Exploring the Nature of Strategic Interactions in the Ratification Process of the Kyoto Protocol

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Résumé / Abstract

Do countries interact when they decide to ratify the Kyoto protocol? What is the nature of these possible interactions? To answer these questions we provide a theoretical analysis based on the notions of strategic substitutability and strategic complementarity. Firstly, we analyze the nature of interactions between countries when they merely seek to provide a global public good (avoiding climate change). Secondly, we argue that countries are interlinked in several dimensions in the real world and we try to shed light on the nature of strategic interactions generated by geographic proximity, trade flows and green investment flows. The empirical investigation is realized via the introduction of spatially lagged endogenous variables in a parametric survival model and our data sample covers the period from 1998 to 2009 for 164 countries. We find evidence that the decisions of neighbors and of green investors matter. Furthermore, our results indicate that the influence of the decision of trading partners is even more substantial.

Mots clés /Key words : International Environmental Agreements, Kyoto Protocol, Ratification, Strategic substitutes/complements, Survival model, Spatial lag

Codes JEL / JEL codes : C41, F53, H41, Q53, Q56

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1. Introduction

From the third earth summit in Rio 1992, which gathered 172 governments in order to make "the difficult decisions needed to ensure a healthy planet for generations to come" (United Nations (1997)), three conventions were born: the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity and the United Nations Convention to Combat Desertification. At the present time, only the UNFCCC has given birth to a binding agreement, the Kyoto Protocol (KP). This shows the difficulty of creating such a treaty between sovereign countries and underlines the particular interest we have to understand why do countries participate in this protocol.

Several authors have tried to reveal the role of countries characteristics in the decision to participates in the KP. For instance Neumayer (2002a), studies the role of democracy level. He finds that democracies are more likely to participate in the KP than autocracies, as suggested by Congleton (1992) with respect to International Environmental Agreements (IEA)[1]. Then, Fredriksson et al. (2007) find that the presence of lobby groups affects the probability of ratifying the Kyoto protocol.

However, the question of interdependence in ratification decisions has never been addressed in the literature. Yet, the proceeding of climate change negotiations suggests that this could be relevant. The European heads of governments tried for example to convince Russia to ratify the KP in order to allow the entry into force of the protocol[2,3]. By contrast in the United States a resolution was adopted by the senators, which stipulated that the US congress was not allowed of ratifying an agreement where the United States would have quantitative emission reduction targets whereas developing countries would not (Barrett (1998)). Following this announcement, Australia, refused to ratify the KP as well, even though it had initially signed the protocol. This anecdotal evidence suggests that participa-

[1]Note that Fredriksson and Gaston (2000) find the same results for the ratification of the UNFCCC.

[2]See among many newspaper articles from the Guardian by Osborn (2001) and from the New York Times by Rohter and Revkin (2004).

[3]Indeed, to enter into force, the protocol had to be ratified by 55 countries representing 55% of Greenhouse Gas (GHG) in 1990.

tion in the Kyoto protocol is not an independent decision. Consequently the present paper tries to answer the following questions. Do countries interact when they decide to ratify the Kyoto protocol? What is the nature of these possible interactions?

Even if these questions are not addressed in the literature for the KP case, several authors have tried to measure the presence of interdependencies in environmental treaties participation decisions. Bernauer et al. (2010) study whether the probability of ratification depends on the behavior of similar countries (*e.g.*, belonging to the same region, same income group). However, this is not really a measure of interactions, since only dummy variables are included as proxies of interdependencies. Davies and Naughton (2006) study whether there exists a spatial dependence in the ratification decision process of IEAs. Using a composite index of thirty-seven agreements these authors investigate whether countries from the same area ratify the same number of agreements, rather than really demonstrating an effect of country j's decision on a country i's one. Finally Beron et al. (2003) analyze the ratification of the Montreal protocol. They consider the situation in 1990 and study why countries that ratified the protocol before 1990 did so. They do not find interdependence in the ratification process. However, on the one hand, they make a cross section analysis, and if there are interactions, they take place over time. On the other hand, they study the Montreal protocol and we are not sure that the participation of countries in this treaty can be analyzed as a cooperative behavior. Indeed, Murdoch and Sandler (1997) explain that the use of CFC substitutes was probably economically profitable.

Therefore, according to our knowledge, there is no study measuring precisely the presence or absence of interactions between States when they decide to participate in an IEA, neither for the Kyoto Protocol nor for any other one. Consequently, our contribution to the literature is to empirically evaluate the presence of interactions between the ratification decisions[4], and this is done for a major binding agreement, the Kyoto protocol. The theoretical analysis

[4]Although signature is not a meaningless act, ratification is more interesting to study, since according to the UN definition "upon ratification, the State becomes legally bound under the treaty" (United Nations, 2006). See also Barrett (1998) for a description of the different stages of a treaty-making.

is based on the notions of strategic substitutability and strategic complementarity. We argue that countries are interlinked in several dimensions in the real world, and try to shed light on the nature of interactions generated by geographic proximity, trade flows and green investments flows.

The empirical investigation is realized via the introduction of a spatially lagged endogenous variable into a duration model and our data sample covers the period from 1998 to 2009. We find evidence that the decisions of neighbors and of green investors matter. Moreover it seems that the influence of the decision of trading partners is even more substantial.

The rest of the paper is organized in the following manner. We analyze the multiple dimensions influencing the negotiation of an IEA in Section 2. Then, in Section 3 we explain how we measure the factors affecting a State decision and we present our estimator. Our results are analyzed in Section 4 and finally, in Section 5, we conclude.

