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# 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 whether or not to ratify the Kyoto Protocol? If so, what is the nature of these 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 are merely seeking to provide a global public good. Secondly, we argue that countries have ties in several spheres in the real world and we try to shed light on the nature of the strategic interactions generated by geographic proximity, trade flows, and green investment flows. The empirical investigation is realized via the estimation of a parametric survival model, and our data sample covers 164 countries for the period from 1998 to 2009. We find evidence that, while countries' ratification decisions are originally strategic substitutes, they became strategic complements when we focus on the ratification decisions of specific peers.

Mots clés /Key words : International Environmental Agreements, Kyoto Protocol, Ratification, Strategic substitutes/complements, Spatial survival model
Codes JEL / JEL codes : C41, F53, H41, Q53, Q56

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## 1. Introduction

Out of the 1992 United Nations Conference on Environment and Development (or $3^{rd}$ Earth Summit) in Rio de Janeiro, 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 fact demonstrates the difficulty of achieving consensus among sovereign nations, and highlights the particular interest we have in understanding the reasons why countries agree to the Kyoto Protocol.

Several authors have tried to reveal the role a country's characteristics may play in its decision to participate 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]. Fredriksson et al. (2007) and Von Stein (2008) find that the presence of lobby groups affects the probability of ratifying the Kyoto protocol.

The question of interdependence in ratification decisions has been poorly addressed in the literature. Yet, the proceeding of climate change negotiations suggests that it could be relevant. For example, the European heads of governments tried 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 Senate, which stipulated that the Congress was not allowed to ratify an agreement in which the United States would have quantitative emission reduction targets while developing countries did not (Barrett, 1998)[4]. Following this announcement, Australia, refused to ratify the KP as

[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.

[4]The Byrd-Hagel resolution.

well, even though it had initially signed the protocol. This anecdotal evidence suggests that participation in the Kyoto protocol is not an independent decision. Consequently, the present paper tries to answer the following questions: Do countries interact with each other when they decide whether or not to ratify the Kyoto protocol? If so, what is the nature of these 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 treaty participation decisions. Bernauer et al. (2010) study whether the probability of ratification depends on the behavior of similar countries (i.e., they include the share of countries from the same region, income group, that have ratified the agreement in the list of independent variables). However, this is not a true measure of interactions. Davies and Naughton (2011) study whether there exists a spatial dependence in the ratification decision process of IEAs. Using a composite index of 247 agreements, these authors investigate whether countries from the same area ratify the same number of agreements, rather than really demonstrating an effect of a 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 that precisely measures the presence or absence of interactions between States when they decide to participate in an IEA, either for the Kyoto Protocol or for any other IEA. Consequently, our contribution to the literature is to empirically evaluate the presence of interactions between ratification decisions[5], and this is done for a major binding agreement, namely the Kyoto Protocol.

[5]Although signature is not a meaningless act, ratification is more interesting to study, since according

The theoretical analysis is based on the notions of strategic substitutability and strategic complementarity. We argue that countries have ties in several spheres 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 164 countries for the period from 1998 to 2009. We find evidence that the decisions of trade partners, and of green investors, matter.

The rest of the paper is organized in the following manner: we analyze the influence of other countries' ratification decisions on a country ratification decision in Section 2. In Section 3 we explain how we measure the factors affecting a State's decision and we present our estimator. Our results are analyzed in Section 4 and finally, in Section 5, we present our conclusion.

## 2. Analysis of the multiple ties 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 treaty by a country[6]. 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, *e.g.*, Clean Development Mechanism

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 the making of a treaty.

[6]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 countries committed themselves. For a study on partication level in IEA, see, for example, Bratberg et al. (2005).

(CDM) projects.

*2.1. Public good provision*

Let us first study how a country is influenced by its peers' decisions when it merely seeks to provide a global public good, namely preventing 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 the public good ($g_i$). Since in the specific context of climate change, the emission of $z$ tons 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 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 exist. Therefore, we argue that ratification could be motivated by considerations other than the provision of a global public good. We study these alternative motivations in the next subsection.

