state *i* is a ratifying state of the Kyoto Protocol in a given year.

As for domestic factors counteracting with diffusion, we include variables related to political liberty, personal income, and urbanization. First, as reported by (Busch and Jörgens 2005), a politically liberal state is expected to achieve better climate performance than its non-liberal counterpart because public preferences on environmental protection are more likely to be channeled into political arenas in the former than in the latter. This hypothesis of political liberalism is tested, using the categorical variable that is derived from the index of "civil liberty" in the Freedom-House data. Second, as theorized by Inglehart (1977) and shown by (Dasgupta et al. 2001), economic affluence, measured by GDP per capita, is expected to facilitate environmental protection and improve emission efficiency because of post-materialistic human conscience and technological progress. However, modernization has a pitfall: concentrated population in urban cities is likely to worsen emission efficiency because of human and traffic congestion. The level of urbanization in state *i* is measured by the ratio of urban population to the state's total population. The data is retrieved from the World Development Index (WDI) provided by the World Bank.

4. RESULTS AND DISCUSSION

We have estimated a fixed-effect version of the proposed SAR model with a spatial weight via maximum likelihood (MLE) (Franzese and Hays 2006, 2008a). MLE is used both because it is an efficient estimator and because it facilitates comparison of rival models based on an information criterion that is important to our analysis, as explained earlier. The pooled cross-national time-series data cover 132 countries and the period between 1991 and 2008. The estimates are summarized in Table 1.

4.1 Model selection and primary diffusion intermediary

The statistical fit of all three spatial models (2-4) with the data is good.[6] The coefficient estimates for the control variables are consistent with intuition, thus buttressing confidence in the model and hypothesis tests. Most importantly, none of the three diffusion mechanisms postulated in the models can be falsified by the data in absolute terms. However, different results appear in relative terms. We have compared the models whose difference hinges solely on spatial weight matrices and selected the best spatial model that fit the data most closely. To do so, we have exploited the flexibility of spatial modeling by examining the fit of alternative spatial matrices with the standard test statistic, the Akaike information criterion (AIC), known as a reliable test statistic for model selection (Kostov 2010).

As shown in Table 1, comparison of AIC across the models leads us to conclude that the best fitted model is the SAR model (3) with the learning matrix based on chemical products (section 5). The SAR model (2) with the GDP-based matrix and the SAR model (4) with the IGO-based matrix perform worse than the model (3).[7] We argue based on these results that the diffusion mechanism, a major component of the informal climate change governance, hinges on learning through trade interdependence and accords with the theory of liberal internationalism. Our assessment is consistent with the overall result of the previous studies (Perkins and Neumayer 2008, 2009) showing that diffusion is driven by learning via trade interdependence. Nonetheless, we have revealed that adverse diffusion transpires through pollution-intensive chemical products, which is not well captured by the previous studies. We also have found through the experiments reported in note 4 that trade in the pollution-intensive chemical sectors induces learning, rather than competition, providing the basis for the best fitted SAR model (3).

This empirical assessment leads to a normative argument that the improvement of climate governance has to rely on numerous trading states as opposed to economically powerful ones. While there is similarity between the two types of states, the diffusion mechanisms differ, nonetheless. Conceptually, realism presupposes a vertical channel based on material power, whereas liberal internationalism uses a horizontal channel based on interdependence processes.

The relative importance of the latter has a significant policy implication that will be discussed in the last section of this paper.

4.2 Diffusion effect

Given the model selection, we rely on the best-fitted model (3) for evaluating the diffusion effect as well as the coefficient estimates for the explanatory variables. In the model (3), diffusion is found to be substantial. The extent of spatial dependence, measured by the ρ coefficient for the spatial autoregressive term, is estimated to be moderate at .36, positive and significant at the 95 % level. We conducted the Wald test whereby to reject the null hypothesis of ρ being equal to 0 at the 1 % level. With the significant ρ, the SAR model (3) is judged as empirically more appropriate than the ordinary least square (OLS) model (1) without a spatial construct.