2. Analysis of the multiple dimensions at stake

The interaction between a country and its peers can evolve in two directions. The utility of a country's contribution to the public good may either (i) decrease with the contribution of its peers, the contributions thus being strategic substitutes; or (ii) increase with the contribution of its peers, the contributions thus being strategic complements. In this paper, the contribution to the public good considered is the ratification of a country[5]. We first analyze the likely nature of contributions when a country merely seeks to provide a global public good. Then, we consider that the ratification could be motivated by other considerations such as neighbor relations, trade relations and the willingness to host sustainable development projects such as Clean Development Mechanism (CDM) ones.

[5]Indeed, we try to understand why countries participate in the KP, not to explain their level of participation. The latter would have been measured by the decrease in GHG's emissions to which they committed themselves.

2.1. Public good provision

Let us first study how a country is influenced by its peer's decisions when it merely seeks to provide a global public good, namely avoiding climate change. Consider the utility function of a country i represented by $U_i(x_i, G)$, where x is the private good and G the public good. The country chooses to allocate its resources to the provision of the private good (x_i) or to the provision of the public good (contribution $= g_i$). Since in the specific context of climate change, the emission of z tonnes of carbon has the same impact whoever emits them, the aggregation technology of contributions is the summation, therefore $G = g_i + \sum_{j \neq i} g_j$. This implies that i's contribution and rest-of-world contributions are strategic substitutes (see Cornes and Sandler (1996), p. 144 and Sandler (1998)). Thus countries will have incentives to let others reduce GHG's emissions, *i.e.*, to free-ride. This leads us to us to make our first hypothesis.

Hypothesis 1. *The ratification utility of a country i is a decreasing function of the participation of the other countries, i.e., participation decisions are strategic substitutes.*

Without considering any other participation determinants, it is difficult to explain the formation of an agreement concerning climate change. As underlined by Glazer and Proost (2008), the free rider problem should deter participation. Furthermore, a large number of theoretical works predict that environmental agreements gathering a relatively large number of countries are not stable (see Finus et al. (2006) for a literature review on this question).

However, we do observe a rise in IEAs. According to Mitchell (2003), more than 700 multilateral agreements and 1000 bilateral agreements would exist. Therefore, we argue that ratification could be motivated by other considerations than the provision of a global public good and we study these alternative motivations in the next subsection.

2.2. Additional dimensions

"If a small group of people who have an interest in a collective good happened also to be personal friends, or belonging to the same social club, and some of the group left the burden of providing that collective good on others, they might, even if they gained economically by this course of action, lose socially by it,.." Olson 1965, p. 64.

In the real world, countries are interlinked in several dimensions, which could lead them to act as members of a social group. Therefore, a country does not attach the same importance to each ratification according to the links it has with the country that ratified the agreement. Indeed, as pointed out by Guzman (2008), the participation of a country in an IEA has external consequences. For instance, it could be viewed as a cooperative signal affecting other dimensions such as diplomatic and trade relations. Moreover it can be considered that the design of the treaty affects the influence of a country on another, for example through the green investment flows ensuing from the Clean Development Mechanism.

2.2.1. The effect of proximity

Geographical proximity often implies cultural similarity, social proximity and economic interdependencies which result in repeated interactions between countries. This is the first idea advanced by Gleditsch and Ward (2001): *"Distance is widely acknowledged to be a primary force shaping the opportunity for interaction among states in the international system."*. This results in diplomatic relations of the utmost importance and leads states to participate in IEA even though they do not have immediate incentives or economic interests to do it. Maler (1990) highlights a meaningful example that illustrates this point. He describes the Columbian River Treaty between the US and Canada concerning hydropower generation and flood protection. The negotiations ended with a gain of about $250 million for Canada and a loss of about $300 for the United States, one of the US negotiators adding that the growth of Canada was of primary importance for the US.

We argue that strong diplomatic ties between neighboring countries could lead them to ratify an unprofitable environmental agreement in order to maintain those ties. Therefore, we expect a country will be positively affected by the decision of neighboring countries.

Hypothesis 2. *Ratification utility of country i and that of its neighbors are strategic complements.*

2.2.2. The importance of trade

Consider now a more economic interdependence, such as the one created by trade flows. As pointed out by Neumayer (2002b), we are in a world where we consider that imports benefit mainly the exporter. Therefore a country aspires to creating and maintaining a good reputation within the international community if it does not want to face trade restrictions. In this context, participation in an IEA constitutes a positive signal that enhances a country's reputation. This positive signal is also important if a country seeks to benefit from new preferential trade agreements. On the other side, several countries are scared that the Kyoto protocol will hamper their competitiveness. The attitude of the US senate described in the introduction is now a classic example but the New-Zealand case is an interesting one too. Yang (2004) detailed the conflict between the Labour-led government and the business lobby. The former wanted a ratification as soon as possible while the latter argued that "New Zealand's ratification of the Protocol should be conditioned on its major trading partners' ratification."

The three effects described, avoiding trade restrictions, reaching new trade agreements and avoiding relative competitivity loss could drive countries to follow the decisions of their trading partners. This leads us to formulate our third hypothesis.

Hypothesis 3. *Ratification utility of country i and that of its trading partners are strategic complements.*

2.2.3. The CDM role

When a developed country ratifies the Kyoto protocol, it is registered as an Annex 1 country and therefore receives emission reduction targets. To meet these targets, a country can decrease its carbon emissions on its own territory or resort to flexibility mechanism such as the Clean Development Mechanism[6]. The main rules governing this mechanism have been defined at the COP 7 held in Marrakesh in 2001 (Lecocq and Ambrosi, 2007). The principle is to finance an emission-reduction project in a developing country, which can lead to the creation of saleable certified emission reduction credits[7]. On the one hand, this mechanism

[6]The study of the Joint Implementation mechanism is of limited interest since it began with the first commitment period in the KP in 2008 (Grubb et al. (2011)).