*2.2. Additional ties*

*"If a small group of people who had an interest in a collective good happened also to be personal friends, or belonged 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. 60.

In the real world, countries are interlinked in several spheres, which could lead them to act as members of a social group. Countries do not attach the same importance to all countries' decisions; the importance one country attaches to another's ratification decision depends upon the former's ties with the latter. 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 spheres, such as diplomatic and trade relations. Moreover, it can be considered that the design of the treaty affects the influence of one 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 among 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 IEAs even though they do not have immediate incentives or economic interests to do so. 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 million 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*

Let us consider now more economic interdependence, such as that created by trade flows. As pointed out by Neumayer (2002b), we are in a world where we consider that imports mainly benefit the exporter. Therefore, a country aspires to create and maintain 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[7]. This positive signal is also important if a country seeks to benefit from new preferential trade agreements. On the other hand, several countries fear 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 also interesting. 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[8].

**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 a flexibility mechanism, such as the Clean Development Mechanism[9]. The main rules governing this mechanism

[7] As shown by Egger et al. (2011) for the case of trade and Rose and Spiegel (2009) for the case of access to credits.

[8] Note that strategic complementarity may also occur in GHGs emission fall, as shown by Copeland and Taylor (2005).

[9] The study of the Joint Implementation mechanism is of limited interest since it began with the first commitment period in the KP in 2008, as opposed to the CDM, which began in 2000 (Grubb et al., 2011).

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[10]. On the one hand, this mechanism provides 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[11]. To host a CDM project, the developing country obviously had to first ratify the KP. 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 countries 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 $\kappa$ and $\vartheta$. A set of $k$ control variables $X$ is introduced whose influence is captured through the $\zeta_k$ parameters. These control variables represent the internal determinants of the KP ratification, namely the country's characteristics. $\eta_{it}$ is the remaining error term. Our data sample covers the period from 1998 to 2009 for 164

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

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

countries. A comprehensive list of the variables, along with their definitions and sources is available in Table 1 of the Appendix.

Parameter $\kappa$ 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 whether or not there is a free-rider problem (driven by a substitutability in ratification decisions).

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 Brueckner, 2003). We estimate a spatial-lag model, where the spatially lagged endogenous variable (hereafter "spatial lag") is of the form $\sum_{i \neq j} \omega_{ij} r_{jt}$. The weighting factor used $\omega_{ij}$ measures the intensity of the links between countries $i$ and $j$ and is obviously specific to each studied sphere. Our weights are normalized (they range from 0 to 100). Their main descriptive statistics can be found in the table 3 of the Appendix.

To evaluate the influence of neighbors' decision, $\omega_{ij}$ 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 to estimate the effect of the decision of trading partners on a country's decision. $\omega_{ij}$ 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 $j$[12]. The weighting factor $\omega_{ij}$ 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 $\omega_{ij}$ 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) and Lockwood and Migali (2009), we construct a "placebo" weighting scheme that will ensure that the results are not driven by model

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

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 ($\omega_{ij}$ taking the value of one), then the second and the second to the last are also considered as linked, and so on. We obviously expect a non significant coefficient associated with this spatially lagged term.

The set of internal determinants first includes the quality of institutions. A country is considered as "Free" (=3) if the sum of its civil liberty index and its political rights 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 the time of its opening to ratification in 1998. This requires the use of a duration model. The main advantage of this kind of model for our case is that it allows us to take into account duration dependence and censoring[13,14].

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

[14] See Lancaster (1992), Box-Steffensmeier and Jones (2004) and Cleves et al. (2010) for good introductions to duration models. They are also referred to as transition data, survival model or event-history analysis in the literature.

