Interest groups and participation in international environmental agreements

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26th June 2021

Abstract

We investigate the determinants of participation in environmental agreements, focusing on the role of domestic interest groups and the quality of institutions. To this end, we collated the largest ratification dataset in the literature. Unlike previous datasets, ours includes both global and regional agreements and identifies all countries eligible for membership in each agreement. This allows us to correct an identification bias affecting previous empirical estimates. We further improve upon past treatments of unobserved heterogeneity by using a multilevel survival approach and Markov Chain Monte Carlo (MCMC) estimator. Our findings show that environmental lobbying has a positive effect on participation in environmental agreements, while the effect of industrial lobbying is statistically insignificant. This unexpected result is robust to changes in specification and proxies used. Our results motivate several policy suggestions. We emphasise regional agreements' ability to deliver higher participation rates than global agreements and highlight the importance of securing early participation of key players.

Keywords: International environmental agreements, ratification, lobbying, regional agreements, international cooperation.

JEL codes: Q58, F53, D72, C23, C41.

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1 Introduction

International cooperation is likely to play a critical role in solving some of the most serious environmental problems of our times. Air pollution, contamination of lakes and rivers, global warming, biodiversity loss, deforestation, desertification, and over-fishing are all problems that cross national borders and affect multiple nations at the same time. In these cases, no single policy maker possesses the power needed to enforce environmental policies in all the countries concerned. This decentralisation of power calls for a horizontal approach based on cooperation (Barrett, 2005). In theory, there is a clear incentive to cooperate since total welfare increases when environmental issues are addressed multilaterally (Carraro & Siniscalco, 1998). However, cooperation is not guaranteed, because there are also incentives to free ride when no central authority is capable of enforcing an international agreement (Barrett, 2008).

International environmental agreements (IEAs) are the primary cooperative tool to solve such transboundary issues. To date, there are more than three thousand bilateral or multilateral environmental agreements (Mitchell, 2017) in force. However, our understanding of their dynamics is limited. The goal of this study is to provide a better understanding of the drivers of participation in environmental agreements. So far, participation in environmental agreements has mainly been studied with game-theoretical modelling and it has remained relatively under-explored from an empirical perspective (Finus et al., 2017). This study provides much needed empirical evidence on the factors motivating treaty participation. By focusing on the role of domestic interest groups and institutional quality, this inquiry is a direct response to the recent developments in the theoretical literature that emphasise the domestic choice-making process of treaty participation (e.g. Habla & Winkler, 2013; Hagen et al., 2016; Marchiori et al., 2017; Battaglini & Harstad, 2020).

Participation in an agreement is a fundamental condition for its success because international agreements are only binding for participating countries. Participation in an agreement generally involves two stages: the *signature* followed by the *ratification*[3]. We focus on the determinants of ratification because it alone formally commits a nation, whereas signature entails no obligations. In short, this study attempts to answer the following: why do certain countries ratify more environmental agreements than others? Which characteristics make an agreement more likely to be ratified? How can policy makers intervene to improve the likelihood of solving transboundary and global environmental issues?

In the next section, we briefly look at the existing literature on treaty participation. Then, in section 3 we introduce our theoretical framework and the key hypotheses that will be tested. Section 4 introduces our data set and motivate the methodological approach adopted. In section 5 and 6, we report our results and use them to simulate ratification probabilities of agreements. We conclude the paper by discussing the policy

[3]In our analysis, we use the term ratification to indicate both the act of ratification and accession. Ratification is defined by the Art. 2 of the Vienna Convention (1969) as the act "whereby a State establishes on the international plane its consent to be bound by a treaty". For multilateral agreements, the procedure involves the deposition of a ratification document. On the other hand, accession is the act of joining a treaty that has already been negotiated (Art. 2, Vienna Convention, 1969). It has the same value as ratification, and the procedure is established in the text of the agreement. Accession often happens for states that did not exist or did not take part in the negotiations.

implications of the study. For the interested reader, we provide two supplementary online appendices documenting our data and reporting the full results of our robustness and convergence checks.

2 Past studies on environmental treaty participation

2.1 Theoretical literature on treaty participation

The prevailing theoretical framework views nations as unitary agents that maximise domestic social welfare. Environmental issues affecting a group of countries can be solved by countries negotiating and participating in international environmental agreements. However, countries also have an incentive to free-ride on environmental agreements to obtain environmental benefits without paying the costs associated with the agreement (Pearson, 2011). This situation has been extensively treated in game-theoretical models predicting both the optimal treaty abatement and participation levels.

The classic participation game has two stages. In the first stage, countries decide if they want to form (and ratify) an environmental treaty; while in the second stage, countries decide their emission levels. In such models, a country joins the coalition of ratifiers only if it is beneficial. Hence, a treaty can only be formed if it is *self-enforcing*— i.e. the incentive structure induces a stable cooperating coalition—but these cases are traditionally deemed rare and do apply to the most pressing environmental issues (Barrett, 2008). Participation in environmental agreements is usually assumed to rely the same criteria used to model cartel stability, thus the equilibrium is often precarious.

To summarise the main results of the classic participation games, Barrett (1994) states three stylised points about the effectiveness of environmental agreements:

1. Agreements codify commitments that countries would undertake unilaterally even without the agreement;

2. When the number of participants to the agreement is large, the agreement brings few obligations and implies a low abatement effort;

3. International cooperation is harder to attain when it is most needed.

These conclusions constitute the "paradox of cooperation" (Barrett, 1994). The implications for ratification are straightforward: high ratification rate are achieved only when the commitment level is low, whereas stringent agreements should not attract ratification. These dire conclusions originate from the structure of the model. Transboundary environmental issues are analysed with games framed as prisoner's dilemmas, where the Nash equilibrium lies in a non-cooperative solution. Later works have corroborated the trade-off underpinning the paradox, with some improvement in the views expressed in the latest contributions (Finus et al., 2017). For example, if instead of framing the problem as a one-off decision, countries are allowed to participate in different periods, outcomes are generally more encouraging. Higher participation rates are attained in repeated games, especially when communication is allowed or when the treaty is linked to other issues (Bloch & Gomes, 2006; Biancardi & Villani, 2015; Wagner, 2016). An important contribution in this area comes from Harstad (2015) and Battaglini & Harstad (2016).

They build a unifying framework to understand treaty participation in a dynamic setting in which countries can invest in green R&D and renegotiate agreements. Their models highlight the role of two fundamental variables which were traditionally overlooked by classic participation games: technological change and the "horizon" of the agreement. These models show that level of participation, treaty duration and investment in green technologies are mutually linked. Short-term agreements can create important disincentives to investment in green technologies (investment holdup problem), thus reducing the free-riding problem and increasing participation in the agreement. This could explain why observed coalition sizes are usually larger than what classic participation games imply.

The economic literature identified additional mechanisms that mitigate the dire predictions of classic participation games. For instance, there are stronger incentives to join if ratifiers are allowed to offer side payments (Barrett & Stavins, 2003; Barrett, 2001; Fuentes-Albero & Rubio, 2010). Side payments do not need to be strictly monetary. For example they could take the form of technological transfers or concessions to the country. This type of transfers is quite common in reality, indeed a large number of environmental agreement include some form of support to developing nations. There is also empirical evidence that these type of mechanisms tangibly boost participation (von Stein, 2008; Bernauer et al., 2013b). Environmental agreements could also be linked with other forms of cooperation through "reputation effects". Hoel & Schneider (1997) define a reputational cost for non-ratifiers that increases with the agreement's number of participants. In their model, reputational costs augment participation by offsetting the free-ride incentives. Finally, specific design features of the treaty could boost participation and commitment. For example, it is often found that free-riding incentives are significantly reduced if the environmental agreement includes some form of trade restriction or sanction (Barrett, 1997; Breton et al., 2010; Hagen & Schneider, 2017). It is also found that minimum participation rules—i.e. clauses imposing a minimum number of ratifiers before the agreement enters into force—may lead to larger stable coalitions corresponding to the minimum number of countries required for the entry into force of the agreement (Rubio & Casino, 2005; Carraro et al., 2009).

Of particular interest is the growing body of literature that seeks to incorporate public choice theory within the classic treaty participation game. Public choice theory promotes an endogenous view of policy decisions in which environmental policies are described as the outcome of tensions between different domestic interests. Kirchgässner & Schneider (2003) and Kollmann & Schneider (2010) state that decisions over environmental policies are influenced by the following domestic agents: *i*) electors, *ii*) public institutions and administration, *iii*) interest groups and *iv*) politicians. A broad body of literature sought to incorporate the tensions between these agents into endogenous models of environmental policy selection. In recent years, this effort has been extended from environmental policies to environmental agreement. So far, research has focused on embedding the effects of lobbying practices (Haffoudhi, 2005; Hagen et al., 2016; Marchiori et al., 2017) and electoral incentives (Habla & Winkler, 2013; Battaglini & Harstad, 2020) into the classic game-theoretical framework of treaty participation. In the lobbying models, environmental and industrial lobbies influence the ratification of environmental agreements through a "political support" function of the policy maker. The political interactions are then grafted on a classic non-cooperative two-stage game of environmental agreement participation (Haffoudhi, 2005; Hagen et al., 2016). In other cases, an additional stage is included either to reflect domestic ratification procedures (Köke & Lange, 2017) or to simulate the bargaining among domestic stakeholders (Marchiori et al., 2017). The models suggest that the traditional trade-off of treaty participation could be easily mitigated if there is a sufficient domestic support in favour of ratification. These models offer a more realistic representation of the domestic-international interplay of treaty ratification (à la Putnam, 1988) which is typically missing in the classic participation literature.

2.2 Empirical literature

The number of empirical studies that investigated countries' participation in environmental treaties is quite limited. To date, much of the research effort has focused on understanding the main drivers of participation in environmental agreements. These factors can be grouped in four main categories: *i*) economic factors that shape incentive to participate and free-ride, such as income or trade openness (Neumayer, 2002b); *ii*) Political factors that influence the ratification process, such as the type of regime and quality of democracy (Congleton, 1992; Cazals & Sauquet, 2015; Schulze, 2014); *iii*) Treaty characteristics, which determine the attractiveness of the treaty and the cost of participation (von Stein, 2008; Bernauer et al., 2013b); *iv*) Country interdependence which mitigates the free-riding incentive (Yamagata et al., 2017; Schneider & Urpelainen, 2013; Bernauer et al., 2010). A comprehensive survey of the empirical literature and its methodology can be found in Bellelli et al. (2021).

To the best of our knowledge, the influence of domestic interest groups and the quality of institutions on ratification has been studied by Fredriksson et al. (2007) and Fredriksson & Ujhelyi (2006). In their framework, the ratification decision of a corruptible policy maker considers the welfare gains from improvements in the quality of environment, but it is also affected by the contributions, bribes and pressure of environmental and industry lobbies. Fredriksson et al. (2007) define the corruption level as the intensity of preference of the state for the contributions instead of the gains in social welfare. Given this definition, more corrupted governments should be more sensible to lobbying activity. To test their hypotheses empirically, the authors use data on ratification of the Kyoto Protocol by 170 countries. They build two models, based on a binary (logit) and a survival dependent variable (Cox PH model stratified for annex I countries with time measured in days). The results show that the ratification probability increases with environmental lobbying, and the more the government is prone to corruption the stronger is this effect. Interestingly, the estimates for industrial pressure were not statistically significant. They experiment with different proxies for industrial lobbying, such as the share of labour employed in the industrial sector, the number of vehicles per capita, the intensity of CO_2 in commercial energy use, the share of fossil fuels in total exports and a dummy for countries that possess an international chamber of commerce.