[7]Each of them is equivalent to one tonne of CO2 and these credits can be used to meet the Kyoto targets (UNFCCC, 2011).

confers to developed countries a more flexible way to meet their targets. On the other hand, it constitutes a great opportunity for developing countries as well. Indeed one objective of the CDM was to promote sustainable development, through the financing of new projects and the technological transfers which might ensue[8]. To host a CDM project, the developing country obviously had to ratify the KP first. Therefore we expect that the ratification decision of a developing country will follow that of the developed countries that will fund the CDM projects on its territory.

Hypothesis 4. *Ratification utility of country i and that of the country funding CDM projects in its own territory are strategic complements.*

3. Empirical strategy

3.1. Data and Measures

To test the hypothesis formulated in the preceding section, we estimate an equation of the following form :

$$r_{it} = \kappa \sum_{i \neq j} r_{jt} + \vartheta \sum_{i \neq j} \omega_{ij} r_{jt} + \sum_{k} \zeta_k X_{kit} + \eta_{it}.$$

The dependent variable r_{it} takes the value of 1 if country i ratifies during the year t (as reported by the UNFCCC) and 0 otherwise. The influence of the participation of other countries j on a country i (the external determinants of ratification) is captured through the parameters κ and ϑ. A set of k control variables X is introduced of which influence is captured through the ζ_k parameters. These control variables represent the internal determinants of the KP ratification, namely the country's characteristics. η_{it} is the remaining error term. Our data sample covers the period from 1998 to 2009 for 164 countries. A comprehensive list of the variables, along with their definitions and sources is available in Appendix A.

The parameter κ allows us to study the reaction of a country when the number of countries engaged ($\sum_{i \neq j} r_{jt}$) increases (variable "Number_ratifications"). This will help us to find out

[8]See Dechezleprêtre et al. (2008, 2009) for a study of the characteristics of these technological transfers.

whether there is a free rider problem (driven by a substitutability in ratification decisions) or not.

Then, in order to study strategic complementarities or substitutabilities in ratification decisions in the three additional dimensions described in our theoretical analysis, we borrow the methodology used in the tax-competition and public spending literature (see for example Case et al. (1993), Brueckner (2003), Lockwood and Migali (2009) or Caldeira et al. (2010)). We estimate a spatial-lag model, where the spatially lagged endogenous variable (thereafter "spatial lag") is of the form $\sum_{i \neq j} \omega_{ij} r_{jt}$. The weighting factor used ω_{ij} measures the intensity of the links between countries i and j and is obviously specific to each studied dimension. To be able to compare our coefficients between the models, our weights are normalized (they range from 0 to 100). Their main descriptive statistics can be found in Appendix B, table 6.

To evaluate the influence of the decision of neighbors, ω_{ij} is defined as $\frac{\frac{1}{d_{ij}^2}}{\sum_{i \neq j} \frac{1}{d_{ij}^2}} * 100$ where d_{ij} is the distance between i's and j's capital provided by the CEPII distance database.

Second, bilateral export flows allows us of estimating the effect of the decision of trading partners on the decision of a country. ω_{ij} is therefore defined as $\frac{X_{ij}}{\sum_{i \neq j} X_{ij}} * 100$, where X_{ij} is the percentage of exports from i to j[9]. The weighting factor ω_{ij} corresponds to the part of exports from i to j in the total exports of i.

Our third weighting factor is the number of registered CDM projects financed by a developed country j in a developing country i, listed in the CDM pipeline UNEP-RISOE database from 1998 to 2009. Therefore ω_{ij} is defined as $\frac{P_{ij}}{\sum_{i \neq j} P_{ij}} * 100$, where $\sum_{i \neq j} P_{ij}$ is the total number of registered projects in a hosting country at the end of the sample period.

Lastly, following Case et al. (1993), Lockwood and Migali (2009) and Caldeira et al. (2010), we construct a "placebo" weighting scheme that will ensure that the results are not driven by model misspecification such as omitted common shocks. This weight is constructed as follows: we consider that the first and last countries in alphabetical order are linked (ω_{ij} taking the value of one), then the second and the second last are considered as linked too

[9]We exploit export data from the UN Comtrade database and X_{ij} is the mean of available bilateral exports for the sample period.

and so on. We obviously expect a non significant coefficient associated with this spatially lagged term.

The set of internal determinants includes first the quality of institutions. A country is considered as "Free" (=3) if the sum of its civil liberty index and its political right index is below 5 , "Non-Free" (=1) if it is above 10 and "Partly-Free" (=2) otherwise (variable "Democracy"). Data comes from the Freedom House. Since the ratification of European Union countries was a joint decision, we introduce a dummy when the country was a member of the EU in 2002 (variable "EU"). We also introduce a dummy variable for Annex 1 countries ("Annex_1"). The other characteristics of countries are taken from the World Bank Development Indicator 2010. We introduce the education level of a country, measured by the rate of gross secondary school enrollment ("Education"). We introduce the GDP per capita and its squared term in order to take into account the environmental kuznets curve effect ("GDPpercap" and "GDPpercap^2"). Finally, following Neumayer (2002b) and Fredriksson et al. (2007), we introduce the ratio of fuel exports on total export, in order to take into account the lobbying that governments could face ("Oil_exports").

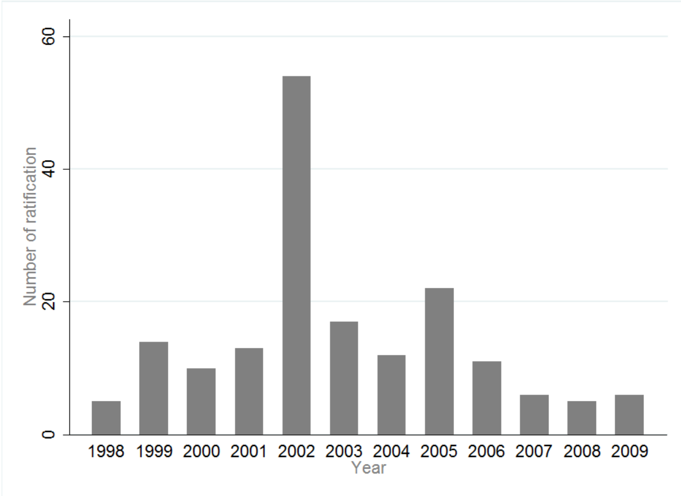
3.2. Duration issues

We try to explain the number of years a country takes to ratify the KP from its opening to ratification in 1998. This requires the use of a duration model. The main advantage of this kind of model is that the individuals could be observed on different sample periods and we can take into account of censor in the sample. In our case, we observe some countries until 2002 (*e.g.*, the EU15 members) and some until 2009, since they never ratified the KP (*e.g.*, the United States)[10].