Since we observe yearly ratifications, our scale time is non-continuous and we are confronted to grouped data. Indeed, as shown by Figure 1, the KP is ratified by 17 countries per year on average, with a peak of 54 ratifications in 2002[15].

[insert Figure 1 here]

Therefore, we are confronted with multiple time failure problems, which makes semi-parametric models like the Cox proportional hazards model 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:

$$h(t|x_c) = h_0(t)exp(\beta_0 + x_c\beta_x), \tag{1}$$

where $t$ is the time scale, $c$ the unit of observation, $\beta_0$ is a constant and $x_c$ a row vector of independent variables and $\beta_x$ a column vector of coefficients (Cleves et al., 2010). The hazard rate ($h(t|x_c)$) is the probability that a country $i$ ratifies ($r_{it} = 1$) during the next period, considering that it has not yet ratified. The baseline hazard $h_0(t)$ is the probability to ratify that everyone faces, this being modified by the value of the $x_c$, specific to each individual.

The estimation of a parametric survival model leads us to make an assumption about the baseline hazard distribution $h_0(t)$ [16]. 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. Therefore, we calculate the Akaike information criterion[17], widely used to discriminate among the different available laws, to choose between a Weibull, Gompertz,

[15]This peak can be explained by the adoption of the CDM mechanism through the Marrakesh Accords in 2001.

[16]Note that this latter is the counterpart of the error term in standard regressions. The two terms will be used interchangeably throughout the rest of the paper.

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

log-normal and log-logistic distribution of the baseline hazard. As found by Fredriksson et al. (2007), the hazard rate of the KP ratification process seems to be best represented by a Gompertz distribution, which implies a monotonous evolution of the hazard. With the specification of the baseline hazard as a Gompertz law, we therefore obtain:

$$h(t|x_c) = exp(\gamma t)exp(\beta_0 + x_c\beta_x), \tag{2}$$

Furthermore, since we have panel data, this allows us to control for the unobserved heterogeneity specific to each individual country. In survival models, this becomes possible with the introduction of a frailty term in the model. The unshared frailty model can be written as follows:

$$h(t|x_c, \alpha_c) = \alpha_c h(t|x_c), \tag{3}$$

where $\alpha_c$ is an unobserved observation-specific effect (Cleves et al. (2010))[18]. 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:

$$h(t|x_{pf}, \alpha_f) = \alpha_f h(t|x_{pf}), \tag{4}$$

where $f$ identifies the group of $N$ observations of the same frailty. This model is estimated using maximum likelihood.

### *3.3. Spatial issues*

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

[18]The distribution of the frailty parameters chosen for its mathematical tractability is the inverse-gaussian distribution. The frailty is assumed to have mean 1 and variance $\theta$ for model identifiability.

the spread of liberalization across countries. However, as discussed by Anselin (1988), we could be facing two problems: endogeneity, and spatial error correlation. These two issues can be treated through the method of moments or maximum likelihood estimation in linear models (see Anselin, 2006). Yet, there is no proper estimator for spatial survival model and it is not the scope of this paper to develop it. However, being aware that our model could be subject to the spatial error correlation problem, and endogeneity of the spatially lagged endogenous variable, we develop several strategies to address this.

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 try to control for correlation between the error terms. We cannot allow spatial error correlation in the way Darmofal (2009) and Banerjee et al. (2003) do. These authors implement (bayesian) parametric spatial survival models, but only 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. This is the reason why we have decided to control for potential correlation between the error terms, while keeping both our temporal and individual dimensions. If the results vary when allowing spatial correlation, then misspecification can be suspected. Therefore, we allow for a correlation between the error terms by specifying a frailty at the continent level, as it is the practice in survival models (Darmofal, 2009).

Our strategy to deal with endogeneity is simple. The endogeneity problem comes from a simultaneity bias, since, at time $t$, a country is influenced by its neighbors but also influences its neighbors. Therefore we introduce the spatial lags, lagged from one year instead of the contemporary values of the spatial lags[19]. This strategy was first applied in a logit model by Dubin (1995, 1997) in her studies of technological innovation diffusion.