We have re-estimated the model without the spatial (diffusion) component and calculated the total of predicted values (823,220.6 gram per GDP) which is smaller than the total of actual values (1,117,407.6 gram per GDP). This means that, on average, states in the data are exposed to adverse diffusion that has a substantial effect in increasing their emission by approximately 294,187 gram per GDP. This adverse or negative diffusion effect is substantial, accounting for approximately 36 percent of the total emission. Moreover, the diffusion effect is a major perpetrator of international discord in climate governance which is often underestimated by states negotiating for solutions to the global problem. Emission performance in a state is not insular, but is influenced significantly by that in other states through cross-border diffusion. Diffusion is integral part of the global problem of climate change.

4.3 Domestic countervailing factors

The coefficient estimate for the lagged dependent variable is positive and large, meaning considerable inertia in the dependent variable that is translated into the difficulty reducing carbon emission as a derivative of economic activity based on widely available fossil fuels. Although this intractability of carbon emission reduction is a fact of life, our analysis indicates the significance of interventions.

With a significant ρ coefficient reported above, a spatial model becomes effective in discerning estimates of the direct, indirect and total effects of an explanatory variable, given its spatial component. In general, the greater the ρ coefficient, the greater the indirect effect relative to the total effect. Contrastingly, if the ρ coefficient were to be indistinguishable from zero, an indirect effect would become negligible with a total effect becoming equal to a direct effect. With a moderate ρ coefficient (.36) estimated in the model (3), indirect effects are also moderate, providing domestic control variables with latitudes to take direct effect without diffusion disturbance.

The carbon-reducing domestic variables represented by political liberty and personal income acquire significant and negative coefficient estimates. Economic modernization involves a dilemma that prosperity characterized as a rise in income is often accompanied by urbanization, while political modernization helps climate stability weakly by improving human consciousness through civil liberty. These estimates suggest that carbon emission reduction is best achieved by a combination of high income, high civil liberty, and low urbanization. What this means is that carbon emission reduction is not a linear function of domestic politico-economic progress and thus has to be guided by prudent international policy interventions—the Kyoto Protocol and the environmental aid regime in our analysis.

4.4 International countervailing factors

The Kyoto Protocol is the first and only international implementation treaty to tackle carbon emission covered in the data. The coefficient for the dummy variable for the ratifying states and years is estimated to be negative and significant. This means that the Kyoto Protocol generated a significant reducing effect. It is worth noting that a relatively large indirect effect of the treaty is estimated in the model (3). Despite the effect, several ratifying states have abandoned the Kyoto Protocol because a greater number of non-ratifying states have taken free ride on their efforts, disseminating their regulatory negligence into ratifying states via diffusion.

As for environmental aid, our statistical analysis shows that even the weak aid regime is registered as a significant contributor to emission reduction in the recipient states. The aid regime has not been established formerly by the Kyoto Protocol although the protocol set forth the clean development mechanism (CDM) and joint implementation (JI) that facilitate technological transfers from high-income states to medium- and low-income states on the basis of market principles. Many developed states have funneled CO_2-reducing aid as part of their official developmental assistance (ODA) programs, including renewable energy, fuel-efficient power plants and urban transportation systems, etc.

As indicated in Table 1, aid generates both a significant direct and a significant indirect effect in reducing carbon emission. Aid strengthens a recipient’s capacity directly and influences its reduction performance indirectly via the improvement of its trading states’ capacities.[8] The indirect effect of aid, albeit informal, should be counted as an important component of the climate governance. It is interpreted that aid may stimulate the competitive or the learning process in a recipient state observing the improvement of performance in its trading partner with aid and thus becoming a bit more motivated to reduce emission than otherwise, insofar as they believe that more aid is funneled to good performers than to mediocre performers (Indeed, our auxiliary analysis has confirmed that more aid is given to states with large emission reduction than to those with small reduction.).