The importance of domestic pressure groups is acknowledged in several studies. For example, the following studies control for lobbying by either environmental or industrial groups: Roberts et al. (2004), von Stein (2008), Yamagata et al. (2013), Bernauer et al. (2013a), Sauquet (2014), Böhmelt et al. (2015) and Yamagata et al. (2017). Some of these studies solely focus on the role of environmental lobbying. For instance, Bernauer

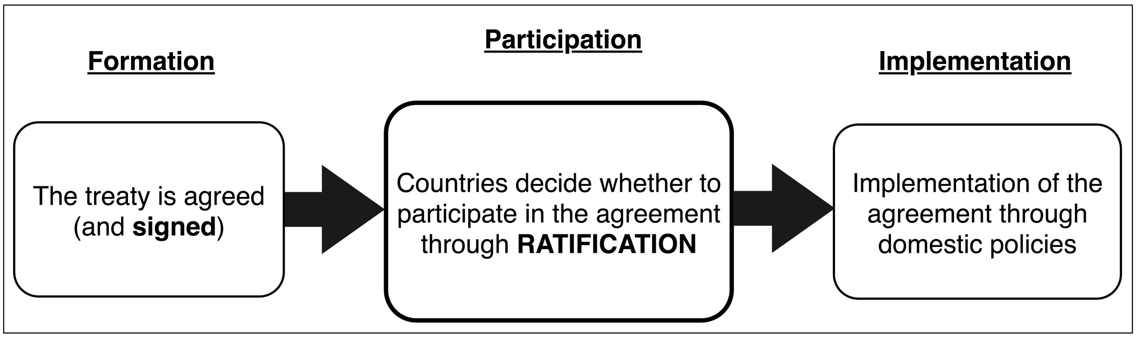

Figure 1: *A model of environmental agreements in three stages*

et al. (2013a) study the interaction between quality of democracy and environmental NGOs (ENGOs) on the probability of ratifying environmental agreements. Using a large sample of environmental agreements and a Cox PH model, they assert that ENGOs have a positive effect on ratification, and in more democratic states the effect of ENGOs is reduced due to substitutability between direct representation and civil society pressure. Böhmelt et al. (2015) investigate the implications of constitutional economics (Persson & Tabellini, 2003; Persson et al., 2007) on treaty participation. Their work focuses on how the effect of ENGOs' lobbying on ratification varies with different electoral rules and government systems. Across studies, environmental lobbying is consistently found to have a positive effect on the ratification probability. In contrast, only in very few cases industrial lobbying has a statistically significant relationship with the ratification of environmental agreements. At the 5% level of confidence, a significant result is found only for one of the three proxies in Fredriksson et al. (2007) and in one out of four specifications in Sauquet (2014). The absence of a relationship is in itself perplexing and contrary to theoretical expectations. The reasons for this counter-intuitive result remain unclear as they have never been explored any further.

3 Framework and key hypotheses

As previously mentioned, the decision to participate in a treaty is implemented in two stages: signature and ratification. We focus on ratification because it is the final and definitive act marking participation in the agreement. We remark that the signature stage is costless as it does not entail any formal commitment to ratify and it does not legally bind the country to environmental actions.

We take the model described in Köke & Lange (2017) as a conceptual reference. The model comprises three stages: the first stage corresponds to the formation of the treaty and its signature by a coalition of countries; in the second stage, the coalition members may or may not ratify the agreement[4]; in the third stage, countries implement their environmental policies. Our study aims to evaluate countries' ratification choice corresponding to the second stage of Köke & Lange (2017) model.

Following Almer & Winkler (2010), we assume that a country behaves rationally and ratifies the environmental agreement only if its net expected benefit of ratification, B, is

[4]Köke & Lange (2017) model presumes that only coalition members can ratify. This is not true in reality.

positive. The net benefit cannot be observed directly, but we postulate it is a function of a series of domestic factors (D), international interactions (I) and treaty characteristics (T). These factors constitute our model's variables and influence either positively or negatively the net benefit of ratification. The ratification choice is presented as follows:

$$Y_{ij} = \begin{cases} 1, & \text{if } B_{ij}\big(D_i, I_{ij}, T_j\big) > 0 \\ 0, & \text{if } B_{ij}\big(D_i, I_{ij}, T_j\big) \leq 0 \end{cases} \tag{1}$$

Where $Y_{ij} = 1$ denotes ratification of treaty j by country i, while $Y_{ij} = 0$ if country i does not ratify treaty j. Domestic factors, denoted by D, include the income level, the quality of the environment, as well as other variables of interest such as the strength of domestic pressure groups or the quality of institutions. International interactions, I, encompass the influence of foreign nations on the decision to ratify. The decision by country i is linked to the ratification of other nations with which it shares economic, diplomatic or cultural ties. I is specific to the treaty; the ratification of the agreement by a foreign nation affects the net benefit of ratification solely for agreement j (i.e. agreements are *independent*). In principle, it is possible to have interrelated ratification choices for groups of environmental agreements. However, the current understanding is that this type of situation is an exception rather than the norm, and linkage is more likely across different types of issues (e.g. environment and trade agreements) rather than two agreements dealing with separate environmental issues (Marrouch & Chaudhuri, 2015). Finally, T encloses the features of the agreement that have an influence on the cost of ratification. For instance, it includes whether a treaty is regional or global, the stringency of its obligations, whether it includes transfers for developing countries, or other design features such as minimum participation rules, the presence of escape clauses or penalties for non-compliance.

Assuming that B_{ij} is continuously differentiable in D, I and T, we can derive the marginal effect of variables of interest on the willingness to join the environmental agreement. The marginal effects would be obtained conditional on the variables in B_{ij} and assuming that the agreement j has been negotiated—i.e. we can only observe agreements that take shape. We specifically answer the question: *Given that an agreement has been agreed, what motivates participation?*

3.1 Hypotheses on domestic variables

Ratification decisions are generally made by the nation's legislative body and represent the ultimate act of acceptance of an environmental treaty. In traditional game-theoretical models, the decision is made by a unitary welfare maximising entity. Still, a more realistic representation depicts ratification as the result of conflicting interests within the country (e.g. Marchiori et al. 2017, Habla & Winkler 2013, Köke & Lange 2017 and Lui 2018). For this reason, it makes sense to analyse the effect on ratification of the two opposing tensions within the country: the so-called environmental and industrial lobbying. This leads to our first set of hypotheses.

Hypothesis 1: *The likelihood of ratifying environmental agreements decreases when industrial pressure is stronger*

Hypothesis 2: *The likelihood of ratifying environmental agreements increases when environmental pressure groups are stronger*

According to Wangler et al. (2013), lobbying has a significant impact during the negotiation and ratification of environmental agreements. Pressure groups are able to influence politicians by providing information, increasing the awareness of electors, providing financial support to government initiatives, funding campaigns or even bribing politicians (Wangler et al., 2013). Inspired by public choice theory, these effects have been incorporated in various theoretical works (e.g. Haffoudhi, 2005; Biancardi & Villani, 2010; Habla & Winkler, 2013; Hagen et al., 2016; Marchiori et al., 2017). In these models, participation in environmental agreements is influenced by the relative strength of the environmental and industrial lobbies. This study provides important empirical evidence for this field of research. As of now, a comprehensive study of ratification and domestic pressure dynamics based on a large sample of treaties is missing. One of the aims of this study is to fill this gap.

The second focus of our research is institutions' role in forging international cooperation over environmental issues. Institutions are defined as the legal and social constraints that structure the interactions between economic agents. They set the operational rules and shape the incentives of agents, affecting economic and social outcomes at different levels. In general, countries with better institutions tend to exhibit higher ratification rates (Frank, 1999). Several theories could explain this observation.

According to institutional economics, good institutions foster economic growth, which in turn fuels higher demand for environmental protection (Cole, 2004). Fredriksson & Gaston (2000) notice that developing countries tend to have slower ratification and link the delay to the inferior quality of institutions. Roberts (1996) and Roberts et al. (2004) stress that developing nations lacking infrastructures and with poor institutions are less likely to ratify environmental agreements. The authors argue that the level of development and the quality of institutions in a country mainly depends on its colonial past. Extraction colonies tend to turn into peripheral countries even after their independence because their political institutions and economic structure were based on the extraction of raw materials to benefit the metropolitan power. Hence, countries that historically depended on extractive resources tend to develop worse institutions with political power concentrated in the hands of dominant economic groups. These two factors lead to lower ratification rates, according to Roberts et al. (2004). We formulate the following hypothesis on the effect of the quality of institutions:

HYPOTHESIS 3: *Countries with better institutions are more likely to join environmental agreements*

Finally, the success of certain lobbying practices may be directly related to the quality of institutions. First of all, better institutions channel more effectively demand for environmental protection, without the need for pressure from environmental groups. Hence, good institutions could act as a substitute to the pressure of environmental groups. Bernauer et al. (2013a) conclude that the effectiveness of environmental pressure groups is reduced in more democratic states because of the increased competition for the provision of environmental protection and more direct accountability of politicians. Secondly, lobbying practices in general, are more effective in corrupt states. As a matter of fact, Fredriksson et al. (2007) find that environmental lobbying has a positive effect on the ratification of the Kyoto Protocol (1997) and the effects of both industrial and environmental lobbying is stronger in countries having more corrupted institutions. We hence formulate the following hypothesis on how domestic pressure groups interact with the quality of institutions:

Hypothesis 4: *The effect of environmental and industrial pressure increases when the quality of institutions is lower*

3.2 Hypotheses on international interactions

Because of the intense network of economic and geopolitical relations between countries, ratification choices by different countries are necessarily related. Assumptions of mutual independence would be ill-founded. A growing body of evidence shows that the likelihood of ratification increases when other nations decide to join the agreement; this is particularly true for geographical neighbours, as well as for economic and cultural partners (Bernauer et al., 2010; Perrin & Bernauer, 2010; Sauquet, 2014; Yamagata et al., 2013, 2017). However, these results are at odds with theoretical expectations, which state that strong free-ride incentives apply to environmental agreements. According to the classic treaty participation models, a country joining the agreement increases the treaty's benefits for non-ratifiers without increasing incentive in participation to other nations (Carraro & Siniscalco, 1998). While there is some degree of consensus on the inherent interdependence between ratification decisions, there are opposing arguments regarding the direction of international interactions. The contrasting conclusions lead to ambiguous expectations on the effect of ratification decisions by foreign countries. Although this is not the main focus of our study, we contribute to the debate by offering additional evidence on how nations interact on ratification.

3.3 Hypotheses on treaty characteristics

As described in the next section, our data set comprises more than 250 environmental agreements, with the peculiarity of distinguishing between global and regional agreements. For the first time, this will allow testing empirically the following hypothesis regarding the regional treaties:

Hypothesis 5: *Regional agreements are more likely to be ratified than global agreements*

For large or global issues, environmental agreements usually do not secure sufficient participation because free-riding incentives become too large to overcome (Perman et al., 2003). Barrett (1999) finds that global agreements can only sustain small coalitions, but he argues that a combination of regional agreements can achieve higher participation for the same issue. The same result is obtained by Osmani & Tol (2010) under weaker assumptions, such as asymmetric payoffs and accounting for different levels of environmental damage. As a result, we expect cooperation efforts to be generally more successful when transboundary environmental issues involve a smaller number of countries.

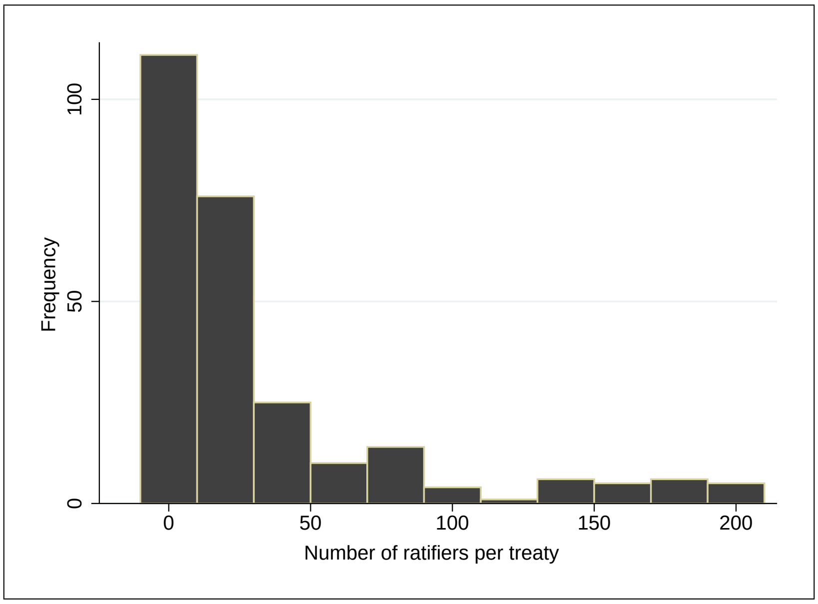

Figure 2: *Number of ratifiers*

Notes: Most of the agreements have fewer than 50 members. The low number of ratifiers is not the consequence of countries' reluctance to ratify (Fig 3), it rather reflects the fact that a large part of environmental cooperation occurs regionally. Hence the relevance of including regional agreements in the analysis.