Since we observe yearly ratifications, our scale time is non-continuous and we are in the case of grouped data. Indeed, as shown by figure 1, the KP is ratified by 17 countries per year on average, with a peak of 54 in 2002.

[10]Technically, we are in the case of single spell data (only one ratification per country) with a right-censored sample (some countries have not yet ratified the KP at the end of the studied period).

Figure 1: Number of countries ratifying the Kyoto protocol by year, from 1998 to 2009.



Therefore, we are confronted with multiple time failure problems, which makes semi-parametric models like the Cox proportional hazards one inaccurate (see Wooldridge (2001)). This leads us to use a parametric survival model.

The general formulation of a parametric survival model in the proportional hazard metric is as follows:

$$h(t|x_p) = h_0(t)exp(x_p\beta_x), \tag{1}$$

where t is the time scale, p the unit of observation and x a matrix of both variant and time invariant independent variables and β_x the corresponding coefficients. The hazard rate ($h(t|x_p)$) is the probability that a country i ratifies ($r_{it} = 1$) during the next period, considering that it has not ratified yet. The baseline hazard $h_0(t)$ is the probability to ratify that everyone faces, this latter being modified by the value of the x_p, specific to each individual.

The estimation of a parametric survival model drives us to make an assumption about the baseline hazard distribution $h_0(t)$. Note that this latter is the counterpart of the error term in standard regressions. The two terms will be used interchangeably in the rest of the paper. From a theoretical point of view, any law representing the distribution of a positive variable can be used to model the distribution of the baseline hazard. However, as noted by Fredriksson et al. (2007) before us, the hazard rate of the KP ratification process seems to increase monotonically. Therefore the Weibull and Gompertz distribution seems suitable to model the baseline hazard. Then the calculation of the Akaike information criterion[11], widely used in order to discriminate between the different available laws, indicates to us that the Gompertz distribution is the most suitable to model the baseline hazard. Therefore we choose to estimate a parametric survival model where the baseline hazard follows a Gompertz distribution law[12].

Since we have panel data, this allows of controlling for the unobserved heterogeneity specific to each individual. In survival models, this becomes possible with the introduction of a frailty term in the model. In a formal form the unshared frailty model can be represented as follows:

$$h(t_p|x_p, \alpha_p) = \alpha_p h(t_p|x_p), \tag{2}$$

where α_p is an unobserved observation-specific effect (Cleves et al. (2010))[13]. By specifying a frailty term shared at the country level, we obtain a model analogous to a random-effect model in panel data regressions (Gutierrez (2002)). Our main results will therefore come from the estimation of parametric survival models with a frailty term shared at the country level.

The shared frailty model can be written as:

$$h(t_{fp}|x_{fp}, \alpha_f) = \alpha_f h(t_{fp}|x_{fp}), \tag{3}$$

where f identifies the group of N observations of the same frailty. This model is estimated

[11]The Akaike information criterion can be defined as $AIC = -2lnL+2(\alpha+\beta)$, where L is the log-likelihood of the estimation, α the number of explanatory variables and β the number of specific distributions.

[12]The gompertz hazard function is equal to $\lambda exp(\gamma t)$, where t is the time in year and γ the shape parameter. When γ is equal to zero, the hazard is equal to λ for all t (Cleves et al. (2010)).

[13]The distribution of the frailty parameters chosen for its mathematical tractability is the inverse-gaussian one. The frailty is assumed to have mean 1 and variance θ for model identifiability.

using maximum likelihood.

3.3. Spatial error correlation

To measure interdependencies in the ratification process of the Kyoto Protocol, we introduce a spatially lagged endogenous variable in a parametric duration model. This methodology is similar to the one used by Simmons and Elkins (2004) in their study of the spread of liberalization across countries. However, we are aware that our model could be subject to the spatial error correlation problem.

The presence of spatial error correlation would mean that the model is misspecified and that there is a correlation between our error terms which would threaten the properties of the estimator (see Anselin (2006)). Therefore, first, we carefully specify our model and then, we allow for correlation between the error terms in several manners. We cannot estimate a proper spatial error correlation in the way Darmofal (2009) and Banerjee et al. (2003) do. These authors implement (bayesian) parametric spatial survival models, but this kind of model only exists for cross-section data.In our case, interactions take place over time and so it is not relevant to investigate them in a cross section setting. That is the reason why we decide to control for potential correlation between the error terms while keeping both our temporal and individual dimensions.

Our strategy is to run estimations while allowing for correlation between the error terms in several manners. If the results vary according to the type of spatial correlation allowed by the model, then misspecification can be suspected. The easiest situation in which we could relax the assumption of no error correlation is the case where our weighting factor is the distance between capitals. In this case, we can think that, if there is a correlation between the error terms, it mainly occurs in a particular geographic area. Therefore, we first allow for a correlation between the error terms by specifying a cluster at the continent level and at the World-Bank regions level[14]. To ensure the robustness of our results, we also specified a

[14]The World Bank classifies the countries in 7 regions that do not correspond exactly to the geographic continents. For example we have: "Middle East & North Africa" and "Sub-Saharan Africa". Note that the developed countries belong to the same region.

frailty model where the frailties are shared at the continent level and the World-Bank regions level.