Despite significance, environmental aid fails to offset the diffusion effect of carbon emission from rich exporting states to low-income importing states. Causes of aid inefficiency may be multifaceted. First, aid is too small in value to improve developing states' carbon-reducing capacities significantly. Second, aid has a marginally decreasing function of emission reduction because of technological limitations. Third, the environmental aid regime has no mechanism to correct recipients' administrative and political deficiencies. Donors view such deficiencies as a structural impediment against the efficient use of aid money and thus are reluctant to expand their aid. This last reason links aid ineffectiveness to the small size of aid programs noted above, generating vicious circularity within the aid regime. This line of argument does not reject the potential efficacy of an aid regime in facilitating carbon emission reduction. As shown in the SAR model, environmental aid, albeit insufficient in size, has an independent and significant effect in reducing carbon emission by recipient states.

Thus far, our findings indicate the following. First, states' poor climate performance generates adverse diffusion to other states via trade interdependence. Second, the adverse diffusion is too immense to be contained by the international countervailing factors of the environmental treaty and aid regime as well as by the domestic countervailing factors of political liberty and economic affluence. The existing governance framework is vulnerable to adverse diffusion precipitated by competitive trading states. What would be an alternative governance framework?

4.5 Simulation analysis

To evaluate this point further, we have conducted the following simulation analysis. We are interested in knowing a coalition of states that is most suitable for eliminating the adverse diffusion effect and thus facilitating effective climate governance at reasonable efficiency-improving costs. The candidate coalitions we evaluated include (1) G20, (2) the Kyoto Protocol Annex 1 without the United States, (3) Annex 1 (original contracting states including the United States), (4) a hypothetical coalition of states with GDP per capita of over US $10,000 and (5) another hypothetical coalition of states with GDP per capita of over US $5,000.

The simulation procedure is outlined as follows. First, we re-estimated the model without the spatial component and calculated the total of the predicted values that disregarded diffusion. As reported earlier, the value is smaller than the total of the predicted values of the original SAR model. The difference between the two totals can be derived from cross-national diffusion. Second, we re-estimated the SAR model with improved emission efficiency at varying rates in the specified coalitions of states outlined above. The simulation results are shown in Figure 1.

The in-sample simulation results indicate that, among the alternatives, a coalition of states over $5000 in (5) is the only one that can achieve the elimination of adverse diffusion with the efficiency improvement rate of approximately 24 percent. In contrast, other coalitions fail to eliminate the adverse diffusion. Consistent with intuition, the more states participate in the coalition, the lesser the burden for each state. However, in general, the difficulty of obtaining consent becomes severe as the income threshold lowers with the expansion of a coalition. Developing states have continuously claimed that they are immune to legal responsibilities for reducing carbon emission because their accumulated emissions are much less than those of developed states that have emitted carbon since the Industrial Revolution. They embrace the principle of common-but-differentiated responsibilities that has influenced international climate talks and coalition formation since the Berlin meeting—the first Conference of Parties (COP 1) of UNFCCC in 1993.

The in-sample simulation results indicate that, without participation by a number of developing states, it would have been extremely difficult to achieve the elimination of adverse diffusion and thus facilitate international cooperation. The results support the claim that the failure to hold these states legally responsible for emission reduction is a major cause of international discord. This is the well-known intractable dilemma that has plagued international negotiations for climate governance. What is new here derived from the empirical search is that an efficiency-improving coalition requires not large states, but trading states that are in a position to generate (and reduce) diffusion via trade.

5. CONTRIBUTIONS AND CONCLUSION

In this paper, we have tried to shed light on diffusion that has received limited attention from negotiators and analysts, even though it is critical to climate governance in influencing trust and incentives for international cooperation. Using spatial modeling and systemic international relations theories, we have found that, on average, diffusion adversely affects other states' emission efficiency and that emission by states with competitive trade activity is a major source of the adverse diffusion. This result holds even if international and domestic countervailing factors are taken into account. Thus, for better climate governance, the adverse diffusion needs to be contained by a large coalition of numerous trading states to promote trust and incentives for international cooperation through reciprocity.

This prescription opposes the idea of G20 with world-largest economies being the engine of global climate governance, instead favoring a large coalition of numerous trading states. This prescription will be confronted with an N-state prisoners' dilemma which should be resolved by prudent institutional arrangements, such as environmental aid or technological transfer.