[19] Including the variable "Number_ratification", since it can be seen as a spatial lag with uniform weights ($\omega_{ij} = 1, i \neq j$).

## 4. Determination of the nature of interactions

### *4.1. Main results*

As previously mentioned, our data sample covers 164 countries for the period from 1998 to 2009. Descriptive statistics on the independent variables are available in Appendix, Table 2 and 3, and the list of countries included in the sample can be found in Table 4. A preliminary examination of the descriptive statistics on the dependent variable available in Table 5 shows that 84% of the countries present in our sample ratified the Kyoto protocol before the end of the period studied and that the median country ratifies 5 years after the opening of the protocol to ratification.

We present our main estimation results in Table 6. 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. $\beta$ coefficients are reported. A positive coefficient means that an increase in the independent variable increases the probability of ratification[20].

[insert table 6 here]

First, we find a robust influence of the democracy level. We observe that the probability of ratification increases with the democracy level, which is consistent with former studies (Fredriksson and Gaston (2000); Neumayer (2002a,b); Von Stein (2008)). We also detect an impact of the oil-lobbies[21]. The power of the oil-lobbies seems to impede participation, as found by Fredriksson et al. (2007) and Neumayer (2002b).

[20]Results from survival models are often presented through hazard ratios. However, in our case, they lose their interpretation. They cannot be interpreted in a stratified model, such as the one we present in the robustness checks (Cleves et al., 2010). Moreover, in a spatial autoregressive model, the researcher would have to calculate a direct effect and an indirect effect to interpret the coefficients as marginal effects, as described in LeSage and Dominguez (2012) for linear models. It is beyond the scope of this paper to extend the current methodologies for survival models. We will therefore restrain ourselves to the interpretation of the sign, but not the magnitude, of the reported coefficients.

[21]P-values oscillate between 0.02 and 0.13.

The coefficient associated with the number of involved countries is negative and significant in the four regressions. 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 strategic substitutes.

However, specifications 3 and 4 indicate that when we take into account the interactions with our trade partners or with countries financing CDM projects, the ratification decisions are strategic complements. Indeed, the coefficient associated with the spatial lag is positive and significant for these two dimensions. Hypothesis 3 and 4 are therefore not rejected by the estimations. Interestingly, Hypothesis is not supported by our data. The influence of the decision of a country's geographic neighbors is not significant. One reason could be that even if a country has an interest in following a neighbor's decision in order to maintain diplomatic ties, the country could be eager to build a strategic advantage compared to a similar geographic neighbor by offering laxer environmental regulations to investors. Another possible explanation is that perhaps the importance of diplomatic relations is nowadays better captured by trade intensity than geographic proximity. Finally, as expected, the coefficient associated with the spatial-lag created thanks to our placebo matrix is non significant, removing doubt 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 trading relations and the willingness to attract green financing, the ratification decisions are strategic complements.

### *4.2. Robustness checks*

To check the strength of our results, we implement several robustness tests. Firstly, we relax the no spatial error correlation assumption, as explained in Section 3.3. Secondly, we distinguish between Annex 1 and Non-Annex 1 countries.

#### *4.2.1. Spatial error correlation*

We first control the robustness of our results by specifying a frailty shared at the continent level, as explained in Section 3.3. Results are presented in Table 7.

[insert table 7 here]

As we can see, our results are robust to the specification of a frailty term shared at the continent level. Regarding the external determinants, the significance of the coefficients associated with 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.

This robustness check, therefore, allows us to reject misspecification generated by spatial autocorrelation problem and the omission of important control variables.