4 Methodology and data

4.1 *If* and *when*: choosing the right approach

In this study, we model ratification choices with an approach based on survival analysis on panel data. This approach allows us to accommodate the time dynamics and deal with the right-censoring problem of observing ongoing ratification processes. An alternative to survival analysis would be to perform a count analysis of ratification (e.g. Egger et al., 2011; Davies & Naughton, 2014). However, this approach is inappropriate because it fails to answer an important question: what treaty is ratified? After all, not all of the agreements are alike. Each treaty has its own peculiar mix of obligations and economic implications. Adding treaties up would hide wide differences in the choice of ratification. Hence, in measuring ratification, we wish to know *if* a treaty has been ratified by a given country, not the total number of treaties ratified by a country.

It is theoretically possible to analyse if a treaty has been ratified at one point in time (i.e. cross-sectionally) with a binary regression, but this approach has some limitations. First of all, whether a ratification occurred depends on the point in time chosen to assess it. There is a second and more fundamental reason to consider a time dimension. Ratification is intrinsically dynamic: what matters is not only *if* but also *when* a country ratified. If we merely focus on the occurrence of ratification, we are ignoring precious information. In fact, ratification could be affected in two ways: *i*) by changing the final outcome (i.e. whether or not the country ratifies), and *ii*) by delaying ratification. We believe that the latter is a crucial aspect in understanding the effects of institutional

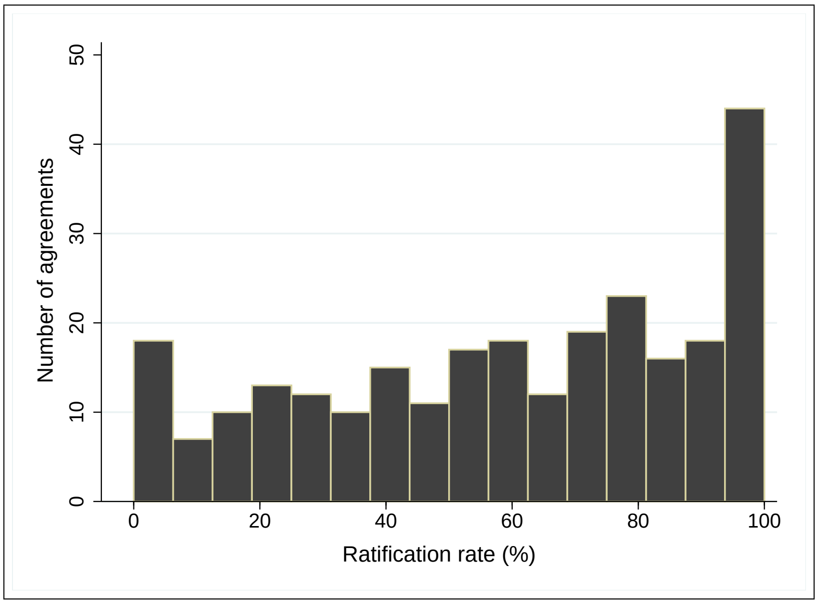

Figure 3: *Ratification rate*

Notes: The figure unveils substantial heterogeneity in the ratification rate of environmental agreements. What factors explain the success or failure of a treaty? We argue that country and treaty characteristics are responsible for this variability. The ratification rate is calculated as the number of ratifiers over the number of potential ratifiers up to 2017.

quality and group pressure on ratification. Timing is also inherently important in understanding the sequence of ratification by different countries. It is impossible to disentangle foreign influence on ratification without a temporal observation of ratification.

In other words, the differences between countries are reflected not only in the final outcome of ratification, but also in its timing. This is especially true for agreements that attracted an almost universal ratification. In which case, a strategy based solely on the outcome would fail to capture the heterogeneity across countries. The same applies to smaller agreements that are ratified by almost all of the potential ratifiers. Agreements with high ratification rates represent an important share of our sample[5] (Figure 3). We argue that, in addition to the decision to ratify, any delay in ratification is a function of treaty and country idiosyncrasies. Both the occurrence and the timing reveal precious information on the determinants of ratification; thus, a panel survival model is the best approach to leverage both occurrence and timing information in the data.

4.2 Model specification

Ratification, as a survival data, is defined by two sets of information: whether the ratification takes place (outcome) and the time to ratification (timing). The ratification timing starts from the agreement's signature date and ends either with ratification or a missed

[5]For example, the UNFCCC (1992) and the Montreal Protocol (1987) both achieved universal ratification with 197 parties. The ratifications did not occur simultaneously: Canada ratified the UNFCCC in 1992 (soon after signing), France in 1994, Turkey in 2004 and Andorra in 2010. Similarly, the Montreal protocol was ratified in 1992 by Australia, Belgium in 1996, Angola in 2000 and Iraq in 2009.

ratification by the country. Despite its continuous nature, we group the ratification data into yearly observations in order to match the observation frequency of the explanatory variables. The alternative would be to take smaller time intervals and assume that the explanatory variables are constant throughout the year. We opt for annual observations, despite the loss in precision, because a shorter time intervals, such as monthly or daily, would result in a cumbersome proliferation of datapoints.

We can handle discrete survival analysis with a binomial regression by thinking of this data as a series of success/failure trials for which we observe a yearly binary response (Allison, 1982). For every country-treaty-year combination, we have a dichotomous response variable that takes the value of 1 if ratification occurred and 0 otherwise. We define the hazard function $h(t)$ as the probability of observing ratification during the time interval t, *given no earlier ratification*:

$$h_{ij}(t) = \Pr\left(y_{ij}(t) = 1 \mid y_{ij}(t-1) = 0\right) \tag{2}$$

Where y_{ij} and t are respectively the response variable and the duration for every country-treaty combination ij. Time is a discrete variable and the hazard is assumed constant over the time interval. Then, our model has the following form:

$$\text{cloglog}\left[h_{ij}(t)\right] = \alpha(t) + \boldsymbol{D_i(t)\beta} + \boldsymbol{I_{ij}(t-1)\gamma} + \boldsymbol{T_j(t)\lambda} + u_i + u_j \tag{3}$$

$$\alpha(t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 \tag{4}$$

$$u_i \sim \mathcal{N}(0,\, \sigma^2_{u_i}) \qquad u_j \sim \mathcal{N}(0,\, \sigma^2_{u_j}) \tag{5}$$

Where $\boldsymbol{D}$,$\boldsymbol{I}$ and $\boldsymbol{T}$ are vectors containing domestic, international and treaty explanatory variables, and $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$ and $\boldsymbol{\lambda}$ are their respective vectors of parameters. Unlike some types of survival models, this specification allows the explanatory variables to be time-varying; for this reason we express them as a function of time. For international interactions ($\boldsymbol{I}$), we use onye-year lagged indicators to avoid simultaneity bias (Bernauer et al., 2010, 2013a; Sauquet, 2014). The lagged values of $\boldsymbol{I}$ are not strictly independent since they depend from past values of country's i ratification decisions. However, past ratification status is a given condition in the estimation of the ratification hazard (equation 2) because it is estimated only for treaty-country dyads which did not already ratify.

The baseline hazard function is denoted by $\alpha(t)$. Following the approach proposed by Carter & Signorino (2010), we model baseline hazard with a cubic polynomial (Equation 4). Another viable alternative would be to use splines (Beck et al., 1998), however, these have the disadvantage of being less easy to interpret. Moreover, Carter & Signorino (2010) show that the cubic polynomial and the spline perform similarly. The cubic polynomial specification is also preferred in in the existing ratification literature. For instance. For instance, Bernauer et al. (2010), Leinaweaver (2012), Spilker & Koubi (2016) and Böhmelt et al. (2015) all use a cubic polynomial. It is also possible to use a non-parametric baseline hazard. Our main reason to prefer cubic polynomials is that a non-parametric definition of the baseline hazard heavily expands estimation time. Nonetheless, robustness of results to this assumption was checked by testing a non-parametric specification — the results do not significantly change.

The ratification model includes two random-effects to account for the unobserved heterogeneity at both the country and treaty level. Fixed effects are not used with survival data because, in several units, they would perfectly predict non-occurrence (Allison & Christakis, 2006). The resulting survival estimates would be based solely on the units that experienced the event and consequently biased. Hence, in the context of survival analysis, unobserved heterogeneity is modelled with frailty terms, which correspond to the inclusion of a random effect. Previous studies did not usually deal with this problem. Common solutions consists in using robust standard errors clustered on countries (e.g. Perrin & Bernauer 2010; Böhmelt et al. 2015 and Mohrenberg et al. 2016). The problem is that observations are clustered not only on countries but also on treaties. That is to say, not only ratification of treaty A and treaty B by France are correlated, but also, Russian and French ratification of treaty A will not be entirely independent. The use of robust standard errors can alleviate the problems linked to the correlation of units but does not correct the bias deriving from unobserved heterogeneity. This is particularly serious in the case of environmental agreements because ratification depends on a large number of unmeasurable characteristics of the agreement; notably, ratification is very likely to be affected by the stringency of the agreement—as pointed out by the "depth vs participation" trade-off widely discussed in the game theoretical literature. Moreover, for longer durations the risk set will increasingly consist of dyads with low risk of ratification. These will participate in the estimation of the baseline hazard and, if we do not control for unobserved heterogeneity, they could tend to accentuate the effect of negative factors on the length of duration and understate the effect of positive factors.

In equation 3, the complementary log-log link function is preferred over a logit or probit function because it approximates a standard survival model with grouped observations. Prentice & Gloeckler (1978) and Allison (1982) demonstrate that the coefficients of a continuous proportional hazards model with grouped data are identical to those obtained from a discrete binary regression using the *cloglog* link function. In addition, the results obtained from a complementary log-log link function can be interpreted in terms of hazard ratios, which is more intuitive than the odds of hazard.

Table 1 summarises the variables in our model. Industrial and environmental lobbying (Hypothesis 1 and 2) are proxied by the variables $ENGO$ and $ResourceRent$. These are respectively the number of environmental NGOs of the country and the sum of fossil fuel rents as percentage of GDP. The quality of institutions (Hypothesis 3) is proxied by $Institutions$, which is the control of corruption index by World Bank (2017b). To ensure that our results are robust, we test four additional proxies for industrial lobbying and two more proxies for environmental lobbying and the quality of institutions. To test our fourth hypothesis, we insert an interaction term between the quality of institutions and environmental/industrial lobbying ($ENGO.Instit$ and $ResourceRent.Instit$). The fifth hypothesis is accounted for by a dummy variable, $Regional$, that takes the value of 1 if only a subset of nations are potential ratifiers to the agreement. Finally, we address international interactions by including the share of neighbours that already ratified the agreement ($RatRegion$) and a series of dummies for the ratification of key international players ($RatUS$, $RatChina$, $RatRussia$, $RatIndia$ and $RatGermany$ for EU countries). All foreign ratifications refer to period $t-1$ to avoid simultaneity bias.

In addition to the variables above, we control for the main determinants identified by the theoretical and empirical literature. We include the logarithm of GDP per capita and

Table 1: *Definitions and sources*

Variables	Variable definitions and sources
$ENGO$	Number of ENGOs memberships to the International Union for the Conservation of Nature by country in 2017. Data from IUCN website (IUCN, 2017a). We assume a constant value over the entire time period because no panel data is available. In the appendix, we perform robustness checks with other time-varying proxies for environmental lobbying.
$ResourceRent$	Sum of fossil fuels (gas, coal, oil, mineral and forest) rent as percentage of GDP, where rents are the difference between the average production cost and commodity price. It captures the extent of monopolistic power in the fossil fuel industry — which we assume correlates with industrial lobbying potential. Data from the WDI dataset (World Bank, 2017a).
$Institutions$	Control of Corruption indicator from the World Governance Indicators (World Bank, 2017b). Expressed in units of a standard normal distribution.
$ENGO.Institutions$	Interaction term between $ENGO$ and $Institutions$
$ResourceRent.Instit$	Interaction term between $ResourceRent$ and $Institutions$
$logIncome$	Natural logarithm of the GDP per capita in current USD. Data from the UN National account estimates (UNSD, 2017a).
$FreedomHouseCL$	Freedom House index of civil liberties. On a scale from 1 to 7, where a lower score indicates greater freedom. Data from Freedom House (2017).
$ThreatenedSpecies$	Based on the Red List Index, an index of the conservation status of species groups in a territory. A higher risk of extinction is associated with lower scores. Data from IUCN website (IUCN, 2017b).
$logForest$	Natural logarithm of the forest area, expressed in thousands of squared kilometres (FAO, 2017).
$RatRegion$	Share of countries in the same M49 sub-region (UNSD, 2017b) that ratified the agreement.
$RatUS$	Dummy variable that takes the value of 1 if the United States already ratified the agreement.
$RatChina$	Dummy variable that takes the value of 1 if China already ratified the agreement.
$RatRussia$	Dummy variable that takes the value of 1 if Russia already ratified the agreement.
$RatIndia$	Dummy variable that takes the value of 1 if India already ratified the agreement.
$RatGermany$	Dummy variable that takes the value of 1 if Germany already ratified the agreement. Since EU countries tend to ratify en bloc, we use this as a proxy for EU ratification. The results do not differ if we take France as our proxy.