For future work, several refinements are in order. A first refinement hinges on the improvement of spatial modeling, particularly the construction of a precise spatial weight matrix that can capture the locally heterogeneous directions of diffusion. In the current paper, informed by the systemic international relations theories, we have been interested in knowing the globally homogeneous (or average) direction of diffusion constrained by the ρ coefficient, although we measured the heterogeneous magnitudes of connectivity between states. A second refinement calls for the incorporation of a detailed set of information, including distance, political ties, and cultural ties, into an analysis of connectivity. A third refinement enriches an out-of-sample simulation for prediction of diffusion and alternative coalitions based on improved information derived from the second refinement. Refined analyses will help improve the efficiency of coalition formation to contain adverse diffusion and facilitate international cooperation for climate governance. The analytical results are valuable in designing an effective international treaty to exploit diffusion in a more constructive way under a coalition of states appropriate for both the complexity of the climatological problem and the heterogeneity of states.

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NOTES

[1] In general, spatial models include a spatial error model, spatial autoregressive model (SAR), spatial geographically weighted regression, Durbin model, and spatial auto correlation model (Fotherington, Brunsdon, and Charlton 2002). The SAR model has been most frequently used in the existing studies of policy diffusion and interdependence. We follow the existing studies on the use of SAR model.

[2] Perkins and Neumayer (2008, 2009) use GDP divided by the amount emissions as the variable.

[3] We calculated the extent of structural equivalence as the correlation coefficient (p) of two states' exports at the bilateral level. A given state's "export profile" is n-1 elements where *n-1* is the total number of export partners of state *i*. p ranges between -1 and 1. The value of 1 means that two states have exactly the same profiles of bilateral exports to other states, while the value of -1 means that two states have the most dissimilar export profiles. We assume that only states sharing the same export market are likely to regard one another as competitors. Hence, we use elements of positive values only in our structural equivalence matrix, by replacing observations of negative values with zero.

[4] We tested the four matrices (section 5, 6, 7, and 5&6&7) for cases of learning and competition, which generated eight matrices in total. We extracted the trade volumes of pollution-intensive sectors from the Freenstra data that include the United Nations' Standard International Trade Classification (SITC) specifying industrial sectors of traded products. Through experiments, we chose the matrix based on section 5 for learning as the best fitted model whose results are reported in the text. This model always outperformed the model for competition.

[5] The original data contain a variety of aid projects ranging from industrial, humanitarian, to environmental. To extract CO_2-reducing projects from the data, we refined the data in the following

manner. In the first step, we extracted the projects categorized as “energy (#23000)” and “environmental protection (#41000).” Because these projects, especially energy-related projects, include both CO_2-increasing energy development projects and CO_2-reducing renewable projects, we excluded the former projects that are coded as “dirty” and “unsure” in the data. In addition, we excluded aid projects given to a group of states in regions and bilateral aid to unspecified recipients. The environmental code indicates the degree of environmental intensity of a given project has more environmental in six different levels: “dirty strictly defined” “dirty broadly defined” “natural” “environmental strictly defined” “environmental broadly defined”, and “unsure”. (“unsure” is coded when project description did not provide sufficient information for environmental coding.)

[6] We estimated a fixed-effect version of the SAR model because, as noted in the text, the data involve 132 countries and the period of 17 years and thus entail a potential problem of heterogeneity that the version is well suited to overcome. In addition, we conducted an auxiliary Hausman test which indicated that the fixed-effect model performed better than its random-effect counterpart. In addition, we tested a spatial Durbin model (SDM) that assumes spatial lags for all independent variables. We could not reject the null hypothesis of all spatial coefficients being equal to zero at the standard statistical levels: $X^2(4) = 4.70$ ($p= 0.32$). Moreover, the likelihood ratio test based on the Akaike information criterion (AIC) indicates that SDM fares worse than the SAR: despite the added spatial components, the former does not improve the likelihood of predicting the data correctly beyond the latter. These results suggest that the SAR model is a reasonable spatial model for the data.

[7] A caveat is in order: the types of IGOs included in the data vary substantially from pro-environment to pro-industry organizations and from humanitarian to military ones. Thus, it is plausible that the spatial analysis here could not discern a positive diffusion effect of pro-environment IGOs from a negative effect of other IGOs. Both types of IGOs might offset their effects, thus making the model (3) perform worse than its rival ones.