*4.2.2. Distinguishing between Annex 1 and Non Annex 1 countries*

Countries are differentiated by their status in the Kyoto Protocol. They can either be Annex-1 countries, which means that they face quantitative commitment to reduce their GHGs emissions, or they can be non-Annex 1, which mainly concerns developing countries. Therefore, following Fredriksson et al. (2007), we can consider that the two groups of countries are in a different dynamic in terms of ratification process. We already make this distinction by introducing a dummy variable equal to 1 if the country is listed on the Annex 1 of the KP. However, one way to more generally take into account this phenomenon in survival models, is to run a stratified estimation. It implies that both the model intercept and the shape parameter of the distribution law vary for each value of the strata variable, here "Annex_1". The baseline hazard, which represent the probability to ratify that everyone face, has therefore a different shape for the two groups of countries. The stratified proportional hazard model can be written as:

$$h(t|x_c) = \begin{cases} exp(\gamma t)exp(\beta_0 + x_c\beta_x) & \text{if Annex 1} \\ exp((\gamma - \gamma_s)t)exp((\beta_0 - \beta_s) + x_c\beta_x) & \text{if Non Annex 1} \end{cases} \quad (5)$$

As a second type of robustness check, we therefore estimate a stratified survival model. We re-estimated the equations presented in Table 6 and present our new results in Table 8.

[insert table 8 here]

Even if the dummy variable "Annex_1" is sometimes significant, the baseline hazard faced by the two groups of countries does not seem different ($\gamma_s$ is never significant). This means that they are not on a different path in the ratification process (the baseline hazards ($h_0(t)$) of the two groups have the same shape). As our estimates show, results are therefore not affected by the stratification of the model. Both magnitude and significance of the coefficients are comparable to the ones found in Tables 6 and 7. We therefore consider that our results are robust.

## 5. Concluding remarks

The purpose of this work is to examine the interactions between countries' decisions to ratify an international environmental treaty such as the Kyoto protocol. We offer 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 find evidence of free riding behavior, which is consistent with the nature of the public good provided. However, we show that when we study the influence of certain countries, such as trading partners or green investors, the decision of a country and that of its partners are strategic complements.

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 reached even if it is subjected to a free rider phenomenon.

The next question is how to use the links among countries highlighted in this work to increase participation in IEAs. One solution would be to move towards the creation of a multiple treaties system, such as a technology-environment or trade-environment agreement, as pointed by Folmer et al. (1993). A country's tendency to follow the decision of its trade partners also raises the potential to use commercial sanctions to ensure compliance, as suggested by Barrett (2003, 2011).

To conclude, this article proposes a framework to understand the formation of International Environmental Agreements. It sheds light on important ties that should not be ignored if we want to build a treaty gathering a large number of participants.

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# Appendix

Table 1: 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. | Official website of the European Union |

Table 2: Descriptive statistics on the independent variables

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| GDPpercap (in level) | 6049.21 | 9232.55 | 80.62 | 48485.15 |
| 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 3: 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 |

Table 4: List of countries

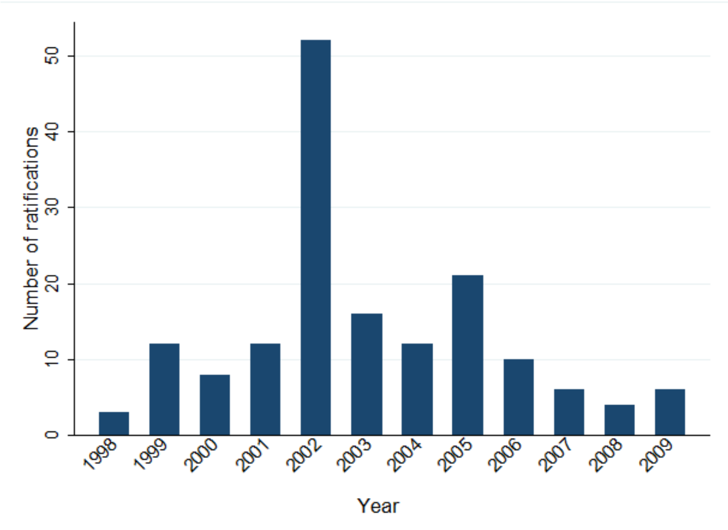
| 164 countries included in the estimation sample | | | | |
|---|---|---|---|---|
| Albania | Comoros | Hungary | Mauritius | South Africa |
| Algeria | Congo, Dem. Rep. | Iceland | Mexico | Spain |
| Angola | Congo, Rep. | India | Moldova | Sri Lanka |
| Argentina | Costa Rica | Indonesia | Mongolia | 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 | |