Variable definitions and sources (continued)

Variables	Definitions and sources
Regional	Dummy variable taking the value of 1 if the treaty is not open to all countries or if the scope of the agreement is regional (e.g. a treaty on the protection of a river basin or EU environmental agreements). The variable has been coded on the basis of the text of the agreement as reported in the IEA Database Mitchell (2017). More information on how the treaties are coded can be found in the online data appendix.
FrameworkAgreement	Dummy variable that takes the value of 1 if the agreement is a framework agreement according to the lineage classification of Mitchell (2017).
t	Duration: number of years the treaty-country combination has spent in the risk set.

its squared value to account for the relationship with income and any inverted bell-shaped relationship as suggested by some previous works (Bernauer et al., 2010; Sauquet, 2014; Böhmelt et al., 2015; Mohrenberg et al., 2016) in analogy with the Environmental Kuznet Curve. We also control for the quality of democracy with the index *FreedomHouseCL*; democracy has consistently been linked to higher probabilities of ratifying (Congleton, 1992; Fredriksson & Gaston, 2000; Neumayer, 2002a). This should also ensure the results we obtain for *Institutions* are isolated from the democratic quality of governments. We control for the state of the environment with *ThreatenedSpecies*, which is an index on the conservation of species. We choose this proxy over the more popular air pollutant emissions (e.g. Leinaweaver, 2012; Spilker & Koubi, 2016; Hugh-Jones et al., 2018) because it captures a broader set of human impacts on the environment. Temperature change, habitat disruption, water pollution, poaching, desertification, air pollution and/or deforestation all have a devastating impact on animal habitat. Moreover, we include the logarithm of forest area (*logForest*) to account for the natural capital endowment of the country. Countries that are rich in environmental assets might engage more often in environmental cooperation and receive stronger international pressure to ratify. Lastly, we include a dummy (*FrameworkAgreement*) to distinguish framework agreements from protocols, which might have more stringent obligations.

4.3 Treaty data and the potential ratifier bias

We analyse ratification with a new data set comprising 263 multilateral environmental agreements and 198 countries between 1950 and 2017. We make this dataset available online for future research. Our data tracks the ratification decisions for almost 20,000 treaty-country dyads. It is one of the largest data set applied in this research area; the only comparable in size is the data set assembled by Bernauer et al. (2010). Their data set was used in several studies of environmental treaty ratification, such as Bernauer et al. (2013b), Böhmelt et al. (2015), Spilker & Koubi (2016), Mohrenberg et al. (2016) and Hugh-Jones et al. (2018). Nonetheless, it has important limitations that we seek to overcome.

Table 2: *Ratification data sets*

Data set	Treaties	Countries	Years	Regional treaties
Our data set	263	198	1950–2017	Yes
Bernauer et al. (2010)	255	180	1950–2000	No
Leinaweaver (2012)	55	193	1980–2010	Yes
Schulze & Tosun (2013)	21	25	1979–2010	Yes, all
Schulze (2014)	64	21	1971–2003	No
Cazals & Sauquet (2015)	41	99	1976–1999	No

First of all, they included many agreements that are not strictly related to the environment, such as those concerning nuclear energy or the Moon Agreement (1979), the Convention on Conditions for Registration of Ships (1986), the Convention on the Law of the Sea (1982), and Disarmament Convention on Biological Weapons (1972)[6]. Our sample of treaties includes exclusively agreements that have a direct connection with environmental issues and that explicitly mention their environmental scope either in the title or in the text of the treaty.

The second and most substantial contribution of our data set is that it solves an identification problem existing in previous works. Past studies implicitly assumed in their models that all the countries that failed to ratify *could* ratify. This works well for universal treaties, but the assumption is violated if regional or less-than-global agreements are included in the studied sample. The centrality of this assumption has been gravely overlooked in past works. If not addressed properly, it introduces a bias in the estimates, leading to underestimated ratification probabilities.

Not all of the treaties are universal in the data set of Bernauer et al. (2010) (as well as in most other major data sets); indeed, some could only be ratified by a subset of countries. We provide two examples of agreements that are in different ways incorrectly included in their data set: *i*) the convention on LRTAP (1979) which is only open to members of the Economic Commission for Europe (UNECE countries) according to the Article 15 of the same convention, and *ii*) the Convention for the Protection of the Mediterranean Sea against Pollution (1976), which would never be ratified by distant nations such as Nicaragua or South Korea. Bernauer et al. (2010) are aware that some of the agreements could be *de facto* open just to a restricted number of countries. In the appendix, they decide to run their model on a reduced sub-sample of treaties that have no obvious regional nature: the total number of treaties is halved to include only 113 environmental agreements.

We addressed this by identifying for each of the 263 agreements in our data set, all the countries that could potentially ratify. As shown in Figure 4, countries are not exposed to the same number of agreements. Failure to take this into account, leads to biased results. Our identification procedure is based on the scope and text of the agreements. For a full reference, we provide a detailed explanation of the data and the criteria used for identifying potential ratifiers in the online data appendix. This feature is fundamental because it allows us to include regional treaties into our analysis. This, in turn, leads to the third limitation of previous works: since most agreements

[6] Cf. the bibliography for the full title of these agreements.

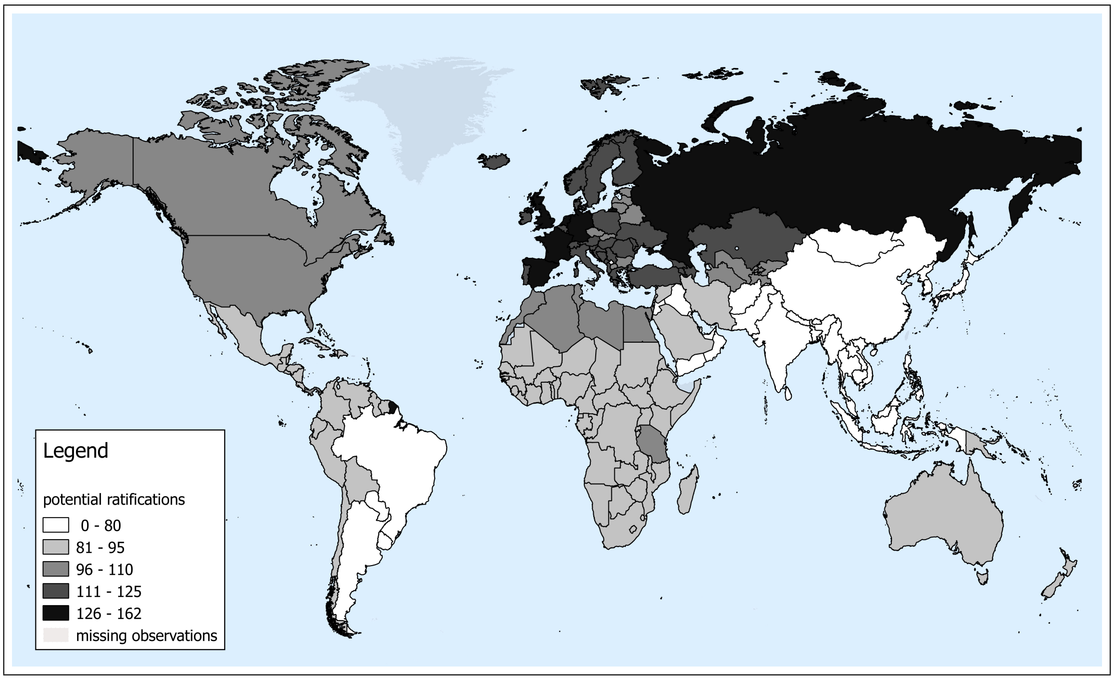

Figure 4: *Potential ratifications by country*

Notes: Not all countries have access to the same number of agreements. The number of agreements ratified by a nation depends on the number of agreements it can potentially ratify.

are regional, we may get a distorted picture by looking only at global treaties. Apart from Leinaweaver (2012), this is the only study covering regional treaties. Management of freshwater resources, protection of habitats and ecosystems, pollution of seas and lakes, etc.. Most environmental issues involve a limited number of countries—they are geographically narrow. Environmental agreements reflect this aspect, the largest part of the international environmental cooperation takes place on a regional scale.

4.4 Censoring and competing risks

Figure 5 illustrates the survival spells for a hypothetical environmental agreement. For existing countries, the survival spell starts with the signature of the agreement. This is when the text of the treaty is agreed upon and becomes formally open to ratification. If a country does not exist at the point of signature, its survival spell starts from the year it acquires independence. Each survival spell ends either with ratification or a missed ratification, in which case we have right-censored data. A third case for the end of the survival spell is the extinction of the country itself. In our data set, only a handful of countries experience extinction: East Germany, USSR, Yugoslavia, Czechoslovakia, South Yemen, South Vietnam. Despite the low incidence, extinction is a potential competing risk. For this reason, we remove dissolved countries from the risk set.

With our data, left-censoring is impossible by definition because the act of signature and ratification is always public and the observation period is uninterrupted until 2017 (the observation year). On the other hand, there are two reasons why right-censoring

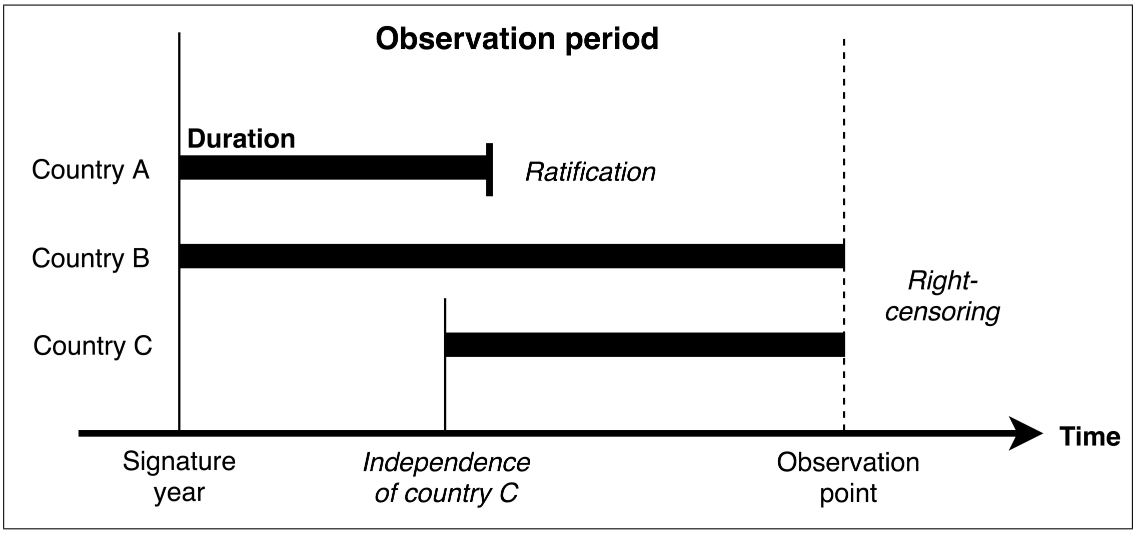

Figure 5: *Censoring in ratification data*

Notes: Survival spells for a representative environmental agreement. The figure also illustrates the difference between the age of the treaty and the concept of duration. The duration is subjective to the country-treaty dyad because the starting points for the survival spells may differ across countries.

could occur: *i*) the country has no intentions to ratify the treaty, *ii*) the country has not yet ratified the treaty. Our data does not allow to distinguish between the two reasons, but our empirical framework should deal with both situations.

For the first case, we are interested in keeping these countries in the sample. We would create sampling bias if only countries that ratified were to be left in the risk set. Even though the country does not ratify immediately, it has a possibility of subsequently re-evaluating its participation in the agreement. Potentially, it could join the treaty at any point in time. Hence it makes sense to keep the country in the risk set. The decision not to ratify cannot strictly be considered a competing risk. Such a decision does not preclude future ratification, but it would certainly delay it.