4. Determination of the nature of interactions

4.1. Main results

As mentioned, our data sample covers the period from 1998 to 2009 for 164 countries. Descriptive statistics on the independent variables are available in Appendix B, table 5 and 6, and the list of countries included in the sample is in Appendix C. A preliminary examination of the descriptive statistics on the dependent variable available in table 4, appendix B, shows that 84% of the countries present in our sample ratified the Kyoto protocol before the end of the period studied, and the median country ratifies 5 years after the opening of the protocol to ratification.

We present our main estimation results in table 1. In column (1) the weighting factor is the distance between capitals, in column (2) the bilateral export flows, in column (3) the number of hosted CDM projects, and in column (4) we used our placebo weight. Since we present the parametric survival model in the proportional hazard metric form, we report hazard ratios.

Table 1: Gompertz estimation results of the probability to ratify the KP

Weighting factor	**Proximity**	**Trade**	**CDM**	**Placebo**
	(1)	(2)	(3)	(4)
Internal determinants				
GDPpercap	3.6881	2.7218	7.0971**	8.6799**
	(0.130)	(0.323)	(0.021)	(0.016)
GDPpercap^2	0.9190	0.9542	0.8864**	0.8732**
	(0.118)	(0.458)	(0.023)	(0.016)
Democracy	1.6978***	1.5574**	1.8033***	1.8147***
	(0.001)	(0.027)	(0.000)	(0.001)
Education	1.0038	0.9907	0.9960	0.9973
	(0.546)	(0.259)	(0.531)	(0.684)
Oil_exports	0.9878**	0.9815***	0.9916*	0.9901*
	(0.020)	(0.007)	(0.097)	(0.060)
EU	2.6434**	1.3962	2.6367**	3.0246**
	(0.042)	(0.559)	(0.043)	(0.034)
Annex_1	0.3591***	0.4488*	0.7434	0.5656
	(0.010)	(0.075)	(0.433)	(0.150)
External determinants				
Number_ratifications	0.9655***	0.9225***	0.9875***	0.9910***
	(0.000)	(0.000)	(0.000)	(0.005)
Spatial lag	1.0301***	1.0477***	1.0100***	1.0001
	(0.002)	(0.000)	(0.000)	(0.969)
Parameter values				
γ	0.9065	1.2671	0.6995	0.7126
λ	-0.5073	0.2265	-0.4532	-0.0303
θ	0.6021	1.2542	0.6356	0.9701
Nb. Countries	164	129	164	164
Nb. Obs.	735	579	742	742

*Notes: ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. p-values associated to the reported coefficients (hazard-ratios) and test statistics are in parentheses. γ and λ are the estimated parameters of the baseline hazard distribution function and θ characterise the distribution of the frailty term.*

First, we find a robust influence of the democracy level and of the oil-lobbies. We observe that the probability of ratification increases with the democracy level, which is consistent with former studies (see Fredriksson and Gaston (2000), Neumayer (2002a,b)). The power of the oil-lobbies seems to impede the participation as found by Fredriksson et al. (2007) and Neumayer (2002b). The coefficients associated with the EU and Annex_1 dummy variables are as expected. On the one hand, the EU-countries ratified sooner than the others, which confirms their leader status. On the other hand, Annex-1 countries show some reluctancy to ratify compared to the Non-Annex 1 countries, which is not surprising since the former face quantitative mitigation constraints whereas the latter do not.

Then, the coefficient associated with the number of involved countries is below 1 and significant. According to our first hypothesis, this result indicates that the ratification process of the Kyoto protocol is subject to a free rider problem. Therefore, ratification decisions seem to be basically strategic substitutes.

However, specifications (1), (2) and (3) indicate that when we take into account the interactions with our geographic neighbors, our trade partners or with countries financing CDM projects, the ratification decisions are strategic complements. Indeed the coefficient associated with the spatial lag is above 1 and significant for the three dimensions studied. The influence of trade partners could be read as follows: when a country to which I export 1% of my products ratifies the KP, it increases my probability to ratify during the next period by 4.7 %. The effect is of lower magnitude in the case of our geographic neighbors but is still substantial. Then, when a country j financing 1% of the projects received by country i ratifies the KP, it increases i's probability to ratify during the next period by 1%. Hypothesis 2, 3 and 4 are therefore not rejected by the estimations. Finally, as expected, the coefficient associated with the spatial-lag created thanks to our placebo matrix is non significant which removes doubts on a potential significance bias of our estimator.

Therefore, we find that even if the ratification of the KP is subjected to a free rider problem, when we study additional dimensions such as geographic networks, trading relations and the willingness to attract green financing, the ratification decisions are strategic complements. Finally, we find that the most substantial external determinant of ratification is the action of trading partners.

4.2. Robustness checks

To ensure the robustness of our results, we implement two kind of robustness tests. Firstly, we relax the no spatial error correlation assumption, as explained in section 3.3. Secondly, we change the ratification year definition.

Spatial error correlation

We first control the robustness of our results by allowing a correlation between error terms. In columns (1) of table 2 we specify a frailty at the World Bank regions level, in column (2) a frailty at the continent level and in columns (3) and (4) we clusterize our error terms at the same respective levels. We compare the result to those found in column (1) of table 1 (results also reported in column (a) of the present table 2).