[8] It is often discussed in the aid literature that the effectiveness of aid depends on the administrative and political efficacy of recipient states. To evaluate this claim, we added an interaction term between the aid variable and the Freedom-House civil liberty variable. The result shows that neither the interaction term nor the other separate variables gain statistical significance, thereby refuting the hypothesis of political sensitivity of aid.

Table 1: Models of CO2 emissions performance

Explanatory Variables	*Model1(OLS)*	*Model2(Power)*	*Model3(Trade)*	*Model4(IGO)*
	Coef [SE]	*Coef [SE]*	*Coef [SE]*	*Coef [SE]*
Main				
Env Aid (ln)	-1.2536	-0.7417	-0.7929	-0.6347
	[0.30]***	[0.31]**	[0.29]***	[0.31]**
Freedom House	-4.1549	-4.665	-5.4615	-5.1547
	[2.89]	[2.79]*	[2.77]**	[2.78]*
Urban population (% of total)	2.8493	4.4002	2.5273	4.6923
	[0.81]***	[0.85]***	[0.78]***	[0.83]***
GDP per capita (ln)	-17.4023	-12.666	-6.2044	-6.3105
	[5.03]***	[4.95]**	[5.06]	[5.17]
Kyoto Protocol	-14.8328	-9.5224	-8.5078	-4.9452
	[4.35]***	[4.34]**	[4.25]**	[4.48]
Lagged DV	0.7387	0.7318	0.7207	0.7263
	[0.01]***	[0.01]***	[0.01]***	[0.01]***
Intercept	101.8208			
	[59.13]*			
Spatial ρ		0.108	0.3497	0.3281
		[0.02]***	[0.03]***	[0.05]***
σ^2		4186.7597	4115.5047	4157.1855
		[118.05]***	[116.07]***	[117.22]***
Direct				
Env Aid (ln)		-0.719	-0.775	-0.6127
		[0.34]**	[0.32]**	[0.34]*
Freedom House		-4.505	-5.3297	-5.0026
		[3.01]	[3.01]*	[3.01]*
Urban population (% of total)		4.4097	2.5372	4.7055
		[0.81]***	[0.74]***	[0.80]***
GDP per capita (ln)		-11.6691	-5.2188	-5.2354
		[4.57]**	[4.75]	[4.81]
Kyoto Protocol		-9.0502	-8.1997	-4.2837
		[4.46]**	[4.37]*	[4.60]
Indirect				
Env Aid (ln)		-0.0871	-0.3932	-0.3028
		[0.04]**	[0.16]**	[0.16]*
Freedom House		-0.5903	-2.8139	-2.6922
		[0.45]	[1.74]	[1.88]
Urban population (% of total)		0.5712	1.3095	2.4998
		[0.20]***	[0.43]***	[0.85]***
GDP per capita (ln)		-1.4627	-2.5984	-2.544
		[0.62]**	[2.31]	[2.34]
Kyoto Protocol		-1.1272	-4.2006	-2.072
		[0.59]*	[2.30]*	[2.41]

Total				
Env Aid (ln)		-0.8061	-1.1683	-0.9155
		[0.37]**	[0.48]**	[0.48]*
Freedom House		-5.0953	-8.1436	-7.6948
		[3.44]	[4.71]*	[4.81]
Urban population (% of total)		4.9809	3.8467	7.2053
		[0.97]***	[1.13]***	[1.53]***
GDP per capita (ln)		-13.1318	-7.8171	-7.7793
		[5.09]***	[7.02]	[7.06]
Kyoto Protocol		-10.1774	-12.4003	-6.3557
		[4.98]**	[6.59]*	[6.92]
N. of observations/countries	2244/132	2244/132	2244/132	2244/132
Log likelihood	-12488.74	-12477.71	-12462.2	-12470.36
AIC	24991.4894	25001.4141	24970.3977	24986.7168

Notes: Standard errors are in parentheses.