The second case of right-censoring mainly concerns recent agreements in the dataset, since most of ratifications fall in the first 10 years following the signature (Figure 6). The event of ratification could occur after the observable time period. This is a classic problem deriving from data truncation. Fortunately, in a survival analysis framework, this should not affect our estimates because we can assume independent censoring — the duration of truncated spells depends uniquely on the exogenous year of signature and the fixed observation point.

4.5 Model estimation

Because of the multilevel structure and binary dependent variables, the likelihood of the observed data does not have a closed-form expression. Therefore estimation methods involve approximation. Some of the most popular methods are quasi-likelihood (such as Goldstein & Rasbash 1996 or Breslow & Clayton 1993), Laplace approximation, adaptive quadrature, and Markov chain Monte Carlo (MCMC).

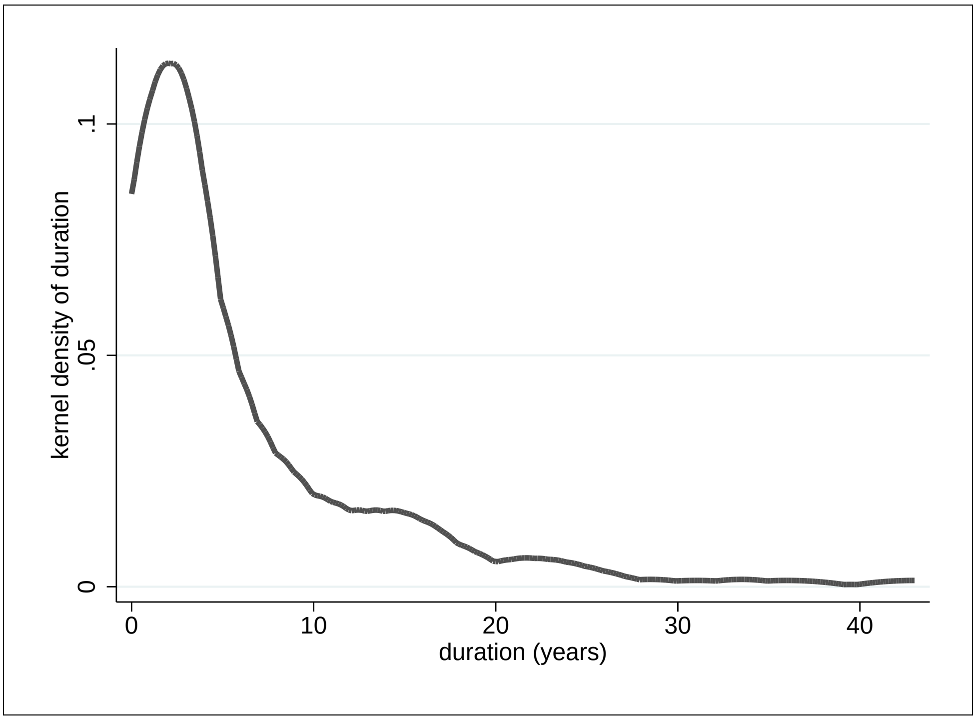

Figure 6: *Kernel density estimates of duration for treaty ratifiers*

Notes: Ratifications tend to concentrate in the 10 years following the signature. Some agreements experience more than one wave of ratifications (e.g. Kyoto Protocol), but generally the chances of being ratified rapidly decay with time.

This type of models can be fitted through iterative algorithms based on generalised least squares (e.g. IGLS or RIGLS) giving quasi-likelihood estimates obtained by alternating between random and fixed part until convergence is reached. Marginal quasi-likelihood (MQL) and Penalized (or predictive) Quasi-Likelihood (PQL) are applicable even though they tend to perform worse with dichotomous variables (Browne & Draper, 2002) and convergence is harder to reach with larger data sets (Capanu et al., 2013). Another common alternative is the use of Laplacian approximation. However, because of the low variation in survival data and the complex structure of random effects, this type of estimation takes a very long time on large data sets and convergence is seldom reached. Compared to maximum likelihood methods, MCMC improves estimation precision at the cost of estimation time (Ng et al., 2006). Browne & Draper (2002) demonstrated that for multilevel cross-classified binary regressions, the results are more precise when estimated with MCMC than quasi-likelihood methods. In fact, MQL and PQL have a notorious tendency to bias the variance components downwards (Browne & Draper, 2002). Furthermore, Beck & Katz (2007) showed that MCMC performs well even when the normality assumptions of the random effects are violated; this result was corroborated by Shor et al. (2007).

We decide to estimate the model using MCMC method because it is a more robust estimator. It can be applied to the binary cross-classified model by using the Metropolis-Hasting algorithm (Hastings, 1970) as a sampler. This Bayesian simulation method estimates the complete distribution of the parameters. We prefer MCMC also because alternative estimation methods often fail to converge given the size of the data set, the complexity of the random effect structure and the low variability of survival data. Furthermore, with uniform priors and large samples, MCMC yields asymptotically equivalent estimates to MLE (Steele et al., 2004). This property is derived from the Bernstein-von Mises theorem, which states that with large-enough samples, the samples' information dominate the influence of the prior and the posterior distribution is asymptotically equal to a normal distribution centred upon the maximum likelihood estimate (Nickl, 2013). The main downside of MCMC is its very long estimation time. We estimate our model with MLwiN (Charlton et al., 2017), a software developed by the Centre for Multilevel Modelling of the University of Bristol expressly to deal with large and complex multilevel models.

We start the estimation procedure by first fitting a simplified hierarchical model with quasi-likelihood method (MQL procedure). This should accelerate the convergence of the Markow chains by providing good initial values for the parameters. The following diffuse priors are used in the MCMC analysis:

$$\Pr(\boldsymbol{\alpha}) \propto 1 \qquad \Pr(\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\lambda}) \propto 1 \tag{6}$$

Where $\boldsymbol{\alpha} = \{\alpha_0, \alpha_1, \alpha_2, \alpha_3\}$ are the coefficients of the baseline hazard and $\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\lambda}$ are the coefficients of the independent variables of the model. For the variance parameters we use the following priors, which correspond to a uniform prior for the logarithm of the variance.

$$\Pr(\sigma_{u_i}) \propto \boldsymbol{\Gamma^{-1}}(\varepsilon, \varepsilon) \qquad \Pr(\sigma_{u_j}) \propto \boldsymbol{\Gamma^{-1}}(\varepsilon, \varepsilon) \qquad \varepsilon = 10^{-3} \tag{7}$$

We run the simulation for as many iterations as needed to guarantee the convergence of the series and reliable inference from the posterior distribution. We run no less than 500,000 iterations. The convergence to the target distribution is evaluated through several tests and measures which are reported in the appendix. To accelerate the convergence rate and improve the efficiency of MCMC estimation we use orthogonal reparametrisation. Browne et al. (2009) document how this technique of reparametrisation affects the mixing and convergence time in the estimation of cross-classified multilevel survival models. Application to our data seem to corroborate their thesis: the number of independent samples obtained with this technique highly increases, and we notice a general improvement in the mixing of the Markow chains. Orthogonal reparametrisation involves a substitution of the model's parameters with an orthogonal vector of predictors that are then used for estimation. These new parameters have the advantage of facilitating sampling by reducing the correlation between variables. The initial set is then retrieved at the end of the estimation (see Browne, 2017).

5 Results

Table 3 reports our main estimation results. Five different model specifications are presented (model I to V). The first two are the study's reference specifications; the estimates correspond to the mean of the marginal posterior distributions, which are also

Table 3: *Main results on ratification*

	Model I			Model II			Model III		Model IV		Model V	
	H.R.	Mean	S.E.	H.R.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
ENGO	1.021	0.021***	(0.006)	1.016	0.016***	(0.005)	0.022***	(0.006)	0.024***	(0.005)	0.022***	(0.006)
ResourceRent	1.004	0.004	(0.004)	1.001	0.001	(0.002)	0.003	(0.004)	0.002	(0.002)	0.000	(0.004)
Institutions	1.103	0.098**	(0.050)	1.080	0.077**	(0.044)	0.167***	(0.046)	0.073**	(0.043)	0.143***	(0.056)
ENGO.Institutions	0.992	-0.008**	(0.004)				-0.011***	(0.004)			-0.009**	(0.004)
ResourceRent.Instit	1.003	0.003	(0.003)				0.003	(0.003)			0.000	(0.003)
logIncome	1.230	0.207*	(0.153)	1.239	0.214*	(0.154)			0.250*	(0.152)	0.244*	(0.170)
logIncome^2	0.989	-0.011	(0.010)	0.988	-0.012	(0.010)			-0.016*	(0.010)	-0.012	(0.011)
AnnexI							0.496***	(0.119)				
FreedomHouseCL	0.879	-0.129***	(0.019)	0.879	-0.129***	(0.020)			-0.122***	(0.019)	-0.102***	(0.022)
ThreatenedSpecies	1.804	0.590*	(0.442)	1.659	0.506	(0.444)	-0.252	(0.457)	0.534	(0.440)	0.352	(0.456)
logForest	1.057	0.055***	(0.015)	1.055	0.054***	(0.016)	0.038***	(0.015)			0.057***	(0.016)
RatRegion	1.804	0.590***	(0.063)	1.809	0.593***	(0.063)	0.582***	(0.062)	0.797***	(0.059)	0.727***	(0.072)
RatUS	0.490	-0.714***	(0.069)	0.490	-0.713***	(0.069)	-0.724***	(0.068)			-0.831***	(0.076)
RatChina	1.435	0.361***	(0.058)	1.432	0.359***	(0.058)	0.365***	(0.058)			0.183***	(0.061)
RatRussia	0.820	-0.199*	(0.134)	0.820	-0.198*	(0.133)	-0.197*	(0.134)			-0.241**	(0.134)
RatIndia	1.289	0.254***	(0.057)	1.285	0.251***	(0.058)	0.246***	(0.058)			0.086*	(0.061)
RatGermany	1.384	0.325***	(0.053)	1.384	0.325***	(0.053)	0.317***	(0.053)			0.529***	(0.063)
Regional	2.370	0.863***	(0.234)	1.091	0.0874	(0.231)	0.89***	(0.235)				
FrameworkAgreement	1.186	0.171	(0.226)	1.164	0.152	(0.220)	0.140	(0.226)	0.077	(0.228)	-0.168	(0.464)
t	1.042	0.041***	(0.010)	1.043	0.042***	(0.010)	0.048***	(0.009)	0.079***	(0.008)	0.087***	(0.012)
t^2	0.994	-0.006***	(0.000)	0.994	-0.006***	(0.000)	-0.006***	(0.000)	-0.007***	(0.000)	-0.007***	(0.001)
t^3	1.000	0.000***	(0.000)	1.000	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)
cons		-5.564***	(0.818)		-5.547***	(0.822)	-4.471***	(0.476)	-4.813***	(0.794)	-5.837***	(0.922)
Random part												
Variance *treaty* level		2.584	(0.305)		2.593	(0.305)	2.625	(0.310)	2.884	(0.331)	3.397	(0.661)
Variance *country* level		0.239	(0.030)		0.248	(0.031)	0.237	(0.030)	0.256	(0.032)	0.249	(0.033)
Units: *treaty*		257			257		257		258		72 global treaties	
Units: *country*		190			190		190		192		190	
Obs: *ratification*		219266			219266		219510		231200		179723	
DIC:		56000.05			55996.29		56074.71		57073.16		33557.32	
Burnin:		200000			200000		200000		100000		150000	
Chain Length:		250000			250000		250000		200000		200000	
Thinning:		2			2		2		2		2	

Notes: ***, ** and * indicate one-tailed Bayesian p-values respectively lower than 0.01, 0.05 and 0.10. For model I and II Hazard ratios are provided.

presented in terms of hazard ratios[7]. The only difference between model I and II is that the latter does not have an interaction term between the quality of institutions and the lobbying variables. Model V is identical to model I but estimated on a sub-sample composed exclusively of global environmental agreements. In Model III the income and democracy variables are replaced with a different proxy for the level of economic development, and Model IV is a simplified specification of model I. All models are estimated with MCMC by performing almost one million iterations per model.