Table 2: Gompertz estimation results with different forms of spatial error correlation allowed

Specification	**Proximity**	**Frailty WB**	**Frailty continent**	**Cluster WB**	**Cluster continent**
	(a)	(1)	(2)	(3)	(4)
Internal determinants					
GDPpercap	3.6881	3.0038	3.0041	3.0041	3.0041
	(0.130)	(0.106)	(0.107)	(0.177)	(0.158)
GDPpercap^2	0.9190	0.9299*	0.9298*	0.9298	0.9299
	(0.118)	(0.087)	(0.088)	(0.169)	(0.164)
Democracy	1.6978***	1.5981***	1.5981***	1.5981***	1.5981***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
Education	1.0038	1.0023	1.0023	1.0023	1.0023
	(0.546)	(0.638)	(0.639)	(0.596)	(0.293)
Oil_exports	0.9878**	0.9902**	0.9902**	0.9902**	0.9902***
	(0.020)	(0.021)	(0.022)	(0.026)	(0.001)
EU	2.6434**	2.7913***	2.7914***	2.7914**	2.7914***
	(0.042)	(0.007)	(0.008)	(0.027)	(0.009)
Annex_1	0.3591***	0.4238***	0.4238***	0.4238***	0.4238***
	(0.010)	(0.008)	(0.009)	(0.000)	(0.002)
External determinants					
Number_ratifications	0.9655***	0.9756***	0.9756***	0.9756***	0.9756***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
Spatial lag	1.0301***	1.0215***	1.0215***	1.0215**	1.0216*
	(0.002)	(0.008)	(0.009)	(0.044)	(0.096)
Parameter values					
γ	0.9065	0.6531	0.6531	0.6531	0.6531
λ	-0.5073	-17.1240	-18.8499	-	-
θ	0.602	0.000	0.000	-	-
Nb. Countries	164	164	164	164	164
Nb. Obs.	735	735	735	735	735

*Notes: ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. p-values associated to the reported coefficients (hazard-ratios) and test statistics are in parentheses. γ and λ are the estimated parameters of the baseline hazard distribution function and θ characterise the distribution of the frailty term.*

As we can see, our results are strongly robust to various alternative specifications allowing for a correlation of the error terms at the geographic level. Regarding the external determinants, the significance of the coefficients associated to the spatial-lag term remains unchanged, and the magnitude of these coefficients varies only very slightly. This is also true for the number of involved countries.

These robustness checks, therefore, allow of rejecting misspecification generated by spatial autocorrelation problem and the omission of important control variables.

Time definition

The ratification of the protocol is officially validated on a specific date. Therefore when we consider that two countries have ratified the protocol during year t, there could be 364 days between their ratifications. It is then interesting to take a different definition of the ratification year. As a second kind of robustness check, we therefore consider that a country ratifies at time t if it has ratified between the 1^{st} of July of year $t-1$ and the 30^{th} of June of year t. We reestimated the same equations presented in table 1 and present our new results in table 3.

Table 3: Gompertz estimation results with modification of the ratification year definition

Weighting factor	**Proximity**	**Trade**	**CDM**	**Placebo**
	(1)	(2)	(3)	(4)
Internal determinants				
GDPpercap	5.5861*	2.3749	7.6013**	9.2913**
	(0.060)	(0.370)	(0.022)	(0.014)
$GDPpercap^2$	0.8977*	0.9583	0.8846**	0.8716**
	(0.060)	(0.483)	(0.027)	(0.017)
Democracy	1.7690***	1.5775**	1.8769***	1.8990***
	(0.001)	(0.020)	(0.000)	(0.000)
Education	0.9982	0.9903	0.9924	0.9937
	(0.795)	(0.218)	(0.256)	(0.362)
Oil_exports	0.9892**	0.9869**	0.9905*	0.9896*
	(0.044)	(0.037)	(0.072)	(0.056)
EU	3.5966**	1.6663	4.0684***	4.8022***
	(0.015)	(0.367)	(0.008)	(0.005)
Annex_1	0.3846**	0.4458*	0.7059	0.5413
	(0.026)	(0.071)	(0.394)	(0.143)
External determinants				
Number_ratifications	0.9465***	0.9141***	0.9840***	0.9869***
	(0.000)	(0.000)	(0.000)	(0.000)
Spatial lag	1.0182*	1.0369***	1.0084***	0.9996
	(0.074)	(0.000)	(0.003)	(0.859)
Parameter values				
γ	1.4474	1.5640	0.8387	0.8540
λ	-0.1342	0.0513	-0.1323	0.1995
θ	0.8744	1.0526	0.8761	1.2208
Nb. Countries	164	130	164	164
Nb. Obs.	809	644	815	815

*Notes: ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. p-values associated to the reported coefficients (hazard-ratios) and test statistics are in parentheses. γ and λ are the estimated parameters of the baseline hazard distribution function and θ characterise the distribution of the frailty term.*

As our estimates show, our results are robust to the change in the ratification year definition. Both magnitude and significance of the coefficients are comparable to the ones found in tables 1 and 2. We observe a decrease in the magnitude of the trading partners influence, but this dimension still dominates the others[15].

5. Concluding remarks

The purpose of this paper was to examine the interactions between the decisions to ratify an international environmental treaty such as the Kyoto protocol. We proposed an analysis of the nature of interactions between countries, followed by an empirical investigation based on the Kyoto protocol ratification timing.

The findings of this paper have implications both for the theoretical study of the formation of international environmental agreements and for the design of new agreements. Indeed, there are interactions between countries and they cannot be ignored.

Through our empirical analysis, we found evidence of free riding behavior, which is consistent with the nature of the public good provided. However, we showed that when we study the influence of specific countries, such as geographic neighbors, trading partners or green investors, the decision of a country and that of its partners are strategic complements. Moreover, we find that the prominent external determinant of ratification is the action of trading partners.

Our results imply that the nature of the dilemma countries face when dealing with climate change, could be altered by the multiple links between countries, *i.e.*, that an agreement gathering a large number of countries can be reach even if it is basically subject to a free rider phenomenon.

The next question is how to use the links revealed to increase the participation in IEAs. One solution would be to move towards the creation of a multiple treaties system such

[15] We also consider a third definition of the ratification year. We consider that a country ratifies at time t if it ratifies between the 16^{th} of March of year t and the 15^{th} of March of year $t+1$, since the first signature was on the 16^{th} of March 1998. Our results are also robust to this modification. Finally, when we do not normalize our spatial weight, the significance of the coefficients remains unchanged. Results are available upon request.

as technology-environment or trade-environment agreements, as pointed by Folmer et al. (1993). The tendency to follow the decision of our trade partners raises also the potential to use commercial sanctions to ensure compliance, as suggested by Barrett (2003, 2011)[16].