Table 5: 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 |

## Figures

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




*Notes: created using STATA, author's calculation.*

## Tables

Table 6: Estimation results of the probability to ratify the KP

| *Weighting factor* | **Proximity** | **Trade** | **CDM** | **Placebo** |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Internal determinants* | | | | |
| GDPpercap | 1.099 | 0.791 | 1.273* | 1.130 |
| | (0.752) | (0.986) | (0.724) | (0.753) |
| $\text{GDPpercap}^2$ | -0.0726 | -0.0309 | -0.0795* | -0.0743 |
| | (0.0471) | (0.0612) | (0.0448) | (0.0471) |
| Democracy | 0.437*** | 0.326* | 0.442*** | 0.435*** |
| | (0.141) | (0.194) | (0.138) | (0.141) |
| Education | 0.000318 | -0.0130* | -0.00127 | 0.000110 |
| | (0.00548) | (0.00785) | (0.00535) | (0.00549) |
| Oil_exports | -0.00659 | -0.0154** | -0.00725* | -0.00666 |
| | (0.00434) | (0.00642) | (0.00434) | (0.00433) |
| EU | 0.551 | 0.200 | 0.405 | 0.594 |
| | (0.421) | (0.526) | (0.392) | (0.419) |
| Annexe_1 | -0.627* | -0.624 | -0.471 | -0.638* |
| | (0.335) | (0.432) | (0.316) | (0.330) |
| *External determinants* | | | | |
| Number_ratifications | -0.0635*** | -0.144*** | -0.0815*** | -0.0641*** |
| | (0.00597) | (0.0110) | (0.00584) | (0.00444) |
| Spatial lag | -0.00398 | 0.0473*** | 0.0191*** | -0.00163 |
| | (0.00974) | (0.00994) | (0.00324) | (0.00242) |
| $\beta_0$ | -10.87*** | -10.20*** | -12.19*** | -10.95*** |
| | (2.853) | (3.736) | (2.778) | (2.857) |
| *Parameter values* | | | | |
| Shape parameter ($\gamma$) | 1.687 | 2.188 | 1.907 | 1.676101 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Variance of the frailty distribution ($\theta$) | 0.172 | 0.862 | 0.057 | 0.174 |
| Nb. Countries | 164 | 129 | 164 | 164 |
| Nb. Obs. | 735 | 579 | 735 | 735 |

*Notes: ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. Standard errors associated to the reported coefficients and parameter values are in parentheses.*