5.1 Environmental and industrial lobbying

We find that environmental lobbying has a positive and significant effect on the probability of ratifying. One additional environmental NGO ($ENGO$) increases the hazard of ratifying environmental agreements by 1.6% (Model II), and by 2.1% (model I) if the quality of institutions is at its average[8]. The positive effect of environmental lobbying is in line with our hypothesis and other literature results (e.g. Fredriksson & Ujhelyi 2006, von Stein 2008, Bernauer et al. 2013a). On the other hand, the results for industrial lobbying are in sharp contrast with our hypothesis on the impact of lobbying. Industrial lobbying is statistically insignificant across all five specifications of table 3. The most puzzling side of this result is that industrial lobbies are often considered to have more economic resources and influence than environmental groups. These findings contradict our expectations; hence they are investigated in more detail in table 4, where four different measures for industrial lobbying are tested to verify the robustness of our estimates ($EnergyUse$, $ShareIndustry$, $IMFresourcerich$, $FossilExports$).

$EnergyUse$ is the per capita energy use measured in kg of oil equivalent. The assumption behind this proxy is that energy-intensive economies have stronger incentives to lobby against environmental regulations. $ShareIndustry$ is the share of manufacture, mining and utilities on GDP at current prices. The weight of industry in the economy is the most common proxy for industrial lobbying in the literature. The following studies have used this measure: Yamagata et al. (2013), Yamagata et al. (2017), Sauquet (2014) and von Stein (2008). $IMFresourcerich$ is a dummy variable that takes the value of 1 if natural resources account for at least 20% of its exports or national income according to the IMF (2012). This variable captures the economic reliance upon non-renewable natural resources such as coal, gas, oil and minerals. We assume that richness in these resources correlates with stronger pressure against the ratification of environmental agreements. The last proxy is $FossilExports$, which is calculated as the share of fossil fuels in the export basket. The fossil industry is chosen because it is one

[7] A hazard ratio higher than 1 indicates an increase in the hazard of ratification while a hazard ratio between 0 and 1 suggests a reduction in the hazard of ratification. Hazard ratios indicate the relative risk of an event between two groups of reference. For example, in the case of $RatUS$, it compares the hazard for treaty-country-year dyads for which the United States has already ratified the agreement with the ones in which it has not. In the case of continuous variables (e.g. $ENGO$ or $ResourceRent$) the comparison is with dyads with a unit increase in the variable.

[8] In model I the interpretation of ENGO's coefficient is made in correspondence of $Institutions = 0$. Since the variable $Institutions$ is normalised, the value of zero is also the average quality of institutions.

of the most polluting industries. The bigger the share of fossil exports in the export basket, the stronger is the power of industrial lobbying. Again, this is not the first time the measure is used in the empirical literature; Sauquet (2014) and Fredriksson et al. (2007) use the share of fossil fuel in the export basket to proxy for industrial lobbying.

The estimates in table 4 are globally stable, and the coefficient estimates are consistent with those in model I–V. The 4 different variables we test in this section yield very inconclusive findings on the impact of industrial lobbying. Just like $ResourceRent$ in Table 3, $EnergyUse$ and $IMFresourcerich$ are not statistically significant. On the other hand, for $ShareIndustry$ and $FossilExports$ the models exhibit contrasting results. A higher share of fossil resources in the export basket is linked to lower ratification probabilities. In contrast, a higher share of manufacture, mining and utilities in the GDP increases the likelihood of ratification. Overall, these results do not provide evidence of a negative impact of industrial lobbying on the ratification of environmental agreements.

A detailed analysis of the literature reveals that whenever a measure for industrial lobbying is included in previous empirical studies, it tends to be statistically insignificant. In table 5 we list all the empirical studies that include a variable for industrial lobbying in their models of ratification. The second column identifies the proxies used in each study and the third column summarises the results regarding the estimates for industrial lobbying.

Table 5: *Industrial lobbying in the empirical literature*

Paper	Proxies	Results
Fredriksson & Ujhelyi (2006)	*i*) Dummy that takes value of 1 if a country has a national Chamber of Commerce. *ii*) Dummy for "fuel" exporting countries. Additional variables are used in non-reported models: a dummy for membership in the World Business Council for Sustainable Development, the numbers of vehicles per capita, the intensity of CO_2 in commercial energy use.	Both proxies are not significant despite 16 different specifications are tested. The variables used in the non-reported models also do not yield significant results according to the authors.
Fredriksson et al. (2007)	Measured by three variables: *i*) Share of the labour force employed in the industrial sector as proxy for importance of carbon-intensive sectors. *ii*) Dummy for countries that possess a national committee or an international chamber of commerce (ICC). *iii*) Share of fuel export as a share of good exports.	ICC and fuel export are never significant, each tested in 3 different specifications. The share of labour in industry is significant with a negative coefficient at the 95% confidence level in 1 out of 3 specifications.
von Stein (2008)	Industry as a percentage of GDP	Industrial lobbying never reaches a statistical significance both for the UNFCCC and Kyoto Protocol

Industrial lobbying in the empirical literature (continued)

Paper	Proxies	Results
Yamagata et al. (2013)	Industrial production as percentage of GDP	Significant at the 10% level for the UNFCCC but not for the Kyoto Protocol (out of 7 different specifications considered).
Sauquet (2014)	Ratio of fossil fuel exports to total exports	Not significant in 3 specifications out of 4.
Yamagata et al. (2017)	Industrial production as a share of GDP.	Significant at the 10% significance level for the period 1981-1990 but not significant (out of 7 different specifications) for the period 1991-2008.

The results are consistent across the 6 studies; in most cases, an insignificant effect is found between industrial lobbying and ratification. Our findings are in line with past results. The evidence from the literature does not support a relationship between the intensity of industrial lobbying and the likelihood of ratification. The reasons for this counter-intuitive result have never been adequately explored. The explanation we advance is that stronger industrial lobbying does not translate into lower probabilities of ratification because industrial lobbying practices do not target ratification. We speculate that actively opposing ratification might reflect poorly on these lobby groups' public perception and might produce reputational damage. As a result, we suggest that, in general, industrial lobbies might prefer to target the implementation phase rather than actively resisting the ratification of environmental agreements. This thesis seems to be confirmed by the documented impact of industrial lobbying on different environmental domestic policies (e.g. Fredriksson et al., 2005; Galeotti et al., 2014; Sineviciene et al., 2017).

5.2 Disentangling institutional effect: institutions, income and democracy

The quality of institutions plays an important role in the ratification of environmental agreements. From model II we estimate that a 1 s.d. increase in the quality of institutions leads to an 8% increase in ratification hazard. In addition, Model I indicates that the effect of ENGO's lobbying is stronger when institutions' quality is lower. We propose two reasons for this. First of all, better institutions should channel more effectively environmental demands and reduce the need of pressure from environmental groups. Hence good quality institutions substitute the effect of environmental groups. A similar conclusion was reached by Bernauer et al. (2013a) on the interaction between environmental lobbying and the quality of democracy. Secondly, lobbying practices, in general, are more effective in corrupt systems of governance. The second argument was proposed by Fredriksson et al. (2007) who find that environmental lobbying for the ratification of the Kyoto Protocol is more effective when institutions are more corrupted.

Table 4: *Industrial lobbying*

	EnergyUse		*ShareIndustry*		*IMFresourcerich*		*FossilExports*	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Fixed part								
ENGO	0.021***	(0.006)	0.022***	(0.006)	0.022***	(0.006)	0.017***	(0.006)
EnergyUse	-0.001	(0.001)						
ShareIndustry			0.008***	(0.003)				
IMFresourcerich					0.095	(0.099)		
FossilExports							-0.003**	(0.001)
Institutions	0.134**	(0.066)	0.100*	(0.073)	0.105**	(0.054)	0.207***	(0.068)
ENGO.Institutions	-0.010***	(0.004)	-0.008**	(0.004)	-0.008**	(0.004)	-0.010**	(0.004)
EnergyUse.Instit	-0.001	(0.001)						
Shareindustry.Instit			0.001	(0.002)				
IMFresourcerich.Instit					0.040	(0.084)		
FossilExports.Instit							-0.003**	(0.001)
logIncome	-0.110	(0.183)	0.114	(0.158)	0.189	(0.153)	-0.149	(0.198)
$logIncome^2$	0.010	(0.012)	-0.007	(0.010)	-0.010	(0.010)	0.010	(0.012)
FreedomHouseCL	-0.125***	(0.021)	-0.140***	(0.020)	-0.129***	(0.019)	-0.108***	(0.025)
ThreatenedSpecies	0.684*	(0.471)	0.493	(0.450)	0.596*	(0.440)	0.890**	(0.488)
logForest	0.031**	(0.017)	0.046***	(0.016)	0.052***	(0.016)	0.045***	(0.018)
RatRegion	0.559***	(0.071)	0.586***	(0.063)	0.586***	(0.063)	0.460***	(0.077)
RatUS	-0.691***	(0.076)	-0.715***	(0.069)	-0.714***	(0.068)	-0.709***	(0.078)
RatChina	0.389***	(0.064)	0.354***	(0.058)	0.361***	(0.057)	0.272***	(0.067)
RatRussia	-0.252**	(0.150)	-0.200*	(0.134)	-0.200*	(0.133)	-0.271**	(0.163)
RatIndia	0.209***	(0.065)	0.250***	(0.057)	0.256***	(0.057)	0.214***	(0.067)
RatGermany	0.336***	(0.058)	0.324***	(0.053)	0.327***	(0.052)	0.329***	(0.059)
Regional	0.866***	(0.227)	0.865***	(0.233)	0.881***	(0.238)	0.757***	(0.239)
t	0.046***	(0.011)	0.044***	(0.010)	0.040***	(0.010)	0.073***	(0.012)
t^2	-0.006***	(0.001)	-0.006***	(0.000)	-0.006***	(0.000)	-0.007***	(0.001)
t^3	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)
cons	-4.188***	(0.799)	-5.058***	(0.827)	-5.475***	(0.802)	-4.318***	(1.005)
Random part								
Variance *treaty* level	2.501	(0.297)	2.581	(0.303)	2.575	(0.302)	2.523	(0.314)
Variance *country* level	0.222	(0.033)	0.245	(0.031)	0.239	(0.031)	0.263	(0.039)
Units: *treaty*	256		257		257		253	
Units: *country*	169		190		191		174	
Obs: *ratification*	160139		219136		220454		151602	
DIC:	47969.89		55919.16		56091.86		44496.01	
Burnin:	200000		200000		200000		200000	
Chain Length:	200000		250000		200000		250000	
Thinning:	2		2		2		2	

Notes: ***, ** and * indicate one-tailed Bayesian p-values respectively lower than 0.01, 0.05 and 0.10.

Both arguments imply that environmental lobbying is an effective tool to stimulate participation of countries with less developed institutions because of a higher marginal effect of lobbying in these governance systems.

Table 6 shows that our measure for institutions' quality exhibits a non-trivial degree of correlation with $logincome$ (0.736) and $FreedomHouseCL$ (−0.681). Richer nations tend to have better institutions and be governed by more mature democracies. To ensure that the estimates of $Institutions$ are not distorted, in model III we omit both $logIncome$ and $FreedomHouse$ and replace them with $AnnexI$ which is used as control for the level of development. $AnnexI$ is a dummy variable that takes the value of 1 if the country is in the "Annex I" list of countries under the UNFCCC (1992). Annex I countries are the nations that have tighter obligations under climate change agreements. This list of countries corresponds to the economically most developed nations in the world and gives a good indication of the level of environmental commitment expected of every nation. A comparison of model I and model III reveals that the difference between the two estimates for $Institutions$ is statistically insignificant[9]. Hence, we conclude that the inclusion of $FreedomHouseCL$ and $logIncome$ does not affect the consistency of the estimates.

Table 6: *Correlation matrix for country variables in model I*

	1	2	3	4	5	6	7
1. ENGO	1.000						
2. ResourceRent	−0.151	1.000					
3. Institutions	0.173	−0.399	1.000				
4. logIncome	0.127	−0.189	0.736	1.000			
5. FreedomHouseCL	−0.127	0.490	−0.681	−0.575	1.000		
6. ThreatenedSpecies	−0.100	0.154	0.020	0.025	0.070	1.000	
7. logForest	0.341	0.181	−0.240	−0.218	0.194	0.084	1.000

$logIncome$ is associated with a higher probability of ratification, but only at the 10% significance level. Moreover, we do not find evidence of a non-linear relationship with income. Income explains part of the difference in ratification behaviour, but the impact of economic development is often mitigated by differentiated terms in the environmental agreements. In other words, several environmental agreements transfer to richer nations most of the costs associated with the agreement in order to secure higher participation.