[16]Note however that this could break-up the domino effect in the participation decisions observed.

Anselin, L. (2006). *Palgrave Handbook of Econometrics: Volume 1: Econometric Theory*, chapter Spatial Econometrics. Palgrave Macmillan, first edition.

Banerjee, S., Gelfand, A. E., and Carlin, B. P. (2003). *Hierarchical Modeling and Analysis for Spatial Data*. Monographs on Statistics and Applied Probability. Chapman and Hall/CRC, first edition.

Barrett, S. (1998). On the theory and diplomacy of environmental treaty-making. *Environmental and Resource Economics*, 11(3):317–333.

Barrett, S. (2003). *Environment and Statecraft: The Strategy of Environmental Treaty-Making*. Oxford University Press, USA.

Barrett, S. (2011). Rethinking climate change governance and its. relationship to the world trading system. *Paper prepared for the international conference: Climate Change Policies and the World Trading System: the Challenges Ahead*.

Bernauer, T., Kalbhenn, A., Koubi, V., and Spilker, G. (2010). A comparison of international and domestic sources of global governance dynamics. *British Journal of Political Science*, 40(03):509–538.

Beron, K. J., Murdoch, J. C., and Vijverberg, W. P. M. (2003). Why cooperate? public goods, economic power, and the Montreal protocol. *The Review of Economics and Statistics*, 85(2):286–297.

Brueckner, J. (2003). Strategic interaction among governments: an overview of empirical studies. *International regional science review*, 26:175–188.

Caldeira, E., Foucault, M., and Rota-Graziosi, G. (2010). Decentralization in Africa and the nature of local governments competition: evidence from Benin. Etudes et Documents 201019, CERDI.

Case, A. C., Rosen, H. S., and Hines, J. J. (1993). Budget spillovers and fiscal policy interdependence : Evidence from the States. *Journal of Public Economics*, 52(3):285–307.

Cleves, M., Gould, W., Gutierrez, R., and Marchenko, Y. (2010). *An Introduction to Survival Analysis Using Stata*. Stata Press, third edition.

Congleton, R. D. (1992). Political institutions and pollution control. *The Review of Economics and Statistics*, 74(3):412–21.

Cornes, R. and Sandler, T. (1996). *The Theory of Externalities, Public Goods, and Club Goods*. Cambridge University Press, second edition.

Darmofal, D. (2009). Bayesian spatial survival models for political event processes. *American Journal of Political Science*, 53(1):241–257.

Davies, R. B. and Naughton, H. T. (2006). Cooperation in environmental policy: A spatial approach. University of Oregon Economics Department Working Papers 2006-18, University of Oregon Economics Department.

Dechezleprêtre, A., Glachant, M., and Ménière, Y. (2008). The Clean Development Mechanism and the international diffusion of technologies: An empirical study. *Energy Policy*, 36(4):1273–1283.

Dechezleprêtre, A., Glachant, M., and Ménière, Y. (2009). Technology transfer by CDM projects: A comparison of Brazil, China, India and Mexico. *Energy Policy*, 37(2):703–711.

Finus, M., Ierland, E., and Dellink, R. (2006). Stability of climate coalitions in a cartel formation game. *Economics of Governance*, 7(3):271–291.

Folmer, H., Mouche, P. v., and Ragland, S. (1993). Interconnected games and international environmental problems. *Environmental and Resource Economics*, 3:313–335.

Fredriksson, P. G. and Gaston, N. (2000). Ratification of the 1992 climate change convention: What determines legislative delay? *Public Choice*, 104(3-4):345–68.

Fredriksson, P. G., Neumayer, E., and Ujhelyi, G. (2007). Kyoto protocol cooperation: Does government corruption facilitate environmental lobbying? *Public Choice*, 133(1):231–251.

Glazer, A. and Proost, S. (2008). Informational benefits of international environmental agreements. Working Papers 070810, University of California-Irvine, Department of Economics.

Gleditsch, K. and Ward, M. (2001). Measuring space: a minimum distance database and applications to international studies. *Journal of Peace Research*, 38(6):739–756.

Grubb, M., Laing, T., Counsell, T., and Willan, C. (2011). Global carbon mechanisms: lessons and implications. *Climatic Change*, 104:539–573.

Gutierrez, R. G. (2002). Parametric frailty and shared frailty survival models. *Stata Journal*, 2(1):22–44.

Guzman, A. T. (2008). How international law works: A rational choice theory. Oxford and New York: Oxford University Press.

Lecocq, F. and Ambrosi, P. (2007). The Clean Development Mechanism: History, status, and prospects. *Review of Environmental Economics and Policy*, 1(1):134–151.

Lockwood, B. and Migali, G. (2009). Did the single market cause competition in excise taxes? evidence from EU countries. *Economic Journal*, 119(536):406–429.

Maler, K.-G. (1990). International environmental problems. *Oxford Review of Economic Policy*, 6(1):80–108.

Mitchell, R. B. (2003). International environmental agreements: A survey of their features, formation, and effects. *Annual Review of Environment and Resources*, 28(1):429–461.

Murdoch, J. C. and Sandler, T. (1997). The voluntary provision of a pure public good: The case of reduced CFC emissions and the Montreal protocol. *Journal of Public Economics*, 63(3):331–349.

Neumayer, E. (2002a). Do democracies exhibit stronger international environmental commitment? A cross-country analysis. *Journal of Peace Research*, 39:139–164.

Neumayer, E. (2002b). Does trade openness promote multilateral environmental cooperation? *The World Economy*, 25(6):815–832.