Table 7: Estimation results with spatial frailty

| *Weighting factor* | **Proximity** | **Trade** | **CDM** | **Placebo** |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Internal determinants* | | | | |
| GDPpercap | 0.995 | 0.169 | 1.253* | 1.028 |
| | (0.688) | (0.724) | (0.701) | (0.689) |
| $\text{GDPpercap}^2$ | -0.0653 | 0.00489 | -0.0779* | -0.0670 |
| | (0.0428) | (0.0455) | (0.0432) | (0.0428) |
| Democracy | 0.431*** | 0.334** | 0.439*** | 0.425*** |
| | (0.131) | (0.149) | (0.135) | (0.130) |
| Education | -0.000706 | -0.0112* | -0.00170 | -0.000830 |
| | (0.00503) | (0.00600) | (0.00515) | (0.00504) |
| Oil_exports | -0.00705* | -0.0149*** | -0.00770* | -0.00739* |
| | (0.00414) | (0.00529) | (0.00422) | (0.00414) |
| EU | 0.511 | 0.110 | 0.399 | 0.574 |
| | (0.383) | (0.393) | (0.378) | (0.379) |
| Annexe_1 | -0.546* | -0.462 | -0.442 | -0.571* |
| | (0.306) | (0.336) | (0.302) | (0.305) |
| *External determinants* | | | | |
| Number_ratifications | -0.0597*** | -0.110*** | -0.0807*** | -0.0610*** |
| | (0.00731) | (0.0149) | (0.00836) | (0.00696) |
| Spatial lag | -0.00745 | 0.0276*** | 0.0193*** | -0.00206 |
| | (0.00874) | (0.00905) | (0.00336) | (0.00233) |
| $\beta_0$ | -10.14*** | -6.982*** | -11.98*** | -10.18*** |
| | (2.602) | (2.706) | (2.679) | (2.596) |
| *Parameter values* | | | | |
| Shape parameter ($\gamma$) | 1.584 | 1.740 | 1.867 | 1.557 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Variance of the frailty distribution ($\theta$) | 1.50e-08 | 5.67e-09 | 3.91e-09 | 2.08e-45 |
| Nb. Countries | 164 | 129 | 164 | 164 |
| Nb. Obs. | 735 | 579 | 735 | 735 |

*Notes: ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. Standard errors associated to the reported coefficients and parameter values are in parentheses.*

Table 8: Estimation results with Annex statification

| *Weighting factor* | **Proximity** | **Trade** | **CDM** | **Placebo** |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Internal determinants* | | | | |
| GDPpercap | 1.051 | 0.0487 | 1.307* | 1.069 |
| | (0.690) | (0.723) | (0.699) | (0.689) |
| GDPpercap$^2$ | -0.0703 | 0.0109 | -0.0833* | -0.0708 |
| | (0.0432) | (0.0457) | (0.0434) | (0.0432) |
| Democracy | 0.441*** | 0.384** | 0.448*** | 0.432*** |
| | (0.130) | (0.149) | (0.133) | (0.130) |
| Education | -0.000345 | -0.0103* | -0.000967 | -0.000480 |
| | (0.00502) | (0.00594) | (0.00515) | (0.00504) |
| Oil_exports | -0.00627 | -0.0121** | -0.00668 | -0.00682 |
| | (0.00424) | (0.00545) | (0.00427) | (0.00422) |
| EU | 0.641 | 0.328 | 0.567 | 0.689 |
| | (0.428) | (0.435) | (0.419) | (0.429) |
| Annexe_1 | -0.913 | -1.300* | -0.978 | -0.874 |
| ($\beta_s$) | (0.594) | (0.681) | (0.600) | (0.590) |
| *External determinants* | | | | |
| Number_ratifications | -0.0593*** | -0.112*** | -0.0815*** | -0.0610*** |
| | (0.00734) | (0.0150) | (0.00850) | (0.00698) |
| Spatial lag | -0.00900 | 0.0285*** | 0.0199*** | -0.00219 |
| | (0.00898) | (0.00902) | (0.00345) | (0.00235) |
| $\beta_0$ | -10.27*** | -6.469** | -12.06*** | -10.26*** |
| | (2.602) | (2.704) | (2.670) | (2.592) |
| *Parameter values* | | | | |
| Shape parameter ($\gamma$) | 1.577*** | 1.718*** | 1.856*** | 1.546*** |
| | (0.138) | (0.152) | (0.156) | (0.132) |
| ($\gamma_s$) | 0.0670 | 0.143 | 0.0982 | 0.0540 |
| | (0.0911) | (0.0967) | (0.0922) | (0.0883) |
| Nb. Countries | 164 | 129 | 164 | 164 |
| Nb. Obs. | 735 | 579 | 735 | 735 |

*Notes: ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. Standard errors associated to the reported coefficients and parameter values are in parentheses.*