[9] A formal hypothesis test shows that the two estimates are not statistically different.

$$H_0\colon \beta^{III} - \beta^{I} = 0$$
$$H_1\colon \beta^{III} - \beta^{I} > 0$$

Where β^{III} and β^{I} are the estimates for $Institutions$ of model III and I, respectively. The Z score for two coefficients of separate regressions is (Paternoster et al., 1998):

$$Z = \frac{\beta^{III} - \beta^{I}}{\sqrt{SE^2_{\beta^{III}} + SE^2_{\beta^{I}}}} = \frac{0.069}{\sqrt{0.05^2 + 0.048^2}} \approx 0.9955$$

With $\alpha = 0.05$, the p-value is approximately $p \approx 0.159$. The null hypothesis is rejected. The difference between β^{I} and β^{III} is statistically insignificant.

Environmental agreements often include facilitating measures, technical assistance, and financial aid to developing nations that decide to take part in the agreement. According to the principle of *common but differentiated responsibilities* the most developed nations are expected to lead the way in terms of environmental commitments and bear the highest share of the cost of treaties. All of these measures could explain why the influence of income is not as clear-cut as anticipated.

After controlling for income and quality of institutions, we still find that democratic states tend to engage more in environmental agreements; a lower score in the $FreedomHouseCL$ index is significantly linked to higher ratification probabilities in all models. These results corroborate the widely accepted relationship between democracy and ratification of environmental agreements (e.g. Congleton, 1992; Neumayer, 2002a; Bernauer et al., 2010).

5.2.1 Regional agreements and treaty characteristics

Figure 7 provides a good summary of our ratification models. The mean survival probabilities of every treaty in the data set are plotted along with the general population mean. Some lines are interrupted before reaching 50 years because they correspond to more recent agreements, which are right-censored at the observation date. As shown in the figure, a hypothetical average treaty has approximately 50% chances of being eventually ratified. Nevertheless, participation upturn varies widely among treaties. The random part of the model shows that most of the variation is explained by heterogeneity at treaty level, which greatly exceeds the impact of unobserved country characteristics. Differences among treaties are the fundamental cause of disparities in ratification. This result is unsurprising, the success or failure of a treaty depends chiefly on the content of the agreement and only secondarily on the country's characteristics or other strategical interaction.

Our results highlight that regional agreements regularly attain a higher participation rate than global agreements. The regionality of the agreement is the single most important factor explaining ratification likelihood in our model. On average, the hazard of ratification of a regional agreement is 2.37 times that of a global agreement. This shows that treaties can be a very effective tool to solve regional environmental issues because they can easily engage small groups of countries. On the contrary, the negotiation of global agreements is more arduous. Finding a compromise for a large number of nations is a complex exercise and could end up penalising participation in or the environmental effectiveness of the agreement.

Besides the impact of treaty features, figure 7 also shows how the probability of ratification changes over time. Most ratification decisions take place in the initial 10 years. Some simple algebra reveals that in our model, conditional on the other variables, the maximum hazard of ratification is reached roughly around the end of the third year from the opening to ratification. After that, the likelihood of ratification decreases as a result of the "cooling down" of the treaty. This behaviour fits well with the ratification timings observed across most environmental treaties.

The ratification of environmental agreements results from of a number of unique factors associated with countries and treaties. In figure 8 we rank the countries and treaties according to the their individual random effect. The figure illustrates how, after accounting for all the covariates, countries and treaties differ in their propensity

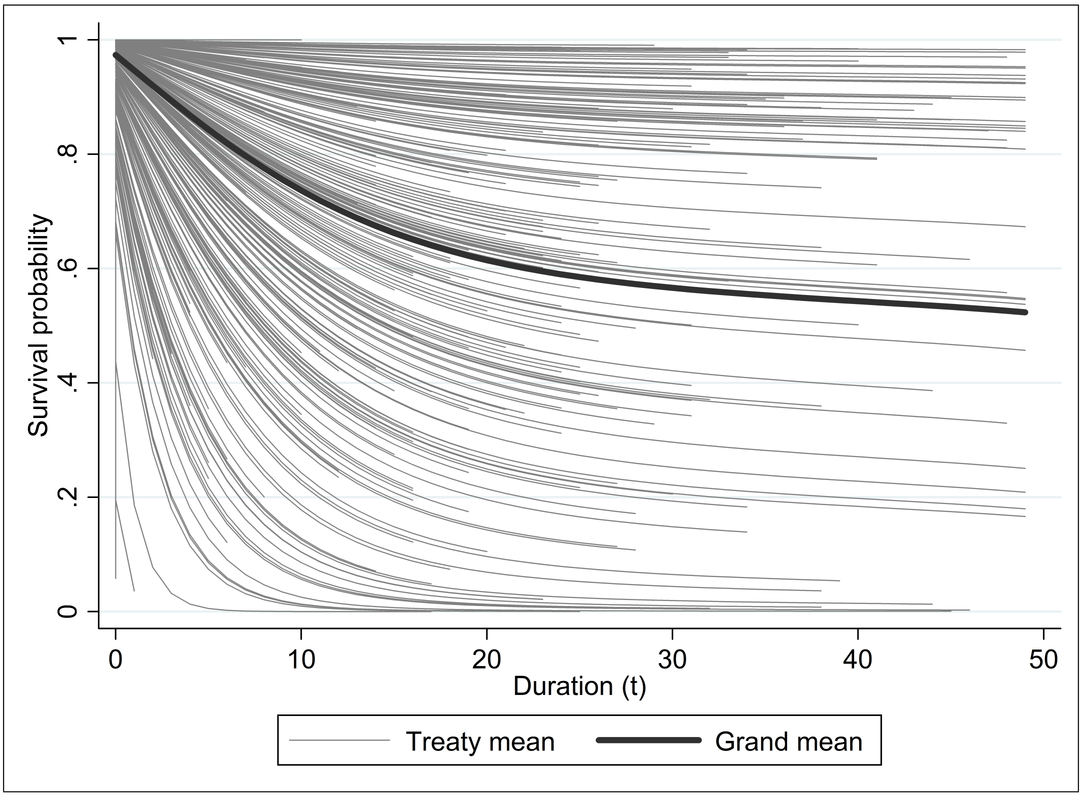

Figure 7: *Survival functions for the environmental agreements*

Notes: The survival functions give the probability that a representative country did not ratify the agreement after t time periods (i.e. "survived" to the agreement). All survival probabilities are calculated by keeping the country variables at their mean values.

to ratification. For example, Norway and the United States are at the two opposite ends of the distribution. At parity of income, lobbying and other control variables, Norway would be significantly more likely to ratify an environmental agreement than the United States. This difference is explained by country-specific cultural, economic and social factors unaccounted for by variables in our model. As we already discussed, the individual unobserved characteristics play an even larger role among treaties. Many agreements located on the left side of the distribution have a large confidence interval. This is due to the presence of a smaller number of potential ratifiers and a low variance in the ratification outcome. For example, the Convention on civil liability for damage resulting from activities dangerous to the environment (1993) is a regional agreement open to a restricted number of countries[10] and, to this date, it has yet to be ratified by any of its potential ratifiers.

[10] According to the article 32 of the Convention the "Convention shall be open for signature by the member States of the Council of Europe, the non-member States which have participated in its elaboration and by the European Economic Community".

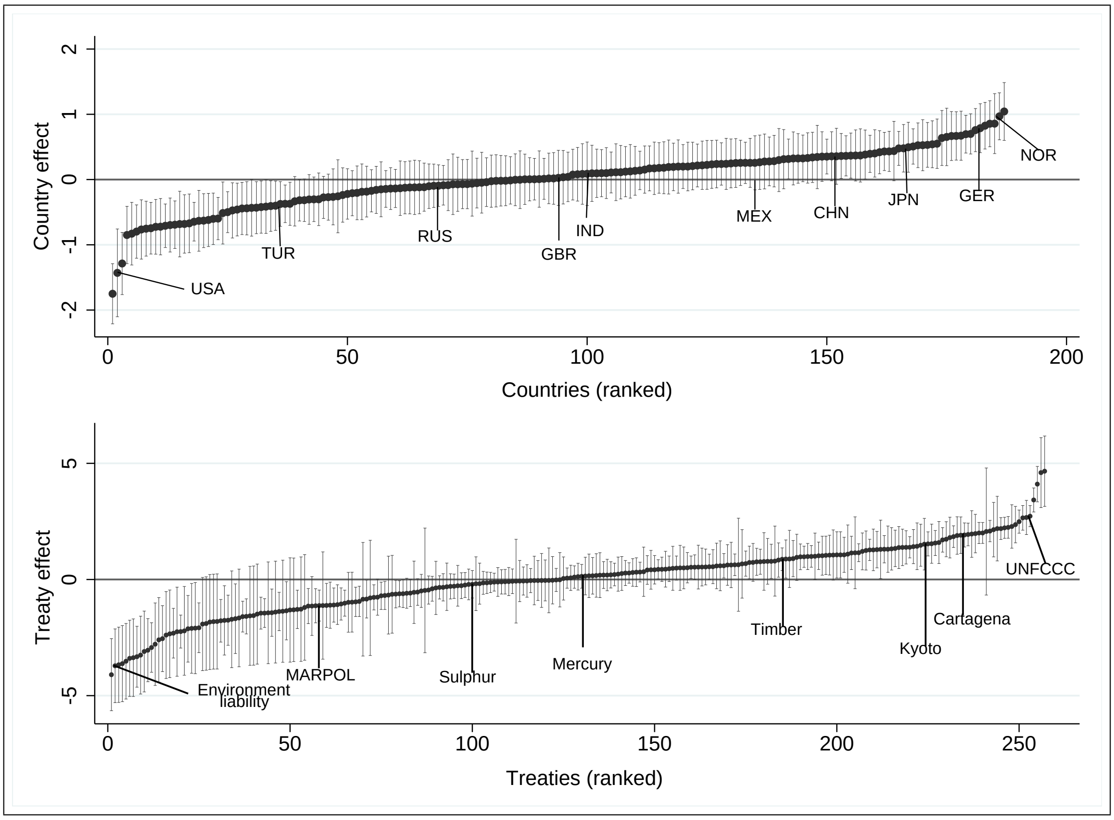

Figure 8: *Caterpillar plots for the treaty and country effects*

Notes & legend: Mean country and treaty effects plotted with their 95% confidence interval. Some countries and treaties have been highlighted as examples. For the caterpillar plot of the treaty effect: **UNFCCC** – United Nations Framework Convention on Climate Change (1992). **Cartagena** – Cartagena Protocol on Biosafety to the Convention on Biological Diversity (2000). **Kyoto** – Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997). **Timber** – International Tropical Timber Agreement (2006). **Mercury** – Minamata Convention on Mercury (2013). **Sulphur** – Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution (LRTAP) on Further Reduction of Sulphur Emissions (1994). **MARPOL** – International Convention for the Prevention of Pollution from Ships (1973). **Environment liability** – Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment (1993).

5.3 International interactions

Besides treaty and domestic characteristics, we find that foreign countries' actions explain an important part of ratification decisions. The game theoretical literature on participation in environmental agreements emphasises that different countries' decisions are strategically linked. Our findings strongly support this contention. If all geographic neighbours ratify the treaty, the ratification hazard increases by as much as 80% (Model I). Furthermore, the ratification decisions of big countries heavily influence the likelihood of ratification by other nations. In particular, ratifications by China, Germany (a proxy for the EU), or India increase the chances of ratifying a treaty. On the contrary, when Russia or the Unites States ratify, the ratification hazard decreases. These results could be explained by the polarising effect that Russia and United States have on world's geopolitical system. Despite the fall of the Soviet Union, both countries still have clearly defined areas of competing influence. The ratification by one of the two countries highly reduces the ratification likelihood by countries in the opposite area of influence, though the effect of Russia's ratification is significant just at the 10% level. The opposite is true for large nations such as China or India, which are often pivotal for the success of an international environmental agreement. The ratification by one of these two nations is a strong signal of success for the treaty because China and India are often indispensable in achieving environmental goals. We estimate that China's ratification increases the hazard of ratification by 43% while India's by 29%. European Union also has a leading role in promoting environmental commitment, but the high impact of Germany's ratification can partially be ascribed to the high correlation between European ratifications. After the institution of the European Union, most of European countries tend to ratify en bloc.