Osborn, A. (2001). Europe should now push Kyoto. *The Guardian, April 6.*

Rohter, L. and Revkin, A. C. (2004). Cheers, and concern, for new climate pact. *The New York Time, December 13.*

Sandler, T. (1998). Global and regional public goods: a prognosis for collective action. *Fiscal Studies*, 19(3):221–247.

Simmons, B. A. and Elkins, Z. (2004). The globalization of liberalization: Policy diffusion in the international political economy. *American Political Science Review*, 98(01):171–189.

UNFCCC (2011). *United Nations Framework Convention on Climate Change official website.*

United Nations (1997). UN Conference on Environment and Development (1992). Brief notes.

United Nations (2006). *Treaty Handbook*. United Nations publication.

Wooldridge, J. M. (2001). *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, first edition.

Yang, J. (2004). New-Zealand and the Kyoto protocol: Ideals, interests and politics. *New Zealand International Review*, 29.

Appendix A: Source and definition of the variables

Variable	Definition	Source
	Dependent variable	
Ratification (r_{it})	Dummy variable equal to 1 if country i ratifies during year t.	UNFCCC website
	Spatial lag weights	
Proximity	Distance in kilometers between two capitals.	CEPII
Trade	Mean of available bilateral exports flows for the sample period, in current dollars.	UN Comtrade
CDM	Number registred CDM projects from 1998 to 2009.	UNEP-RISOE database
	Internal Factors	
Democracy	The country is considered as "Free" (=3) if the sum of its civil liberty index and its political right index is below 5 , "Non-Free" (=1) if it is above 10 and "Partly-Free" (=2) otherwise.	Freedom House
GDPpercap / GDPpercap^2	Logarithm of GDP per capita, in PPA, dollars 2000.	World Development Indicator 2010
Oil_exports	Ratio of fuel exports on total exports.	World Development Indicator 2010
Education	Gross secondary school enrollment in percent.	World Development Indicator 2010
Annex_1	Dummy variable equal to 1 if a country is registered on the Annex_1 of the Kyoto Protocol.	UNFCCC website
EU	Dummy variable equal to 1 if the country was a member of the European Union in 2002.	Portail de l'Union Européenne

Appendix B: Descriptive statistics

Table 4: Ratification timing description

			(Per subject)		
Category	total	mean	min	median	max
Nb. of subjects	164				
Nb. of records	735	4.48	1	4	12
(first) entry time		0	0	0	0
(final) exit time		5.65	1	5	12
failures	138	0.84	0	1	1

Table 5: Descriptive statistics on the independent variables

Variable	Mean	Std. Dev.	Min	Max
GDPpercap (in level)	6049.21	9232.55	80.62	48485.15
GDPpercap^2 (in level)	1.22e+08	2.99e+08	6500.33	2.35e+09
Democracy	2.03	0.925	0	3
EU	0.09	0.28	0	1
Education	70.23	33.89	5.18	161.78
Oil_exports	17.77	29.64	0	99.66
Annex_1	0.26	0.44	0	1

Table 6: Descriptive statistics on the spatially lagged variables

Weighting factor	Mean	Std. Dev.	Min	Max
Distance	24.98	23.25	0.2574998	93.36
Trade	28.04	34.99	0	99.01
CDM	9.32	28.62	0	100
Placebo	32.30	46.80	0	100

Appendix C: List of countries

164 countries included in the estimation sample				
Albania	Comoros	Hungary	Mauritius	South Africa
Algeria	Congo, Dem. Rep.	Iceland	Mexico	Spain
Angola	Congo, Rep.	India	Moldova	Sri Lanka
Argentina	Costa Rica	Indonesia	Mongolia	St. Kitts and Nevis
Armenia	Cote d'Ivoire	Iran, Islamic Rep.	Morocco	St. Lucia
Aruba	Croatia	Iraq	Mozambique	St. Vinc. & the Grenadines
Australia	Cyprus	Ireland	Namibia	Sudan
Austria	Czech Republic	Israel	Nepal	Suriname
Azerbaijan	Denmark	Italy	Netherlands	Swaziland
Bahamas, The	Djibouti	Jamaica	New Zealand	Sweden
Bahrain	Dominica	Japan	Nicaragua	Switzerland
Bangladesh	Dominican Republic	Jordan	Niger	Syrian Arab Republic
Belarus	Ecuador	Kazakhstan	Nigeria	Tanzania
Belgium	Egypt, Arab Rep.	Kenya	Norway	Thailand
Belize	El Salvador	Kiribati	Oman	Togo
Benin	Equatorial Guinea	Korea, Rep.	Pakistan	Tonga
Bhutan	Eritrea	Kuwait	Panama	Trinidad and Tobago
Bolivia	Estonia	Kyrgyz Republic	Paraguay	Tunisia
Bosnia and Herzegovina	Ethiopia	Lao PDR	Peru	Turkey
Botswana	Fiji	Latvia	Philippines	Uganda
Brazil	Finland	Lebanon	Poland	Ukraine
Brunei Darussalam	France	Lesotho	Portugal	United Arab Emirates
Bulgaria	Gabon	Liberia	Romania	United Kingdom
Burkina Faso	Gambia, The	Libya	Russian Federation	United States
Cambodia	Georgia	Lithuania	Rwanda	Uruguay
Cameroon	Germany	Luxembourg	Samoa	Uzbekistan
Canada	Ghana	Macedonia, FYR	Saudi Arabia	Vanuatu
Cape Verde	Greece	Malawi	Senegal	Venezuela, RB
Central African Republic	Grenada	Malaysia	Seychelles	Vietnam
Chad	Guatemala	Maldives	Sierra Leone	Yemen, Rep.
Chile	Guinea	Mali	Slovak Republic	Zambia
China	Guinea-Bissau	Malta	Slovenia	Zimbabwe
Colombia	Guyana	Mauritania	Solomon Islands	