*** Significant at 1%; ** significant at 5%; * significant at 10%

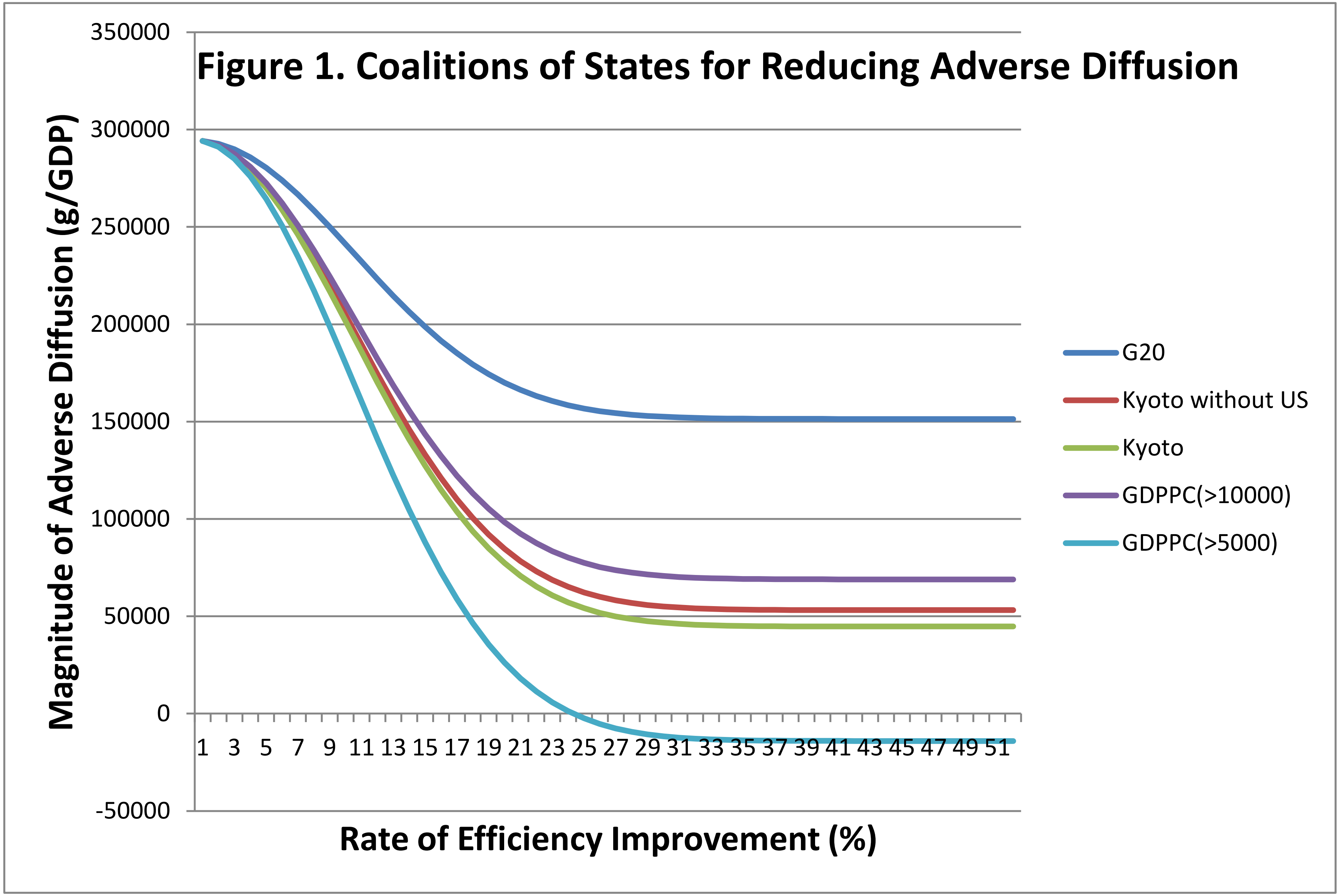
Figure 1. Coalitions of States for Reducing Adverse Diffusion
350000
300000
250000
200000
150000
100000
50000
0
-50000
Magnitude of Adverse Diffusion (g/GDP)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
Rate of Efficiency Improvement (%)
G20
Kyoto without US
Kyoto
GDPPC(>10000)
GDPPC(>5000)