5.4 Convergence and robustness checks

We assess the robustness of the results by checking fundamental assumptions of the model. All the results mentioned in this section are provided in a supplementary online appendix. To begin with, we run a battery of tests to assess the convergence of the MCMC chains. We report the moments of the marginal distributions, the effective sample size (ESS), Raftery-Lewis statistics and the Brooks-Draper statistic. These statistics suggest that the simulation has generated a sufficient number of independent samples and that the estimator has converged. This is confirmed visually by the traces of the chains and the histograms of the marginal posterior distributions. These traces show that the chains seem to have converged around a mean and explored the joint distribution efficiently. To further test the convergence of the chains, we follow Gelman & Rubin (1992) who suggest starting estimation from several different points in order to ensure the algorithm explored the entire joint distribution and rule out the possibility of pseudo-convergence. The results of these simulations converge to the same distribution and yield identical results to those presented here.

The estimation of multilevel survival models with MCMC notoriously yields highly correlated chains (Browne et al., 2009). For this reason, we opted for a very high number of iterations. In total we perform almost one million iterations for each model, out of which we discard one every two samples, for a total of 550,000 generated samples. We then discard the initial 300,000 out of 550,000 samples to make sure the inference is based on a chain that has converged. The number of iterations has been selected in a prudent manner to reduce risks of non-convergence.

We assess the estimates' sensitivity for our main variables in the same way it was done for industrial lobbying. We experiment with two new proxies for environmental lobbying and two more for the quality of institutions. The results, corroborate model I's findings. In addition to the four models above, we also re-estimate our model with a different link function and with a non-parametric specification of the baseline hazard. The cubic polynomial seems to be a good approximation of the non-parametric version and does not seem to bias the final results. Finally, the appendix reports the Q-Q plots for the treaty and country effects as well as a specification of the model without these two effects. We find that the standard errors would be pushed downward by their omission, leading to erroneous conclusions on the parameters' significance. These results validate our modelling choices and highlight the stability of the estimates.

6 Simulating ratification probabilities

Our model estimates can be put to several uses. For example, negotiators and researchers of environmental agreements can use them to simulate ratification probabilities, which can be calculated from the survival function of the treaty-country combination of interest. In table 7, we simulate the probability of ratifying two hypothetical agreements for five nations. The first agreement is a *regional protocol*, while the second is a *global framework* agreement. We call regional—as opposed to global—any agreement that is not open to all nations in the world. Regional agreements tend to have higher ratification rates than global ones: our model predicts that, on average, a regional agreement has more than twice the ratification hazard of a global one. Framework agreements are defined here as the first treaty on a specific topic. Framework agreements usually set the goals, scope and principles. Very often, binding actions are incorporated into subsequent protocols. As a result, framework agreements usually obtain higher rates of ratification than protocols.

Table 7: *Simulated probabilities for two hypothetical environmental treaties*

	Regional Protocol		Global framework agreement	
	5 years	10 years	no neighbours	all neighbours
United Kingdom	36%	55%	44%	64%
United States	16%	26%	20%	34%
Russia	27%	42%	30%	48%
Turkey	15%	25%	22%	36%
Brazil	44%	65%	46%	67%

Notes: All variables are assumed at the country average for the period 1990-2015. Probabilities of ratifying the regional protocol are given for a period of 5 and 10 years. In the case of the global framework agreement we present the final ratification probability (capped at 30 years) respectively when no other country and all other countries in the same geographic area have ratified.

In table 7 we explore how the forecasted ratification probabilities change with time (5 and 10-year horizon) and when neighbouring countries ratify the treaty (all neighbours versus none do so). The model shows that among these five nations there is a big differences in the probability of joining treaties. For instance, the United Kingdom is twice as likely to ratify than the United States. The difference in probabilities between these two countries is mostly due to idiosyncratic factors captured by the country effect (Figure 8). The results also show that the likelihood of ratifying a treaty improves greatly when the neighbouring nations decide to join—in the case of the United Kingdom and Brazil, it boosts the probability of ratifying by as much as 20 percentage points. This effect alone could greatly contribute a treaty's success by triggering a "domino effect" whereby foreign nations are drawn to a treaty by the example of lead countries. Finally, designing environmental governance as interlocking regional agreements could also be used to secure higher participation. Our example shows how the probability forecast of ratification for a protocol over ten years reaches approximately that of its underlying framework agreement.

Besides hypothetical treaties, the model can also be applied to generate predictions on actual agreements. In table 8 we simulate out-of-sample probabilities of ratification for the Minamata Convention (2013). The Minamata Convention deals with the supply of mercury, in particular with its mining and trading. It defines a phase-out period, sets standards on storage and disposal of waste and imposes restrictions on the trade in mercury with states outside the convention. We use our model to generate predicted probabilities for the same five countries of ratifying the convention by 2018. Then, we compare the probabilities with the actual ratification status. Predictions are made by assuming all variables constant at their 2013 value for the country.

Table 8: *Simulated probabilities and ratification status for the Minamata Convention on mercury*

Minamata Convention (2013)		
Country	Ratification prob. (2013-2018)	Ratification year
Brazil	31%	2017
United Kingdom	22%	2018
Russia	14%	—
United States	11%	2013
Turkey	10%	—

Notes: Ex-ante probabilities of ratifying the Minamata Convention by the end of 2018. All variables are assumed constant at their 2013 values. The last column reports the ratification status as of December 2018.

In table 8, Brazil and the United Kingdom are the two countries with the highest probability of ratification. The model predicts that Brazil is twice as likely as Russia to ratify the Minamata Convention by 2018. These predictions seem to be verified by the current ratification status. At the moment of writing (March 2021), Russia and Turkey have not yet ratified the convention. In this application, our model provides an approximate idea of the *ex ante* ratification probability for a given treaty. Estimates for a specific treaty can be improved by introducing treaty specific variables or important covariates. For example, in the case of the Minamata convention, coal reliance is an important aspect behind ratification because coal plants are the second biggest global emitters of mercury (Kessler, 2013). It would also be appropriate to include controls for mercury production and consumption. Despite this, the model predicts reasonably well the ratification order among the five countries. We can see that countries with higher probabilities were among the first to ratify. The notable exception is the United states. The predictions generated by the model should be interpreted as tendencies. Specific political and circumstantial reasons may affect the ratification process in unforeseeable ways. In the case of the Minamata Convention, the United States was the first country to ratify, and it did so after only one month from the opening to ratifications in order to signal environmental commitment after several other negotiation attempts had failed (Kessler, 2013). An important role was played by the Obama administration's impulse which weighed politically on such early ratification (Leenknedt, 2013). Moreover, several clauses of the agreement are very similar to regulations on mercury that had already been implemented within the US, hence lowering this country's cost for the domestic implementation of the treaty (Leenknedt, 2013).

7 Conclusion and policy implications

Our model highlights that treaty characteristics are responsible for a much larger share of ratification heterogeneity than country factors (roughly ten times as much). This result is intuitive: the main factor determining the success of a treaty is the content of the treaty itself. Specific characteristics of the treaty can influence the ratification rate. For example, we have shown that regional agreements are more than twice as likely to attract ratification than global agreements. This finding supports the claim by Asheim et al. (2006) and Osmani & Tol (2010)—among others—who argue that a more efficient approach to tackle global environmental issues involve designing a set of interrelated regional agreements instead of a monolithic global treaty.

Another salient point of the analysis is the relevance of institutional and political variables in determining ratification. Across all specifications, the quality of institutions and democracy consistently affect the likelihood of joining environmental agreements. This result reinforces the findings of the empirical literature (e.g. Neumayer 2002a, Fredriksson et al. 2007, Bernauer et al. 2013a). It shows that the conclusion holds even for a larger sample, on regional agreements, and after correcting for the bias linked to the identification of potential ratifiers. Differences in income also affect the country's capacity to participate in a treaty; however, the impact is less conspicuous than expected. Not only does the coefficient struggle to reach a significant level, but we also find no evidence of the supposed non-linearity in the relationship with income postulated by some authors (e.g. Egger et al. 2011 or Bernauer et al. 2010). We advance two reasons to explain this result. Firstly, many environmental agreements often include special provisions that facilitate participation by developing nations. These provisions mitigate the impact that a lower income level might have on the willingness to join the agreement. Secondly, income levels tend to correlate with the quality of institutions and democracy. Hence, it is possible that the environmental benefits associated with an increase in income should in part be attributed to improvements in the quality of institutions and political representation.

Furthermore, our findings show that environmental lobbying has a positive effect on the ratification of environmental agreements, while industrial lobbying does not seem to affect it. We propose an explanation for this result based on the lobbying preferences of environmental and industrial groups. Environmental lobbying targets treaties because they see it as a necessary step to legitimise their action and international agreements constitute an effective tool to build consensus over environmental issues. Environmental treaties can also be used to back the claims of ENGOs and force governments to act. Since transboundary environmental problems involve several countries, environmental agreements are also the most cost-effective way for environmental lobbying to address large environmental issues. Lobbying national government could also be part of a coordinated effort to address the problem globally. Countries are generally reluctant to abate unilaterally because of the free-riding incentive that it creates for other countries; hence, countries are more likely to engage in environmental regulation if they expect other countries to follow suit. An environmental agreement can guarantee this reciprocity. In addition, the ratification of environmental agreements is a single legal act; this makes it easier to influence and verify progress than other types of regulations that are more diffuse or capillary. Conversely, industrial lobbies target the implementation phase because it is relatively easier to delay, often draws less attention, and could be easier to influence by local influential groups.

With regards to the interactions between nations, our findings corroborate the results of Bernauer et al. (2010), Perrin & Bernauer (2010), Sauquet (2014) and Yamagata et al. (2017) on the interdependence between the ratifications of different countries. Ratifications by other countries in the same geographical region have a strong and significant positive effect on the likelihood of joining the treaty. We estimate that if all geographic neighbours ratify the treaty, the hazard of ratification increases by as much as 80%. Furthermore, we find that the ratification by superpowers and big nations can have a notable effect on other countries' ratification probabilities. Ratification by large countries, like China or India, have tremendous implications for the success of environmental agreements. When one of these two countries ratify, they significantly increase the ratification probability of other nations. This could justify the game theoretical prediction that considers two probable outcomes for a treaty: either a very low turnout or a "world coalition". However, the question is more nuanced and is invariably affected by the specific agreement's content and implications. This study stresses the importance of securing influential nations' participation, which could play a critical role in the treaty's success. These nations can have a decisive effect in tilting neighbouring nations towards ratification and triggering a "domino effect". In this regard, early ratification is key for the success of a treaty; the probability of ratification decreases precipitously after the first five years.

This study presents several contributions to the literature on environmental agreements. Firstly, we collated the largest data set in the empirical ratification literature. This is also the first to include both regional and global agreements. This feature makes it more representative of the population of treaties. A unique characteristic of our data set is the identification of the potential ratifiers for every treaty. This allows us to correct the identification bias of previous studies, which resulted in an overestimation of survival probabilities. While survival analysis is not a novelty in the empirical ratification literature (e.g. von Stein 2008, Bernauer et al. 2010, Sauquet 2014), it is the first time a multilevel strategy is used to account for unobserved heterogeneity both at the treaty and country level. Moreover, we are the first to use MCMC—a Bayesian estimation technique—to estimate the ratification model. We argue that MCMC is the best-suited estimation method for survival data which has low intrinsic variability and for models with complex structures.

Future research could tackle some of the remaining limitations of our study. First of all, there is uncertainty surrounding the measurement of some of our key variables. In particular, environmental and industrial lobbying are two concepts that are hard to quantify and for which available data is limited and fuzzy. We have tried to mitigate this problem by validating our results with a large number of proxies. Clearly, the research would greatly benefit from more complete and accurate data on the activity of interest groups. Secondly, our study is based exclusively on agreements that have taken shape. However, on some occasions, the negotiation of treaties never occurs or the countries fail to agree on a treaty. In these cases, environmental problems remain unaddressed. Failed cooperation could be investigated in general study of cooperation over transboundary environmental issues looking at *when* an agreement is agreed. Lastly, ratification models have so far always assumed independence in the ratification of distinct treaties. However, there could be cases in which agreements are directly linked. For example, two agreements could be substitutes because they deal in contrasting ways with the same issue; hence participation in one of the agreements precludes participation in the other. This situation could subsist between countries that fail to agree on a unified course of action or when competing solutions are offered. A set of agreements could also be linked oppositely, that is to say, they are complementary ratifications. We believe the assumption of independence is reasonable and better describes the general process of ratification, but there is scope for a deeper inspection of this assumption. Future research could also investigate the presence and extent of links between the ratification of different agreements.

Acknowledgments

The authors are grateful to Thomas Renstrom, Alexandre Sauquet, Laura Marsiliani and Hong Il Yoo for comments on earlier versions of this work. This paper has not been submitted elsewhere in identical or similar form. The authors declare that they have no conflict of interest.

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